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EXHIBITS

DEFENDANTS'		MARKED
MM	- Letter dated April 8, 1974 (2 pages) (Exhibits, Vol. VI, pp. 1, 2)	4
NN	- Xerox of article, "Progress in Detecting the Worker Hypersusceptible to Industrial Chemicals" (2 pages) (Exhibits, Vol. VI, pp. 3, 4)	4
OO	- "Industrial Hygienist GS-690-12" (6 pages) (Exhibits, Vol. VI, pp. 5 - 10)	4
PP	- "Maritime Safety Data, for Shipyards" (4 pages) (Exhibits, Vol. VI, pp. 11 - 14)	4
QQ	- Blank Material Safety Data Sheet (2 pages) (Exhibits, Vol. VI, pp. 15, 16)	4
RR	- "Revisions under Consideration" (1 page) (Exhibits, Vol. VI, p. 17)	4
SS	- "EEL's Recommended by NAS-NAE/NRC Committee on Toxicology" (2 pages) (Exhibits, Vol. VI, pp. 18, 19)	4
TT	- "BUMEDINST 6270.3F, 15 August 1972, Table G-3 -- Mineral Dusts" (8 pages) (Exhibits, Vol. VI, pp. 20 - 27)	4
UU	- "Notice of Intent to Establish Threshold Limit Values, Ultraviolet Radiation" (5 pages) (Exhibits, Vol. VI, pp. 28 - 32)	4
VV	- "BUMED 6270.3D, BUMED-732-rmo, 15 February 1966" (9 pages) (Exhibits, Vol. VI, pp. 33 - 41)	4
WW	- "Physical Exam Schedule," first document dated 20 November 1973 (8 pages) (Exhibits, Vol. VI, pp. 42- 49)	4
XX	- Group of documents bearing cover, "Cincinnati Environmental Health Group Report" (52 pages) (Exhibits, Vol. VI, pp. 50 - 101)	4
YY	- Rosters (12) "American Conference of Governmental Industrial Hygienists, Inc., 1977-1978"; "American Conference of Governmental Industrial Hygienists, 1976-1977"; "American Industrial Hygiene	

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EXHIBITS (Continued)

DEFENDANTS'		MARKED
(YY - Continued)	Association, Membership Book, 1974-1975"; "American Industrial Hygiene Association, 1975-1976 Membership Directory"; "Roster of The American Academy of Industrial Hygiene, 1970-1971"; "American Industrial Hygiene Association, Southern California Section, 1968 Membership Roster"; "Roster of Membership, Navy Industrial Hygiene Association (30 January 1974)"; "Roster of Membership, Navy Industrial Hygiene Association (30 January 1974)"; Blue Address Guide; "Workshop Attendees, San Francisco, 15-19 Nov. '71"; "Key Person Course, Resource Agencies/References"; "Medical Department Personnel Roster" (370 pages) (Exhibits, Vol. VI, pp. 102 - 471)	4
ZZ	- "R. Manning Correspondence," first document dated 30 November 1973 (70 pages) (Exhibits, Vol. VI, pp. 472 - 541)	4
AAA	- "Industrial Hygiene - Other Shipyards" first document dated 20 May 1973 (148 pages) (Exhibits, Vol. VI, pp. 543 - 689)	4
BBB	- "Industrial Hygiene Reports" first document dated 20 February 1974 (90 pages) (Exhibits, Vol. VI, pp. 690 - 779)	4
CCC	- "IH Program Analysis, I. J. Smith" first document dated 30 June 1970 (26 pages) (Exhibits, Vol. VI, pp. 780 - 805)	4
DDD	- Memorandum dated 20 December 1972 (1 page) (Exhibits, Vol. VI, p. 806)	4
EEE	- "OCMM Notice 12810" dated 29 Mar 1973 (3 pages) (Exhibits, Vol. VI, pp. 807 - 809)	4
FFF	- Pamphlet, "Vinyl Chloride in Air" (11 pages) (Exhibits, Vol. VI, pp. 810 - 820)	4
GGG	- Notebook, "Hazardous Materials Manual, NAVSHPYDBREM Instruction 5100.54" (119 pages) (Exhibits, Vol. VI, pp. 821 - 939)	4

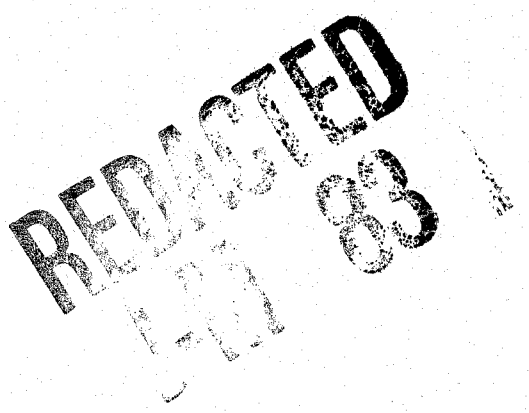
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EXHIBITS (Continued)

DEFENDANTS'		MARKED
HHH	- Notebook, "Industrial Ventilation, A Manual of Recommended Practice, 12th Edition" (341 pages) (Exhibits, Vol. VI, pp. 940 - 1280)	4
III	- Notebook, "Safety Manual" (794 pages) (Exhibits, Vol. VI, pp. 1281 - 2074)	4



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AMERICAN INDUSTRIAL HYGIENE ASSOCIATION

1975-1976 MEMBERSHIP DIRECTORY

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OFFICERS AND DIRECTORS 1975-76

PRESIDENT
EDWARD J. BAIER
National Institute for
Occupational Safety and Health
5600 Fishers Lane
Rockville, MD 20852
301-443-1530

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Vice President
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Kalamazoo, MI 49001
616-382-4000,Ext.3150

Past President
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Managing Director
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Theodore A. Felton
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408-297-3000, Ext.3394

Paul M. Giever
Stanford Research Institute
703-524-2053

John A. Janous
American Iron & Steel
Institute
202-452-7211

Howard L. Kusnetz
Shell Oil Company
713-220-5604

James E. Long, Sc.D.
3M Company
612-733-7635

William H. Revoir, Jr.
Welsh-A Textron Co.
401-943-4400

Joseph E. Zatek
Mine Safety Appliances
Company
412-241-5900

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Incorporated 1956 under the General-Not-For-Profit Corporation Act of Illinois

FORMATION

The American Industrial Hygiene Association was established in 1939 by leading industrial hygienists. The first meeting was held in Cleveland, Ohio.

OBJECTIVES

The objectives of the Association as stated in the Articles of Incorporation are:

1. To promote the study, evaluation, and control of environmental stresses arising in or from the work place, or its products, in relation to the health or well-being of workers and the public.
2. To increase the knowledge of industrial and environmental health through interchange and dissemination of information and to bring together persons interested in the various phases of industrial and environmental health.
3. To promote the profession through the encouragement of interest within and cooperation with governmental, industrial, educational, and other professional bodies.

DEFINITION OF INDUSTRIAL HYGIENE

Industrial Hygiene is that science and art devoted to the recognition, evaluation and control of those environmental factors or stresses, arising in or from the work place, which may cause sickness, impaired health and well being, or significant discomfort and inefficiency among workers or among the citizens of the community.

DEFINITION OF AN INDUSTRIAL HYGIENIST

An Industrial Hygienist is a person having a college or university degree or degrees in engineering, chemistry, physics, or medicine, or related biological sciences who, by virtue of special studies and training, has acquired competence in Industrial Hygiene. Such special studies and training must have been sufficient in all of the above cognate sciences to provide the abilities: (1) to recognize the environmental factors and to understand their effect on man and his well being; (2) to evaluate, on the basis of experience and with the aid of quantitative measurement techniques, the magnitude of these stress in terms of ability

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to impair man's health and well being; and (3) to prescribe methods to eliminate, control or reduce such stresses when necessary to alleviate their effects.

DEFINITION OF "PROFESSIONAL" INDUSTRIAL HYGIENIST

A professional industrial hygienist is a person possessing either a baccalaureate degree in engineering, chemistry or physics, or a baccalaureate degree in a closely related biological or physical science from an accredited college or university and who also has a minimum of three years of industrial hygiene experience. A completed doctorate in a related physical, biological or medical science, or in related engineering, can be substituted for two years of the three-year industrial hygiene experience requirement. A completed master's degree in a related physical or biological science, or in related engineering, can be substituted for one year of the three-year requirement. Under no circumstances can more than two years of graduate training be applied toward the three-year period.

While this definition does not include certification, AIHA recognizes the need for such certification by every professional industrial hygienist as an appropriate hallmark by one's peers and strongly urges all members eligible for such certification to do so.

MEMBERSHIP QUALIFICATIONS AND TYPES

As stated in the Bylaws in Article II, membership in the Association shall be open to persons who are engaged in industrial hygiene activities and such other persons or organizations as may be provided in the Bylaws. There shall be no limitation or discrimination because of race, creed, sex or color. Approval by two-thirds of the Board of Directors shall be required for election to all classes of membership.

The classes of membership are: Student, Associate, MEMBER, Emeritus, Honorary, and Sustaining. Applications for membership may be obtained from the office of the Managing Director.

Any organization may apply for Sustaining Membership, and must be approved by a two-thirds vote of the Board of Directors. Persons particularly distinguished in the general field of industrial hygiene or in a closely related scientific field may be granted Honorary Membership by the Board of Directors.

LOCAL SECTION MEMBERSHIP

Any person having a professional interest in industrial hygiene may become an associate member of a local section, entitled to all the privileges of membership of the section, except those of the national Association. Application for Associate membership in a local section should be made in writing, and must be sponsored by two members or associate members of that local section.

ARTICLES OF INCORPORATION

Incorporated under the General-Not-For-Profit Corporation Act of Illinois filed with the Secretary of State of the State of the State of Illinois on September 21, 1956.

ARTICLE I

Name

The name of the corporation is: AMERICAN INDUSTRIAL HYGIENE ASSOCIATION.

ARTICLE II

Duration

The period of duration of the corporation is: PERPETUAL.

ARTICLE III

Address

The address of its Registered Office in the State of Illinois is: 200 E. Randolph Dr., in the city of Chicago, County of COOK, and the name of its Registered Agent at said Address is: Jerome T. Siedlecki.*

ARTICLE IV

First Board

The first Board of Directors shall be sixteen in number.

ARTICLE V

Object

1. To promote the study, evaluation, and control of environmental stresses arising in or from the work place or its products, in relation to the health or well-being of workers and the public.
2. To increase the knowledge of industrial and environmental health through interchange and dissemination of information and to bring together persons interested in the various phases of industrial and environmental health.
3. To promote the profession through the encouragement of interest within and cooperation with governmental, industrial, educational, and other professional bodies.

*The Registered Agent for the American Industrial Hygiene Association in the state of Ohio is William E. McCormick.

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ARTICLE VI

Membership

The Association may have one or more classes of members. The designation of such class or classes and the qualifications and rights of members of each class shall be as set forth in the Bylaws.

ARTICLE VII

Officers

Section 1. The officers of the Association shall be President, a President-Elect, a Vice-President, a Secretary, and a Treasurer. The officers shall be elected by members of the Association and shall serve until their successors are elected and installed. A Vice-President shall be elected and installed annually. Upon election and installation of his successor, the Vice-President shall become President-Elect. The President-Elect, upon installation of his successor, shall become President. The Secretary and Treasurer shall be elected for a term of three years. Their tenure of office shall not run concurrently.

ARTICLE VIII

Administration

Section 1. The Association shall be governed by the Board of Directors. The Board of Directors, by a resolution adopted by a majority of the Directors in office, may designate an Executive Committee. The Executive Committee shall consist of the five officers of the Association and the most recent Past President.

Section 2. The Board of Directors shall consist of nine elective directors, five officers, and for a period of one year following their terms of office, the Past President, Past Treasurer and Past Secretary.

Section 3. A change in the number or qualifications of Directors of the Association shall be made only by amendment to the articles of incorporation.

Section 4. Three elective Directors shall be elected each year and each shall serve for a term of three years.

Section 5. A Managing Director may be appointed by the Board of Directors. He need not be a member of the Association and shall hold office at the pleasure of the Board of Directors.

Section 6. Committees not having and exercising authority of the Board of Directors in the management of the Association, may be designated by resolution adopted by a majority of the Directors present at a meeting at which a quorum is present.

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ARTICLE I

Meetings

Section 1. The annual meeting of the Association shall be held at the time and place selected by the Board of Directors. There shall be at least one business session during the annual meeting.

Section 2. Written notice of all annual and special meetings of the Association stating the place, day and hour of the meeting and, in the case of a special meeting, the purpose or purposes for which the meeting is called, shall be sent by mail to the members by the Managing Director, at the direction of the President, at least thirty days in advance of the date set for them.

Section 3. The Managing Director, on direction of the President, shall notify in writing each member of the Board of Directors at least two weeks in advance of a meeting, as to the time, place, and purpose of the meeting of the Board of Directors. A majority of the Board of Directors shall constitute a quorum.

ARTICLE II

Membership

Section 1. Membership in the Association shall be open to persons who are engaged in industrial hygiene activities and such other persons or organizations as may be provided in these Bylaws. There shall be no limitation or discrimination because of race, creed, sex or color for membership in the Association. Approval by two-thirds of the Board of Directors shall be required for election to all classes of membership.

Section 2. The classes of membership shall be: Student, Associate, MEMBER, Emeritus, Honorary, and Sustaining Members.

Section 2a. A full-time student at the college undergraduate level may become a Student Member upon a yearly application and submission of adequate matriculation documentation to the Managing Director of the Association. A Student Member may not serve on committees, vote or hold office. A Student Member shall have an option to subscribe to the Association JOURNAL at a price established by the Board of Directors.

Section 2b. An Associate Member shall be a person who has graduated from an accredited school of college grade and is currently engaged, a majority of his time, in industrial hygiene activities as defined by the Board of Directors, or who is a full-time graduate student in industrial hygiene or a cognate discipline. Membership as an Associate Member is limited to a maximum of five years. An Associate Member may serve on committees and vote but may not be elected to any office of the Association.

Section 2c. A MEMBER shall be a person who, for at least three years has been and is currently engaged a majority of his time in industrial hygiene activities

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as defined by the Board of Directors, and who has been graduated from an accredited school of college grade. Full-time graduate study in industrial hygiene or a cognate discipline may be accepted on an equivalent time basis for any portion of the required three years of experience. A MEMBER may serve on committees, vote and be elected to the Board of Directors or any office of the Association.

Section 2d. Upon receipt of application, the Board of Directors may approve Emeritus membership to a MEMBER who has become retired in fact. An Emeritus Member retains all privileges of the Association but will not be assessed dues.

Section 2e. The Board of Directors may elect as Honorary Members such persons as are particularly distinguished in the general field of industrial hygiene, or in a closely related scientific field. Honorary Membership shall be considered as purely honorary and requiring no dues; an Honorary Member may not vote on Association matters unless he is also a MEMBER in good standing or an Emeritus Member.

Section 2f. The Board of Directors may approve as Sustaining Members such organizations as may apply for this status. The dues for Sustaining Members and the privileges of this class of membership shall be defined by the Board of Directors.

Section 2g. In exceptional cases, the Board of Directors, by a three-fourth's vote of all its members, may waive the requirements specified for any membership category.

Section 3. Application for membership shall be made on forms approved by the Board of Directors. Each applicant must be sponsored by two MEMBERS in good standing; Emeritus Members may also act as sponsors.

Section 4. Dues become payable on the first day of January of each year. The dues per year for the various types of membership shall be first set by the Board of Directors and may be changed only by a plurality vote of the membership at any duly constituted business meeting of the Association or by a mail ballot.

Section 5. Any member whose dues are unpaid on March 1st is not in good standing, and he shall have no vote. When the dues of any member shall not be paid within one year after they are due, his membership is automatically terminated.

Section 6. Any member dropped for non-payment of dues may be reinstated at any time previous to the convening of the annual meeting of the year following his delinquency by payment of dues in arrears and also dues for the current year.

ARTICLE III

Election of Officers and Directors

Section 1. No person shall be nominated or elected as an officer or director unless at the time of such nomination or election such person is an Emeritus Member or a MEMBER of the Association in good standing. Nominations for officers and elective directors shall be made by a Nominating Committee of three MEMBERS to be appointed by the Board of Directors. Each MEMBER of the Nominating Committee shall be from a different local section or geographical area. At least ninety days prior to the annual meeting, the Nominating Committee shall select two nominees for each elective office and shall select five nominees for elective directors. The list of nominations shall thereupon be forthwith mailed to each member of the Association. The members will vote and return their ballots not later than six weeks prior to the annual meeting. In making nominations for elective directors and officers, the Nominating Committee shall give consideration to maintaining on the Board of Directors a balance of representation from industrial, governmental, educational, insurance and professional interests and from different geographical areas.

In addition to the nominations made by the Nominating Committee, nominations for officers and Board of Directors may be made by a petition of a minimum of 5% of the members eligible to vote. Each petition must include a letter from the nominee stating his willingness to stand for election. Such petition must be submitted to the Managing Director no later than 120 days prior to the annual meeting. The names of all petitioned nominees must appear on the ballot. The Managing Director shall certify to the Board the vailidity of the petition.

Officers and directors shall be elected by a plurality of the votes cast.

Section 2. In case of a tie vote in any election for office in the Association, the tie shall be resolved by a majority vote of all members of the Board of Directors.

Section 3. Installation of officers and directors shall take place at the last business session of the annual meeting. Upon expiration of term of office, the President, Secretary and Treasurer shall become members of the Board of Directors for one year.

Section 4. In the event of a vacancy in the office of President, the President-Elect shall fill this vacancy and the Vice-President shall succeed to the office of President-Elect. In the event of a vacancy in the office of President-Elect, the Vice-President shall fill this vacancy. Any vacancy in the office of Vice-President shall be filled by a special election called by the Board of Directors. In addition to filling the office created by a vacancy, the officer shall serve the term in office for which normal succession would have been in effect.

Should there be a vacancy in the office of the Treasurer, the Secretary shall assume the functions of that office until the Board of Directors, at its discretion, acts to fill the vacancy either by appointment or by election. Should there be a vacancy in the office of the Secretary, the Treasurer shall assume the functions of that office until the Board of Directors, at its discretion, acts to fill the vacancy either by appointment or by election.

The Board of Directors shall be empowered to fill a vacancy among the elective directors. The appointee shall serve the unexpired term.

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In the event of multiple simultaneous vacancies in the offices or directorship of the Association, the Board of Directors shall fill these vacancies by appointment or by election.

The Board of Directors shall have the authority to call special elections. Special elections shall follow the same procedures as regular elections.

Section 5. In the event that any officer or director be incapable of fulfilling the obligations of his office whether by geographical restriction, illness, or other cause, the Board of Directors shall be empowered to declare this office vacant and the vacancy shall be filled according to the Bylaws. Inability to fulfill the obligation of an office shall be determined by a three-fourth's vote of all members of the Board of Directors.

ARTICLE IV

Duties of Officers

Section 1. The President shall be the principal administrative officer of the Association, of the Board of Directors, and of the Executive Committee; shall preside at all meetings of the Association and shall perform such other duties as may be directed by the Board of Directors. He should keep in contact with developments in the field of industrial hygiene and guide the Association in the formulation of constructive activities.

Section 2. The President-Elect shall be responsible for nominating Chairmen and members to all committees serving during the year of his presidency. These shall be subject to confirmation by the Board of Directors. The President-Elect shall also perform any other duties delegated to him by the Board of Directors or assigned to him by the President and approved by the Board of Directors.

Section 3. The Vice-President shall be Chairman of the Program Committee. He shall perform any other duties delegated to him by the Board of Directors or assigned to him by the President and approved by the Board of Directors.

Section 4. The Treasurer shall be the Chairman of the Finance Committee and the Controller of the funds of the Association. He shall prepare an annual budget for approval by the Board of Directors. He shall submit an annual report to the Association in such form as may be determined by the Board of Directors. The Treasurer shall be bonded in such an amount as shall be determined by the Board of Directors, from year to year and in a company approved by the Board of Directors. Expense of bond shall be borne by the Association. In the event the Managing Director is unable to perform the duties of his office, the Treasurer will perform those duties relating to receiving and disbursing the funds of the Association until other arrangements have been made.

Section 5. The Secretary shall keep an accurate record of all the transactions of all meetings of the Association, of the Board of Directors and of the Executive Committee.

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Section 6. The Managing Director shall manage the business affairs of the Association, shall be the custodian of the monies and property of the Association; shall receive monies due to the Association and pay all authorized bills against the Association. The accounts shall be submitted for audit at the close of the fiscal year and a report presented to the Board of Directors. He shall be bonded in such amount as shall be determined by the Board of Directors, and in a company approved by the Board of Directors. Expenses of bond shall be borne by the Association. The Managing Director shall carry on the correspondence of the Association, shall keep an accurate list of the members and their status, and shall perform such other duties as may be directed by the Board of Directors.

ARTICLE V

Duties of the Board of Directors and Executive Committee

Section 1. The Board of Directors shall hold regular meetings at least twice a year, one of these meetings to be held during the annual meeting of the Association. They shall review the activities of the Association, as presented by the President, and consider such other matters as may be brought to their attention.

Section 2. The Executive Committee shall administer the affairs of the Association as delegated by the Board of Directors. Any expenditures to be assessed against the funds of the Association not authorized previously by the Board of Directors shall be approved by the Executive Committee prior to their being incurred. The Executive Committee may authorize the President to approve the payment of any regular items of expenditure up to any amount established by the Board of Directors. It shall assist the President in carrying out his activities. It shall be responsible to the Board of Directors for its actions.

ARTICLE VI

Committees

Section 1. The Board of Directors shall appoint a Program Committee. The membership of the committee shall be as determined by the Board of Directors. The Vice-President shall act as Chairman of the Program Committee. The duty of the Program Committee shall be to provide the program for the annual meeting of the Association.

Section 2. The Board of Directors may appoint an Ethics Committee of three MEMBERS. Upon recommendation of the Ethics Committee a membership may be terminated by the Board of Directors, provided that a copy of the charge against the member shall be furnished to him in writing at least thirty days before the meeting at which action is to be taken. A three-fourth's vote of all members of the Board of Directors shall be required to terminate membership.

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Section 3. All resolutions for submission to the Association shall be referred to the appropriate committee for study and recommendation.

Section 4. The Board of Directors shall appoint an Editorial Committee. This Committee shall establish procedures to carry out the editorial policies of the Association and may recommend to the Board of Directors that certain policies be established.

Section 5. The President shall appoint members to serve and to represent the Association on committees formed by other organizations.

Section 6. The Board of Directors shall appoint an Awards Committee. This Committee may select, and present such selections for approval by the Board of Directors, a member or group of members of the Association to receive the American Industrial Hygiene Association awards. These awards shall be made in recognition of outstanding service in the field of industrial hygiene and shall be presented not more frequently than once a year.

Section 7. The Board of Directors shall appoint such other committees as they deem necessary. They shall appoint special committees at their discretion to facilitate handling the affairs of the Association or its activities.

Section 8. The membership of all committees shall terminate with the last business session of the annual meeting.

ARTICLE VII

Local Sections

Section 1. The Board of Directors shall have the power to foster the formation of Local Sections. The Board of Directors shall consider an application from six or more members of the Association to establish a Local Section and shall establish the geographical area of such sections.

Section 2. Any member of a Local Section in good standing may hold any elected office of that section; however, at least one member of the Local Section's Executive Committee must be a MEMBER in good standing of the American Industrial Hygiene Association.

Section 3. The Constitution and Bylaws of each Local Section must be approved by the Board of Directors.

Section 4. Before a Local Section publishes or otherwise issues publicly any statement upon a policy or technical matter which purports to represent the opinion of the American Industrial Hygiene Association it must obtain the consent of the Board of Directors.

Section 5. Before any officer or director of a Local Section publishes or otherwise issues publicly any statement upon a policy matter which is within the policy area of the Local Section, he shall determine by a poll that the statement expresses the majority opinion of the members of the Local Section.

Section 6. The Board of Directors shall establish a Local Sections Council. Two MEMBERS of the Association, in good standing, shall be elected or appointed to this Council by each Local Section of the Association. To promote continuity in the Council, the councilors should be the two highest ranking officers of the Local Section. If not these officers, the councilors should be equally familiar with their Local Section Affairs.

The chairman of the Local Sections Council shall call a meeting of this Council at the time of the annual meeting. The Local Sections Council shall conduct its activities with the advice of the Board of Directors and communicate to the President any wishes of the Local Sections. The President shall present the actions of the Local Sections Council to the Board of Directors for their consideration during the period of that annual meeting.

Section 7. The Board of Directors, by a two-thirds vote, shall have the power to dissolve any local section.

ARTICLE VIII

Inter-Organizational Relations

The Board of Directors may establish reciprocal relations with any organization or federation whose work and activities are closely allied to industrial hygiene.

ARTICLE IX

Seal

The Board of Directors shall provide a corporate seal which shall be in the form of a circle and shall have inscribed thereon the name of the Association and the words, "Corporate Seal, Illinois."

ARTICLE X

Amendments

Section 1. Amendments to Bylaws may be proposed at any annual meeting by a majority vote of the attending members eligible to vote. Proposed amendments shall be circulated to the voting membership with a letter ballot. A majority of letter ballots returned within thirty days shall be required for adoption.

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PRESIDENTS OF THE ASSOCIATION

*1939	William P. Yant, Sc.D.
1940	Warren A. Cook
*1941	Donald E. Cummings
*1942	Philip Drinker, Sc.D.
1943	Helmuth H. Schrenk, Ph.D.
1944	John J. Bloomfield
1945	Robert A. Kehoe, M.D.
1946	Frank A. Patty
1947	Theodore F. Hatch
1948	James H. Sterner, M.D.
1949	Edgar C. Barnes
*1950	Allen D. Brandt, Sc.D.
1951	Anna M. Baetjer, Sc.D.
1952	William R. Bradley
1953	Henry F. Smyth, Jr., Ph.D.
1954	Herbert T. Walworth
1955	Nathan V. Hendricks
1956	Lester V. Cralley, Ph.D.
*1957	Charles R. Williams, Ph.D.
1958	Kenneth W. Nelson
1959	Elmer P. Wheeler
1960	Jack C. Radcliffe
1961	Willis G. Hazard
1962	Kenneth M. Morse
1963	Harry F. Schulte
1964	William E. McCormick
1965	Vincent J. Castrop
1966	William T. McCormick
1967	Clyde M. Berry, Ph.D.
1968	Lewis J. Cralley, Ph.D.
1969	David W. Fassett, M.D.
*1970	Franklin W. Church
1971	John A. Zapp, Jr., Ph.D.
1972	Paul D. Halley
1973	Jerome T. Siedlecki
1974	John A. Pendergrass
1975	Edward J. Baier

*Deceased

BOARD OF DIRECTORS 1969-1977

	1969	1970	1971	1972	1973	1974	1975
Officers:							
President:	D.W.Fassett	F.W.Church	J.A.Zapp,Jr.	P.D.Halley	J.T.Siedlecki	J.A.Pendergrass	E.J.Baier
President-Elect:	F.W.Church	J.A.Zapp,Jr.	P.D.Halley	J.T.Siedlecki	J.A.Pendergrass	E.J.Baier	P.E.Caplan
Vice-President:	J.A.Zapp,Jr.	P.D.Halley	J.T.Siedlecki	J.A.Pendergrass	E.J.Baier	E.E.Campbell	P.F.Woolrich
Secretary:	E.J.Baier	E.J.Baier	E.J.Baier	C.L.Cheever	C.L.Cheever	C.L.Cheever	R.H.Sommer
Treasurer:	P.E.Reid	D.A.Fraser	D.A.Fraser	D.A.Fraser	R.A.Harris	R.A.Harris	R.A.Harris
Past Officers on Board of Directors							
Past President:	L.J.Cralley	D.W.Fassett	F.W.Church	J.A.Zapp,Jr.	P.D.Halley	J.T.Siedlecki	J.A.Pendergrass
Secretary/ Treasurer:	E.E.Baltzer	P.E.Reid		E.J.Baier	D.A.Fraser		C.L.Cheever

	1967-1969	1968-1970	1969-1971	1970-1972	1971-1973	1972-1974	1973-1975
Elected Directors	A.F.Jones	D.K.Anderson	T.R.Bonsby	R.C.Lemon	W.A.Burgess	J.R.Fahey,Jr.	J.A.Jones
	E.J.Lampert	B.A.Harris	E.E.Campbell	P.L.Oglesby	E.E.Christofano	J.R.Johnston	E.L.Kamens
	J.A.Pendergrass	E.Kohler	P.F.Woolrich	P.E.Vendola	E.J.Reid	D.K.McFee	W.R.Bevan,Jr.
	1968-1970	1969-1971	1970-1972	1971-1973	1972-1974	1973-1975	1974-1976
	D.K.Anderson	T.R.Bonsby	R.C.Lemon	W.A.Burgess	J.R.Fahey,Jr.	J.A.Jones	P.E.Caplan
	B.A.Harris	E.E.Campbell	P.L.Oglesby	E.E.Christofano	J.R.Johnston	E.L.Kamens	P.M.Glaser
	E.Kohler	P.F.Woolrich	P.E.Vendola	E.J.Reid	D.K.McFee	E.E.Tebbens	E.E.Baltz
	1969-1971	1970-1972	1971-1973	1972-1974	1973-1975	1974-1976	1975-1977
	T.R.Bonsby	R.C.Lemon	W.A.Burgess	J.R.Fahey,Jr.	J.A.Jones	P.E.Caplan	A.L.Dahmerch
	E.E.Campbell	P.L.Oglesby	E.E.Christofano	J.R.Johnston	E.L.Kamens	P.M.Glaser	P.A.Nelson
	P.F.Woolrich	P.E.Vendola	E.J.Reid	D.K.McFee	E.E.Tebbens	J.E.Baltz	J.E.Lowy
Executive Secretary*	C.L.Clayton	C.L.Clayton	E.L.Eckel	E.L.Eckel	M.E.McCormick	M.E.McCormick	M.E.McCormick

*Changed to Managing Director, 1970 and subsequent years

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HONORARY MEMBERS

In 1955 a class of "Honorary Membership" was established. The Board of Directors may elect to such membership persons who are particularly distinguished in the general field of Industrial Hygiene, or in a closely related scientific field. Honorary Membership shall be considered as purely honorary and requiring no dues, and it does not permit such members to vote on Association matters unless such person is also a member of the Association in good standing. Persons considered for Honorary Membership shall be elected by a two-thirds vote of the Board of Directors.

The following individuals have been thus honored:

Anna M. Baetjer, Sc.D.
John J. Bloomfield
Heinrich Brieger, M.D.*
Ethel Browning, M.D.*
Jacob Cholak
Florence Clayton
Warren A. Cook
A.G. Cranch, M.D.*
Philip Drinker, Sc.D.*
A.Christine Einert, M.D.
Hervey B. Elkins, Ph.D.
J.William Fehnel*
Leonard Greenburg, M.D.
Paul Gross, M.D.
Alice Hamilton, M.D.*
T.F.Hatch
Don D. Irish, Ph.D.
Robert A. Kehoe, M.D.
A.J.Lanza, M.D.*
Carey P. McCord, M.D.
Heinz Oettel, M.D., Ph.D.
Frank A. Patty
Edward C. Riley, M.D.
Royd R. Sayers, M.D.*
Helmuth H. Schrenk, Ph.D.
Clarence D. Selby, M.D.*
Henry F. Smyth, Jr., Ph.D.
H.Wilbur Speicher
James H. Sterner, M.D.
Ludwig Teleky, M.S.*
W.F.von Oettingen, M.D., Ph.D.
Herbert T. Walworth
William P. Yant, Sc.D.*

*Deceased

ANNUAL MEETINGS

PAST MEETINGS

1939 June 5-6	Cleveland,OH
1940 June 4-5	New York, NY
1941 May 5-9	Pittsburgh, PA
1942 April 15-17	Cincinnati, OH
1943 May 25-26	Rochester, NY
1944 May 10-11	St. Louis, MO
1945	(No meeting)
1946 April 8-11	Chicago, IL
1947 April 29-May 1	Buffalo, NY
1948 March 30-April 1	Boston, MA
1949 April 5-7	Detroit, MI
1950 April 25-27	Chicago, IL
1951 April 24-26	Atlantic City, NJ
1952 April 22-24	Cincinnati, OH
1953 April 21-23	Los Angeles, CA
1954 April 26-29	Chicago, IL
1955 April 25-28	Buffalo, NY
1956 April 23-27	Philadelphia, PA
1957 April 22-26	St. Louis, MO
1958 April 22-25	Atlantic City
1959 April 27-May 1	Chicago, IL
1960 April 25-28	Rochester, NY
1961 April 9-13	Detroit, MI
1962 May 13-17	Washington, DC
1963 May 6-10	Cincinnati, OH
1964 April 26-30	Philadelphia, PA
1965 May 3-7	Houston, TX
1966 May 16-20	Pittsburgh, PA
1967 May 1-6	Chicago, IL
1968 May 13-17	St. Louis, MO
1969 May 12-16	Denver, CO
1970 May 11-15	Detroit, MI
1971 May 24-28	Toronto, Canada
1972 May 14-19	San Francisco, CA
1973 May 21-25	Boston, MA
1974 May 12-17	Miami Beach, FL
1975 June 1-6	Minneapolis, MN

FUTURE MEETINGS

1976 May 16-21,Marriott Hotel	Atlanta, GA
1977 May 22-27,Fairmont Hotel	New Orleans, LA
1978 May 7-12,Biltmore Hotel	Los Angeles, CA
1979 May 27-June 1,Palmer House	Chicago, IL
1980 May 18-23,Hyatt Regency Hotel	Houston, TX
1981 May 24-29,Hilton Hotel	Portland, OR

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CUMMINGS MEMORIAL AWARD

A feature of the annual meetings is the presentation of the Cummings Memorial Award for outstanding contributions to the knowledge and practice of the profession of Industrial Hygiene. The award was established by the Board of Directors in 1943 in memory of Donald E. Cummings, our third president. The award recipients are listed below.

1944	Leroy Gardner, M.D.*
1947	William P. Yant, Sc.D*
1948	Alice Hamilton, M.D.*
1950	Philip Drinker, Sc.D.*
1951	Theodore F. Hatch
1952	Leonard Greenburg, M.D.
1953	Warren A. Cook
1954	Frank A. Patty
1955	James H. Sterner, M.D.
1956	Henry F. Smyth, Jr., Ph.D.
1957	Helmuth H. Schrenk, Ph.D.
1958	John J. Bloomfield
1959	No Award
1960	Gordon C. Harrold, Ph.D.
1961	Manfred Bowditch (Posthumously)*
	William G. Fredrick, Sc.D.Lecture
1962	Herbert T. Walworth
	Robert A. Kehoe, M.D., Lecture
1963	Allen D. Brandt, Sc.D.*
1964	Anna M. Baetjer, Sc.D.
1965	Charles R. Williams, Ph.D.*
1966	Don D. Irish, Ph.D.
1967	Harvey B. Elkins, Ph.D.
1968	Willis G. Hazard
1969	Herbert E. Stokinger, Ph.D.
1970	Edgar C. Barnes
1971	Lester V. Cralley, Ph.D.
1972	Harry F. Schulte
1973	George D. Clayton
1974	Mary O. Amdur, Ph.D.
1975	William B. Deichmann, Ph.D., M.D.(Hon)
	Robert A. Kehoe, M.D.

*Deceased

WILLIAM P. YANT AWARD

In 1964 the Board of Directors established the Yant Award in memory of the first president of the Association, William P. Yant, Sc.D. The award is presented for outstanding contributions in Industrial Hygiene or allied fields, to an individual residing outside the United States, who has been recommended by the Past Presidents of AIHA and approved by the Board of Directors. Recipients have been the following:

1965	Henry L. Green Salisbury, Wiltshire, England
1966	Alberto Hurtado, M.D. Lima, Peru, South America
1967	Sven Forssman, M.D. Stockholm, Sweden
1968	Leo Noro, M.D. Helsinki, Finland
1969	Enrico C. Vigliani, M.D. Milan, Italy
1970	Etienne P. Grandjean, M.D. Zurich, Switzerland
1971	W.H.Walton Edinburgh, Scotland
1972	Jaroslav Teisinger, Sc.D. Prague, Czechoslovakia
1973	C.H.Wyndham Marshalltown, Transvaal
1974	Clifford G. Warner, Ph.D. South Wales, United Kingdom
1975	Werner Klosterkötter, Dr.Med. Essen, West Germany

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INSIGNIA

The new logotype of the Association is shown on the front cover of this book. This design was approved by the Board of Directors at its meeting June 1, 1975.

A few emblems of the former insignia, in the form of gold lapel or tie tacs and watch charms are still available and may be obtained from the Managing Director for $5.00 postpaid, inclusive of Federal Tax.

ASSOCIATION MEMBERSHIP

TABLE 1-Growth in Membership

Year	Number of Members	Year	Number of Members
1940	160	1958	1022
1941	270	1959	1110
1942	290	1960	1165
1943	322	1961	1196
1944	359	1962	1260
1945	353	1963	1324
1946	371	1964	1362
1947	427	1965	1415
1948	493	1966	1441
1949	548	1967	1511
1950	621	1968	1600
1951	707	1969	1644
1952	763	1970	1649
1953	800	1971	1616
1954	860	1972	1630
1955	946	1973	1627
1956	974	1974	1987
1957	1007	1975	2344

BOARD COORDINATORS

(For all Standing and Technical Committees)

STANDING COMMITTEES

John A. Janous	Local Sections Council Law Public Affairs
Howard L. Kusnetz	Membership Monograph Sustaining Membership
William H. Revoir, Jr.	ANSI Representation Manpower and Career Development Society Representation
Joseph E. Zatek	Editorial Long Range Planning Trade Practices

TECHNICAL COMMITTEES

Paul E. Caplan	Engineering Personal Protective Equipment Respirator
Allen L. Cudworth	Analytical Chemistry Direct Reading Gaseous Detecting Systems
Theodore A. Felton	Air Pollution Laboratory Accreditation
Paul M. Giever	Ionizing Radiation Non-ionizing Radiation Noise
James E. Long	Ergonomics Hygienic Guides Toxicology

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AD - HOC COMMITTEES

Direct Reading Gaseous Detecting Systems

1974 - Joseph W. Klinsky, Chairman
1975 - Serafino J. Fisco
1975 - Leroy L. Garcia
1974 - Melton M. Garcia
------ Arthur E. Johnston (Emeritus)
------ Nelson A. Leidel (Consultant)
------ Adrian L. Linch (Emeritus)
------ Michael M. Roder (Consultant)
------ H.W.Speicher (Emeritus)
1972 - Alvin L. VanderKolk

Respirator

1973 - George L. Morse, Chairman
------ John M. White, Vice Chariman (Emeritus)
1974 - Robert J. Barghini
1975 - Darrell A. Bevis
------ Jerrold L. Caplan (Consultant)
1974 - Theodore A. Felton
------ Alan K. Gudeman (Consultant)
------ Patricia Gussey (Consultant)
1974 - Bruce J. Held
------ Edwin C. Hyatt (Emeritus)
1975 - Arthur E. Johnston
1974 - John A. Jones
1972 - Edwin J. Kloos
1972 - Ross N. Kusian
1973 - Joe Lipera
------ Stewart G. Luxon (Emeritus)
1975 - Henry J. McDermott
1975 - Alexsandra Nawakowski
1974 - John A. Pritchard
1975 - William H. Revoir, Jr.
1975 - Alan E. Sherr
------ Richard L. Stein (Consultant)

LOCAL SECTIONS COUNCIL

Chairman: Theodore A. Aucoin, Jr.
Vice Chairman: John D. Yoder, Sc.D.
Secretary: Charles S. Laubly

STANDING COMMITTEES

Awards
1975 - John A. Pendergrass, Chairman
1974 - Charles L. Cheever
1974 - Paul M. Giever
1974 - Howard L. Kusnetz
1974 - Jerome T. Siedlecki

CONFERENCE
Gordon Nifong, General Chairman
Vice Chairman, AIHA: James L. Burson
Vice Chairman, ACGIH: Thomas W. Freeman

Arrangements Committee
James L. Burson, Chairman
William F. Crowder
George Hayes
Paul Richter

Banquet Committee
John Savidge, Chairman
Seneca Foote
James McHale

Commercial Exhibitors
Robert R. Weeks, Chairman

Entertainment
Gwen Dekle, Chairwoman

Program Committee
Paul F. Woolrich, Chairman
Robert S. Ajemian-Noise
Edward J. Hobbs-Toxicology
Eliezer Kamon-Ergonomics
Ross N. Kusian-Respiratory Protective Devices
William S. Lainhart, M.D.-Occupational Medicine
Robert Magor-Air Pollution
Owen R. Moss-Aerosol Technology
William E. Murray-Non-Ionizing Radiation
John P. Sapia-Engineering
John M. Selby-Ionizing Radiation
Frederick M. Toca-Analytical Chemistry
Richard L. Sweitzer-Personal Protective Devices
Henry M. Taylor,Jr.-Personal Protective Devices

Ladies Hospitality Committee
Virginia Nifong, Chairwoman
Gwen Dekle
Alice Farrar

Publicity
Holmes Pyles, Chairman

Refresher Courses
Leon D. Horowitz, Chairman

(The year shown is when first appointed to committee.)

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Registration
R.A.Tremblay, Chairman

Scientific Exhibits
Wendell Ringer, Chairman
Richard Lux

Editorial
1975 - Harley H. Bovee, Chairman
1975 - Ralph E. Allen
1975 - James L. Burson
1975 - Steven M. Cant
1975 - David Dunham
1975 - Lester Levin
1975 - Henry B. Lick
1975 - Gary E. Myers
1975 - Donald M. Ross
1975 - Noel J. Varela
1975 - Michael O. Varner
1975 - Maurice H. Weeks

Finance
1973 - Bruce A. Hertig, Chairman
1975 - James E. Long
1975 - John A. Pendergrass
1975 - Paul F. Woolrich
1974 - Joseph E. Zatek

Journal Associate Editors
Franklin D. Griffith
Thomas T. Mercer
James O. Pierce
Richard F. Scherberger
Harry F. Schulte
John S. Shockley, Jr.

Laboratory Accreditation Committee
1972 - Russell VanHouten, Chairman
1974 - Fred M. Toca, Vice Chairman
1972 - James O. Pierce, Past Chairman
1973 - O'Neil Banks
1974 - George Boylen
1973 - John V. Crable
1975 - H.F.Herr
1973 - Arthur E. Johnston
William E. McCormick, Ex officio
1975 - William D. Kelley
1975 - Newton Whitman
1974 - J. Lloyd Monkman
1973 - Betty O'Shea
1975 - C.E.Roessler
1975 - Lawrence G. Silverstein
1974 - Ralph G. Smith

Law Committee
1973 - Charles H. Powell, Chairman
1975 - Ralph E. Allen, Vice Chairman
1975 - Morton Corn
1973 - Kenneth D. Johnson
1973 - William T. Keane
1973 - Frank L. Paschal, Jr.
1973 - Stanley T. Wagner
1975 - Claudia Prieve
1975 - Grover C. Wrenn

Long-Range Planning
1975 - Jerome Siedlecki, Chairman
1975 - J. Leroy Balzer
1975 - Charles L. Cheever
1975 - Gerald E. Devitt
1973 - Ernest M. Dixon
1975 - Virgil J. Konopinski
1975 - Erwin R. Tichauer
1974 - Paul E. Toth
1975 - Dennis A. Tyler

Managing Directors' Operations
1975 - Clyde M. Berry, Chairman
1975 - Allen L. Cudworth
1975 - Gerald E. Devitt
1975 - Bruce A. Hertig
1975 - Gordon D. Nifong
1975 - Edward B. Radden
1974 - Jerome T. Siedlecki

Membership
1974 - J.K.Sugg, Chairman
1974 - E.R.Evavold, Vice Chairman
1973 - R.S.Ajemian
1973 - R.D.Ashley
1973 - T.A.Aucoin, Jr.
1973 - W.J.Brown, Jr.
1974 - F.J.Darcy
1973 - M.S.Gabis
1973 - J.T.Garrett
1974 - F.L.Oglesby
1975 - Edward J. Sowinski
1973 - R.A.Tremblay

Monograph
1973 - Elmer P. Wheeler, Chairman
1973 - William A. Burgess
1973 - John F. Ege, Jr.
1973 - Harry F. Schulte

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Nominating
1975 - John A. Pendergrass, Chairman
1975 - Cois M. Brown
1974 - Jerome T. Siedlecki
1975 - John D. Yoder

Public Affairs
1973 - Allen L. Cudworth, Chairman
1973 - Dennis A. Tyler, Vice Chairman
1975 - Robert Diakun
1973 - Charles P. Dorsey
1973 - Theodore A. Felton
1973 - John W. Feuk
1973 - Frank M. Parker, III
1973 - William H. Persky
1973 - Jerry F. Shultz
1973 - Mario Storlazzi

Sustaining Membership
William LaRocque, Chairman (Emeritus)
Russell C. Ruhf, Vice Chairman (Emeritus)
1975 - Robert J. Archer
1974 - Louis S. Beliczky
1975 - Robert Comboy
1975 - Roy J. Covert
1973 - Dale Culp
1974 - W.T.Keane
1974 - John D. Neefus, Sr.
1975 - Charles A. Peterson
1974 - Wendell Ringer
1973 - Jon R. Swanson
1975 - Ronald Stolberg

Tellers
1973 - Louis S. Beliczky, Chairman
1973 - Robert W. Modrell
1974 - George L. Wilson

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Air Pollution
1974 - William H. Krebs, Chairman
1973 - Rodney R. Beard
1974 - G.J.Butler
1973 - Robert P. Belliles
1973 - Gerald E. Devitt
1975 - William L. Dyson
1973 - Edward R. Hermann
1973 - Robert C. Magor
1975 - Charles E. McJilton
1975 - Albert J. Rosso
1973 - William E. Stocum
1975 - Donald E. Waid
1973 - Lowell G. Wayne

Analytical Chemistry
1973 - Billy S. Smith, Chairman
1973 - William R. Burg
1975 - Therese Donovan
1973 - John Dunstan
1975 - William H. Dyre
1975 - Reginald Griffin
1973 - Fred I. Grunder
1973 - Albert C. Holler
1975 - James Jackson
1973 - Morris Joselow
1974 - Daniel Lillian
1973 - Robert C. Magor
1975 - George U. Oleru
1975 - Louis Press
1975 - Stephen M. Rappaport
1974 - Cecil L. Smith
1975 - Edward J. Sowinski
1974 - Jeanne M. Stellman
1973 - Robert L. Stoffer
1973 - Frederick M. Toca
1973 - Thomas J. Walker

Engineering
1973 - Thomas Anania, Chairman
1973 - Donald R. Lyman, Vice Chairman
1975 - David J. Burton
1973 - William Cleary
1975 - Richard J. Coombs
1975 - Roy J. Covert
1975 - Louis J. DiBarardinis
1975 - David Dunham
1975 - John M. Hochstrasser
1973 - G.J.Krafcisin
1975 - Lee B. Larsen
1975 - John E. Mutchler
1975 - Joseph Nachtman
1975 - Peter W. Pharis
1974 - John Polhemus
1973 - F.M.Renshaw
1973 - John P. Sapia

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Ergonomics
Jerry D. Ramsey, Chairman (Emeritus)
1973 - John R. Brown
1974 - Don B. Chaffin
1975 - D. Francis Dukes-Dobos
1975 - Austin F. Henschel
1974 - Bruce A. Hertig
1974 - Eliezer Kamon
1974 - Jerry L. Purswell
1975 - Paul E. Smith
1975 - Stover H. Snook
1975 - Erwin R. Tichauer
------ Thomas A. Walker (Emeritus)

Hygienic Guides
1975 - Howard E. Runion, Chairman
1975 - Charles H. Powell, Vice Chairman
1975 - Oneil M. Banks
1975 - Lial W. Brewer
1975 - Paul E. Caplan
1975 - Emil E. Christofano
1975 - David P. Discher
1975 - Richard E. Fulwiler
1974 - Bruce S. Horvath
1975 - William C. Janes
1975 - Mars Y. Longley
1975 - H.J.Trochimowicz
1975 - Carl Zenz

Ionizing Radiation
1972 - Robert G. Thomas, Chairman
1973 - William J. Friedman
1975 - Andrew A. Mammarelli
1973 - David Rimberg
1974 - L.G.Silverstein
1975 - Emery E. Sobottka
1975 - Robert G. Wissink

Noise
1972 - Alonzo M. Webber, Chairman
1974 - Stanley H. Judd, Vice Chairman
1973 - Robert S. Ajemian
1975 - N.R.Dotti
1973 - Walter L. Eneidi
1975 - Aram Glorig
1975 - William M. Ihde
1975 - Francis S. Jana
1975 - George W. Kamperman
1975 - Gene X. Kortsha
1974 - Rudolph M. Marrazzo
1975 - John B. Masaitis
1975 - Donald R. McFee
1975 - Arthur Neilson
1975 - Paul B. Ostergaard
1975 - S.I.Roth
1973 - Frank C. Sentz, Jr.
1975 - Edwin H. Toothman

Noise, cont.
1974 - Guy F. VanAuken
1974 - Thomas K. Wilkinson

Non-Ionizing Radiation
1975 - Charles R. McHenry, Chairman
1975 - Richard F. Boggs
1973 - Thomas W. Freeman
1975 - Alphonse F. Klascius
1975 - Wordie H. Parr
1973 - Frank L. Paschal, Jr.
1974 - Howard B. Perry
1973 - Robert A. Rennicks
1975 - Alan E. Sherr
1975 - Thomas K. Wilkenson

Personal Protective Devices (Other than Respiratory)
1974 - Richard L. Sweitzer, CO-Chairman
1974 - Henry M. Taylor, Jr., Co-Chairman
1975 - W. Lee Barnhart
1975 - Louis P. Gendernalik
1974 - Ronald L. Guinn
1975 - Gerald L. Hess
1975 - H.V.Hodnick
1975 - Thomas E. Kreichelt
1975 - Henry A. Makino
1975 - George L. Morse

Toxicology
1973 - Franklin D. Griffith, Chairman
1975 - Evelyn G. Burtis
1972 - Charles C. Clarke
1974 - Ernest M. Dixon
1974 - E.J.Hobbs
1974 - Morris M. Joselow
1972 - John G. Keller
1973 - Moreno L. Keplinger
1974 - George J. Levinskas
1975 - Harold N. MacFarland
1972 - James N. McNerney, Jr.
1975 - Andrew L. Reeves
1975 - Marshall Steinberg
1975 - Andrew Tegeris
------ Carrol S. Weil (Emeritus)
1973 - Claude H. Wolf

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Trade Practices
1973 - William J. Uber, Chairman
1973 - C.H.Borcherding, Vice Chairman
1974 - R.J.Barghini
1974 - Z.B.Bell, Jr.
1973 - Dennis R. Dalley
1973 - Stephen C. Davis
1974 - W.L.Dyson
1973 - T.A.Felton
1973 - Edward B. Landry
1973 - P.W.McDaniel
1973 - Gyan S. Rajhans
1973 - A.J.Rosso
1974 - A.E.Sethre
1973 - David N. Staples
1974 - J.M.Stellman
1973 - A.G.Widner

AIHA OFFICIAL REPRESENTATIVES TO SOCIETIES

Air Pollution Control Association	R.C.Wanta
American Academy of Occupational Medicine	Carl U. Dernehl,M.D.
American Association for the Advancement of Science	Knowlton J. Caplan
American Society for Testing and Materials	
D22 Committee	Paul M. Giever J.Brennan Gisclard
D26 Committee	Zeb G.Bell, Jr.,Sc.D.
E34 Committee	John W. Feuk
Inter-Society Committee on Industrial Hearing Conservation	Paul L. Michael, Ph.D. LCDR Joseph J. Drozd, Jr.
Inter-Society Committee for Preparation of Manuals on Ambient Air Sampling and Analysis	George D. Clayton
Subcommittee No. 6	Fred I. Grunder
Subcommittee on Stack Sampling	M.Dean High
National Council on Radiation Protection	Harry F. Schulte George M. Wilkening
National Sanitation Foundation Advisory Committee for Personal Dosimetry	J.D.Eastes
National Scouting Organizations	John Hochstrasser Martin Ornosky
National Society for Medical Research	Claude H. Wolf
Occupational Health Institute	Jerome T. Siedlecki
Commission on Accreditation of Occupational Health Programs	John A. Pendergrass, Commissioner

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REPRESENTATIVES ON ANSI
CODE COMMITTEES

A-11, Industrial Lighting

Rep.: John J. Ferry
Alt.: H.Wilbur Speicher

A-40.8, National Plumbing Code

Rep.: Howard Perry
Alt.: Jerome C. Flato

B-30, Safety Code for Cranes, Derricks, and Hoists

Rep.: Lewis Barbe
Alt.: Elmer J. Hlavaty

B-31.6, Chemical Process Piping

Rep.: Norman G. White, Ph.D.

C-95, Radio Frequency Electro-magnetic Radiation Hazards

Rep.: H. Wilbur Speicher

K-13, Identification of Gas Mask Canisters

Rep.: Edward Hyatt
Alt.: William Revoir, Jr.

K-68, Epoxy Resins

Rep.: Frank M. Parker, III
Alt.: Loren B. Canada

L-18, Specifications for Protective Clothing

Rep.: Adrian Linch

Nuclear Advisory Board

Rep.: Thomas Burnett
Alt.: William Ray

N-12, Nuclear Terminology

Rep.: James Martin

N-13, Radiation Protection

Rep.: H. Wilbur Speicher
Alt.: William Kelley

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Z-9, Safety Code for Exhaust Systems

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Z-12, Safety Code for Prevention of Dust Explosions

Rep.: Murray Jacobson

Z-35, Industrial Accident Prevention Signs

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*Z-37, Acceptable Concentrations of Toxic Dusts and Gases

Rep.: Moreno L. Keplinger, Ph.D.
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Z-83, Code for Direct Gas-Fired Make-up Air Heaters
Rep.: Kenneth Robinson

Z-84, Glossary of Environmental Terms
Rep.: Russell Ruhf

Z-87, Safety Code for Eye Protection
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Z-88, Safety Code for Respiratory Protection
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Z-105, Code for Air Cleaning Equipment
Rep.: Knowlton Caplan
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Z-117, Safety Requirements for Working in Tanks and Confined Spaces
Rep.: Byron Berg
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Z-135, Safety in Professional and Commercial Diving Operations
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Z-136, Lasers and Masers
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San Ramon, CA 94583
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Rm. 2519-600 Grant St.
Pittsburgh, PA 15230

Strelecki, Ronald R.
11 Bell Ave.
Pittsburgh, PA 15205
(Harbison-Walker Co.)

Stricoff, R.Scott
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Arlington, MA 02174
(Arthur D. Little, Inc.)

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Philadelphia, PA 19103
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1718 Peachtree Rd., N.W.
Atlanta, GA 30302

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1709 Hargrove St. #4
Antioch, CA 94509
(Crown-Zellerbach Co.)

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Toney, Charles R.
Bendix Launch Supp. Div.
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Cocoa Beach,FL 32931

Tovatt, Gerald L.
Continental Ins. Co.
360 W. Jackson
Chicago, IL 60606

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Eastman Kodak Co.
Rochester, NY 14650

Vila, Ramon V.
Avda. Reina Mercedes 19-C
Sevilla, Spain
(Plan Nac. de Hig. y
Seguridad del Trabajo)

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5171 N. 107th St.
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(Limnetics, Inc.)

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(Grad. Student)

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Skan, Maryellen
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Wilson, Lynn D.,Ph.D.

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Russell, Major Harry C.

CALIFORNIA (225)

Adams, Jack L.
Allan, Ralph E.
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Bachman, James M.
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Ballou, E.Vernon
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Brown, A. Robert
Brown, Harold V.
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Chang, Hsing-Chi
Channell, Lynn R.,Lt.,Col.
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Clayton, Florence
Clayton, George D.
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Cohen, Jerry J.
Cohen, Kenneth S.
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Davis, Douglas J., Capt.
Davis, Stephen C.
Dennerline, Richard L.
Devlin, Thomas K.
Diamond, Philip
Discher, David P., M.D.

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Dolliver, Richard E.
Drake, George E.
Dryden, Stanley L.
Easley, Charles W.
Ebersole, Edward W.
Einert, Amy Christine,M.D.
Eisen, Jerome
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Felton, Theodore A.
Felton, J.S., M.D.
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Flinn, Robert H.,M.D.
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*Grasso, Harvey D.
Graul, Robert J.
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Hine, C.H.,M.D.,Ph.D.
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Johnson, James S.
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Kane, Donald A.,Capt.
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Kenen, Richard C.
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Phillips, Ronald D.

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Popendorf, William J.
Port, Eugene A.
Proctor, Nick H.
Psathas, John G.
Reich, Arthur R.
Reischl, Uwe, Ph.D.
*Richmond, Bradford S.
Roddy, Earle L.
Rogers, Jack C.
Roncetti, Peter M.
Rosati, Guido J.
Rummerfield, Philip S.,D.Sc.
Rush, Donald
Salazar, Alfredo
Sapp, Loren W.
Schmelzer, Lawrence L.
Schneider, Meier
Seto, George
Shahid, Rafat A.
Sherman, George A.
Shingler, Larry H.
Shiroma, Paul T.
Shone, Lloyd B., M.D.
Sidlow, Anthony J.
*Simmons, Rodney J.
Smead, Major Philip E.
Smith, Lt. Col. Billy S.
Smith, David R.
Smith, Evelyn J.
Sobol, Oscar J.
Spear, Robert C.
Spence, John A., Ph.D.
Spence, Robert W.
Spielman, Howard B.
Spies, Wendell E.
Steffan, William W.
Sterner, J.H., M.D.
*Stobbe, Terrence J.
Stone, Jack H.
Sutay, Capt. Robert J.
Swann, Henry E.,Jr., Ph.D.
Sweigart, Marlin L.
Taloff, Paul
Theap, Raymond J.
Thienes, Clinton H., M.D.,Ph.D.
Thompson, James L.
*Thorne, Jerry T.
Tom, Baldwin
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Weinstock, Alex
Weiss, Herbert V., Ph.D.
Wennemann, Roy H.
Wolf, William J.
Yaffe, Charles D.
Yamamoto, Yoneo
Young, Jensen

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Angell, Otis H.
Appelbaum, Jerry J.
Bank, Walter
*Bellmar, Richard K.
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Bocim, Warren T.
Bokowski, Dale L.
Brennan, Ray A.
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Chmielowiec, Frank V.
Christensen, Denny R.
Conti, T.J.
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Fehringer, M. Renee
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Hill, John E.
Hilmes, Howard J.
Hobbs, Farrel D.
Kittinger, Wilbur D.
Leigh, Jack D.
McGilvray, William A.
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Reitze, William B.
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Searle, Ronald J.
Stellman, Jeanne M., Ph.D.

*Associate Grade
**Student Grade

COLORADO (continued)

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Teitelbaum, Daniel T., M.D.
Thielke, Stanley A.
Torrey, Jack D.
Uhle, Ronald J.
Walker, Robert J.

CONNECTICUT (58)

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Blaney, Lamson, M.D.
*Bolton, John D.
*Briggs, Elaine S.
Brubaker, Robert E., M.D.
*Bryant, Steve E.
Culp, Dale A.
Deck, Edward N.
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Dudarevitch, Mitchell D.
Dunstan, John
Ege, John F., Jr.
*Eident, Christopher J.
Engle, Edward G.
Feliu, Leopoldo
Flanagan, Joseph T.
Guy, Allen C., Jr.
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Hancock, Robert L.
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Hosein, H. Roland
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Kay, Kingsley, Ph.D.
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Mayes, Gerald A.
Meade, William G.
Meigs, J. Wister, M.D.
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Muranko, Henry J.
Nebbia, Russell A.
Parsons, Floyd B., Jr.
Parsons, George E., Jr.
Pedalino, Joseph S.
Press, Louis
Rapp, Harry W., Jr.
Robinson, Donald B.
Robinson, John M.

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Sallee, Elgin D.
Saylor, James I.
Schmidt, Rudolph, Jr.
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Sunderman, F.William,Jr.M.D.
Taylor, John A.
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Turk, Amos, Ph.D.
Wedig, John H., Ph.D.
Wheeler, Stephen R.
Yocom, John E.

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Wheeler, Allan G.
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Byrd, Roland E.
Cesta, Ramon P.
Daley, Michael J.
Deichmann, W.B., Ph.D.,M.D.(hon.)
Greenburg, Leonard, M.D.
Gross, Paul, M.D.

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*Mannion, Cathie M.
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Urone, Paul, Ph.D.

GEORGIA (30)

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Morgan, K.Z., Ph.D.
Nifong, Gordon D., Ph.D.
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Schutz, Rodney K.
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*Ige, Jordan T.
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Steffee, Elizabeth V.
Yamamoto, Robert K.

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*Null, David
Poppe, Walter H.

ILLINOIS (98)

Alpaugh, Edwin L.
Angelos, Frank J.
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Becker, Henry F.
Bleier, Richard I.
Borcherding, Charles H., Jr.
Bridge, Dennis P.
Brower, John F.
Calandra, Joseph C., M.D.
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Christoffer, Willard C.
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Cook, Fred
Cooper, Gerald L.
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Davis, Joseph R., Ph.D., M.D.
Deeg, Frederick H.
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Geishecker, Dorothy K.
Gidley, M. David
*Gies, Richard T.
Golonka, Edward J.

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Grawey, Gerald W., M.D.
Hall, Stephen K., M.D.
Halley, Paul D.
*Hallstein, Roger E.
Hermann, Edward R., Ph.D.
Hernandez, Peter A.
Hertig, Bruce A., Sc.D.
Hickey, C. Raymond
Hilker, Robert R.J., M.D.
*Hinterman, Ralph H.
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Huelsen, William B.
Ihde, William M.
Jana, Francis S.
Jaworski, Harry E.
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Kinoshita, Florence K., Ph.D.
Kinser, Richard E.
Kirschner, Leon
Krafcisin, George J.
Landis, George
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Shevick, Billie H., M.D.

*Associate Grade

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Siedlecki, Jerome T.
**Skan, Maryellen
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Spiegl, Charles J.
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*Tovatt, Gerald L.
*Vaughan, Allen D.
Walsh, Eugene L., M.D.
Ward, A. Neal, M.D.
Wessa, Lowell G.
*Wheater, Robert H.
Willens, Nathan
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Woodring, James L.
Wronski, Joan A.

INDIANA (26)

*Anderson, Gary J.
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Christy, H.R.
Dorsey, Charles P.
Dunning, Preston M., M.D.
Edwards, Albert
Elson, Ross J.
Fitch, John J.
Hohl, Arthur R.
Jones, Karl K.
Keppler, J. Frederick
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Kryszek, Stanley H., Ph.D.
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Roberts, Warren C., M.D.
Rushmore, Charles H., M.D.
Sapia, John P.
Taylor, James A., M.D
Waid, Donald E.
Weber, Herbert J.
Wiehrdt, William
Wright, William N.
Zolkos, Leonard M.

IOWA (20)

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Bickford, Ward W.
Campbell, Charles L., Ph.D.
Dolan, Michael F.

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Ekey, Danzel B.
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*Jewett, William R.
Konz, Stephen A., Ph.D.
*Lancour, Gerald W.
Murphy, Thomas E., Jr.

KENTUCKY (18)

Baker, Richard C.
Castle, Galen E.
Clausen, Judith H., Ph.D.
Clay, Maurice F.
Conners, Edward W., Jr.
Dyson, William L.
*Flannery, Deborah A.
Kane, John M.
*Keith, John B.
Miller, James A.
Purcell, Thomas C., Ph.D.
Quinn, Patricia M.
Redman, William A., Jr., M.D.
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*Schoen, Russell J.
Turok, Charles W.
Unterbrink, Robert C. Jr.
Westlin, Karl L.

LOUISIANA (27)

Aucoin, Theodore A., Jr.
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Batchelor, Bruce B.
Cope, Robert F., Jr.
Deaton, Hillman E.
Graef, Warren D.
*Hall, James J. III
*Halphen, Charles E.
Hanemann, Sheldon J.
*Herron, Stephen D.
LaBauve, Joseph E.
Leemann, James E.
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Pancamo, Beverly
Pappas, George
Phillips, Carolyn F.
Repko, John D.
Richard, Max L.
Rinehart, William E., Sc.D.
Schonberg, John C.
Snyder, Louis J.
Spraul, James H., M.D.
Storment, John W.
Taylor, Henry M., Jr.
Venable, Fred S.
*Watts, J. David
Zavon, Mitchell R., M.D.

MAINE (3)

Broaddus, Samuel T.
Fassett, David W., M.D.
Schacht, Harry T.

MARYLAND (89)

Ackerman, Harry H.
Ashley, Roy D.
Baetjer, Anna M., Sc.D.
Baier, Edward J.
Bales, Ronald E.
Barnes, Capt. Edward S.
Beegan, James A.
Berger, David L.
Bien, Ching-Tsen
Biskup, Ronald K.
Blackman, Alfred C.
Boggs, Richard F., Ph.D.
Borawski, Edward T.
Borkowski, Thomas V.
Bovee, Harley H., Ph.D.
Bradigan, Terrance A., Jr.

*Associate Grade

MARYLAND (continued)

Brown, Carlton E., Sc.D.
Browning, David R.
*Chien, Paul T.
Christensen, H.E., D.Sc.
Ciuchta, Henry P.
Collins, John T., Jr.
Dahle, Elkins W., Jr.
Duggar, Benjamin C., Sc.D.
Edwards, Phillip M.
*Ellis, William D.
Fischoff, Robert L.
Flowers, Delbert L.
Gabis, Max S.
Gillis, Albert D.
Gundaker, Walter R.
Haile, Fred H.
Halpin, Walter R.
Hamilton, Allan C.
Hancock, Roger P.
Hanna, Fayez B. Ph.D.
Hay, Errol B., III
Hess, Thomas L.
Jacobson, Keith H., Ph.D.
Johnson, Arthur T., Ph.D.
Jurinski, Neil B.,Ph.D.
Kendig, John D., Major
Kennedy, James L.
Kirwin, Carroll J., Jr.
Knessey, Alfred D., Lt. Col.
Kruse, Cornelius W.
Landry, Edward B.
*Lee, William L.
Levine, Marshall, M.D.
Lillian, Daniel, Ph.D.
Malone, Winfred F.
Marquiss, Richard P.
Mitchell, Frank L.
Owens, Edmond J.
Payne, William W., Sc.D.
Podolak, George E.
Powell, Charles H., Sc.D.
Proctor, E. Gene
Pyne, Frederick W.
Radden, Edward B.
Ray, William H.
Reichenbach, G.S.
Roan, Clifford C.
Robinson, Linda L.
Ronk, Richard M.
Rose, Vernon
Sansone, Eric B., Ph.D.
Siegel, Capt. Jacob, USN
Slaback, Lester A., Jr.
Sliney, David H.
Smith, Donald W.
Smith, Douglas L.
Smith, Col. Francis J.
Smith, Paul E., Jr.
Sneeringer, Paul V.
Sprague, George F., III
Staples, David N.
Steinberg, Marshall
Strickland, Gordon D.
Svirbely, Joseph L., Ph.D.
Thomas, Armand P.
Urman, Stephen C.
Vocci, Frank J.
Vorpahl, Maj. Kenneth W.
Weeks, Maurice H.
Wilde, Ralph M.
Wilkinson, Thomas K.
Wiswesser, W.J.
Wrenn, McDonald E., Ph.D.

MASSACHUSETTS (85)

Amdur, Mary O., Ph.D.
*Balya, Dennis R.
Banks, O'Neil M., Ph.D.
Bavley, Harold
Benoit, Merrill P., M.D.
Benson, Arthur L.
Billings, Charles E., Ph.D.
Boehm, Arthur J.
Bohn, Victor O.
*Boundy Costa, Maryanne
Boylen, George W., Jr.
Bulba, Eli
Burgess, William A.
*Campbell, Donald W.
Cares, Janet W.
Chamberlin, Richard I.
Chew, F. Freeland, Jr.
Cieplinski, Edward
Comproni, Elise M.
Cudworth, Allen L.
Dennis, Richard
DiBerardinis, Louis J.
Driscoll, John N.
Drucker, Marjorie A.
Elkins, Hervey B., Ph.D.
Ferris, Benjamin G., Jr., M.D.
First, Melvin W., Sc.D.

*Associate Grade

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MASSACHUSETTS (continued)

Flanagan, Joseph E., Jr.
Furman, Richard C.
Gantt, William A.
*Gempel, Robert F.
Gleason, Robert P.
Goldman, Ralph F., Ph.D.
Gordon, David
Griffin, Reginald M., Ph.D.
Grillo, Gene P., Ph.D.
Gussman, Robert A.
Hinds, William C.
Holaday, Duncan A.
Horowitz, Leon D.
Huckeba, George W.
*Hynes, George M.
Jaeger, Rudolph J.
Johnson, Richard S.
Jones, John A.
*Joseph, Fred E., Jr.
Killian, Charles B.
LaRocque, William R.
LaTorre, Philip
Leahy, Joseph E.
Loring, John H.
Magor, Robert C., Ph.D.
Maloof, Clarence C., M.D.
Metcalf, Robert F., Jr.
Mitchell, Charles A.
Moeller, Dade W., Ph.D.
Morin, Ronald E.
Neukuckatz, Ernest
Nugent, Albert E., Jr.
Pagnotto, Leonard D.
Pallaria, Dominic J., Jr.
Palm, Paul E., Ph.D.
Partridge, Lawrence J., Jr.
Peters, Claudia A.
Peters, Howard A., Ph.D.
Peters, John M., M.D., Sc.D.
Piccolo, Stephen K.
Pierce, William M.
Pihl, Stanley E.
*Ploss, F. David
Renzi, Ralph L.
Sacco, Anthony M.
Salmonsen, Patricia A.
Siroonian, Barkev
Snook, Stover H., Ph.D.
Storlazzi, Mario
*Stricoff, R. Scott
Underhill, Dwight W.
VanHouten, Russell W.
*Vegella, Thomas
Viles, F.J., Jr.
Wanta, R. C.
*Weingast, Joel M.
Whittenberger, James L., M.D.
Yurgilas, Vincent A.

*Associate Grade

MICHIGAN (149)

Ajemian, Robert S.
*Alexander, Cheri L.
*Alshallal, Mejren
*Amato, Duane F.
Barrett, James C.
Berke, Harry L., Ph.D.
Bianconi, William O.
Birmingham, Donald J., M.D.
Block, Duane L., M.D.
Boettner, Edward A.
Bonvallet, George L.
Braun, Edwin F.
Brown, Robert M.
*Brusk, Norman
Burgess, Dale E.
Byers, Dohrman H.
Carlson, Paul
Castrop, Vincent J.
Chaffin, Don B.
Chmielnicki, Ferd J.
Chynoweth, Benjamin H.
Clarke, John H.
Cleary, William M.
Cochran, Kenneth W., Ph.D.
Cornish, Herbert H., Ph.D.
Csire, N. Charles
Davis, Irving H.
Donovan, Therese
Eisler, Albert W.
Eschelback, Donald
Eschelman, Phelps S.
*Federonko, Conrad
Flores, George H.
Fowler, Don G.
*Frazee, Patrick R.
Frazho, Arthur E.
Frederick, W.G.,Sc.D.
Ganshow, John H., M.D.
Gelman, Charles
Gendernalik, Louis P., Ph.D.
*Glazier, Daniel P.
Glidden, G.M.
Gonzalez, D.J.
Gordon, L.E.
Greschaw. Donald A.
Gutekunst, Herbert W.
Hahn, Kolman J.
Hanson, Victor W.
*Harris, Patrick J.
Harrold, Gordon C., Ph.D.

MICHIGAN (continued)

Hartung, Rolf
Hecker, Lawrence H., Ph.D.
*Himmelsbach, Bernard
Hobbs, Edward J.
Hogan, Geoffrey K.
Hoyle, Harold R.
Irish, Don D., Ph.D.
Jankowski, Paul A.
Jenson, Leonard L.,Ph.D.
Kerfoot, Edward J.
*Kilgore, William B.
Knowles, John
Konn, Walter H.
Kortsha, Gene X.
Krebs, William H., Ph.D.
Kumler, Kathleen
Langner, Ralph R.
LaTorre, Libardo
Lavetter, Victor E.
Lee, Albert P.
Leong, Basil K.J.,Ph.D.
Lick, Henry
*Luchtefeld, Paul H.
Lusk, Gene B.
*MacLeod, Donald F.
Malzahn, Delno D.
*Maxson, Ray M.
McCollister, Donald
McCord, Carey P., M.D.
McDermott, Fred T.
McNab, R. Warren
Medved, Joseph B.
Mirer, Franklin E.
Mooney, Thomas F., Jr., Ph.D.
*Mosher, Gary E.
Mutchler, John E.
*Nawakowski, Alexsandria
Northrop, Dick, Jr.
*O'Brien, Michael J.
Olivieri, Joseph B.
Olson, Richard D.
*Oppelt, William G.
Padden, David A.
Padden, James B.
Perlewitz, Raymond P.
Plasters, Charles E.
Poblete, Rudolph G.
*Poosch, Michael S.
*Puhala, Edward S.
Rabinovitz, Sheldon H., Ph.D.
Rapp, Donald E.
Redmond, Louis
Reeves, Andrew L., Ph.D.
Rodenhouse, Louis N.
Roslinski, Lawrence M., Ph.D.
Rowe, Verald K., Ph.D.
Rye, William A., M.D.
Sachs, Ronald A.
Schaffer, Arnold W.
*Schnauder, Andrew G.
Schneider, E.J.
Schuman, Marvin M.
Scovill, Russell G.
Shapiro, Dale M.
Silverstein, Lawrence G.
Skory, Lyman K.
*Slavin, Thomas J.
Smith, Cecil L.
Smith, Ralph G., Ph.D.
*Snyder, Philip J.
Socha, Gregory E.
Soule, Robert D.
Soulliard, Clarence L., Jr.
Stephens, John F.
Stevenson, Michael F.
Stoecker, George C.
Stolberg, Ronald A.
Swanson, John R., Ph.D.
Taylor, Yvonne P.
*Terlecki, James E.
*Terlep, Richard F.
Thalacker, A.O.
*Tillotson, Michael R.
Torkelson, Theodore R., Sc.D.
Toth, Paul E.
VanderKolk, Alvin L.
Van Farowe, Donald E.
Vecchio, Janet L.P.
Von Oettingen, W.P., M.D.,Ph.D.
Wabeke, Roger L.
Weber, James R.
Weir, Francis W., Ph.D.
Whipple, G. Hoyt, Ph.D.
Wilson, Joseph E.
Wolf, Mark A.
*Wong, Ben
*Wood, Richard D.
Woolrich, Paul F.
*Zaebst, Dennis D.

*Associate Grade

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MINNESOTA (57)

Anderson, Darrell E.
Anderson, John E.
Anderson, K. Wesley
Barber, Donald E.,Ph.D.
Barghini, Robert J., Sr.
Belgea, Frank J.
Caplan, Knowlton J.
Craig, James L.
Dykoski, K.E.
*Ellringer, Paul J.
Elvin, Richard W.
Evavold, E. Roscoe
*Farmer, B. Craig
Feuk, John W.
Foley, Gregory H.
Fossum, John H.
Frazier, R.E.
Geisen, Richard J.
Giuliani, Robert L.
Goppers, Velta
Grassel, Eugene E.
Griffith, Franklin D., Ph.D.
*Heim, William L.
Hoffman, David W.
Holler, Albert C.
Jacoby, John S., M.D.
**Kersten, Ronald M., Jr.
*Knutson, Gerhard W.
*Koonce, George R.
Labernik, Frank C.
Larsen, Donald J.
*Larson, Stephen R.
Liu, Benjamin Y.H.
Long, James E., Sc.D.
*Mahlberg, Craig D.
Makino, Henry K.
Mattila, Walter
Paulus, Harold J., Ph.D.
*Paulus, Patricia A.
Pendergrass, John A.
*Pitcher, J.R.
Raschka, George J.
Rees, LaVerne W., Ph.D.
*Rushfeldt, Victor L.
Schaller, Robin E.
Sethre, Arthur E., M.D.
Sorenson, Stanley D.
Spielman, Robert A.
Stone, Steven J.
Sugg, James K.
Summar, Marion T.,M.D.
Sweitzer, Richard L.
Thompson, Fay M., Ph.D.
Ubel, Frank A., M.D.
VanAuken, Guy F.
Wissink, Robert G.
Zimmerman, Dallas D.

MISSISSIPPI (1)

Sansing, John W.

MISSOURI (39)

Barton, Jack A.
Bohl, Carl D.
Brendlinger, Robert L.
*Covington, C. Jack
Davis, Richard H.
*Durio, Lawrence R.
Edgerley, Edward, Jr.
Eley, Bruce W.
Garber, Louis F.
Garrett, Jack T.
Gershaw, Roger L.
Hackathorn, David R.
Heida, Vivian
*Henshaw, John L.
Holt, Denver L.
Holtshouser, Joseph L.
*Hussain, Kazi F.
Johannsen, Frederick R.
Jones, Herbert H.
Jurgiel, John A.
*Kugler, David J.
Lalli, Frank E.
Lavalette, David R.
Levinskas, George J., Ph.D.
Linck, Thomas C.
McGrath, William J.
Meunier, John J.
*Murphy, Mary K.
Pierce, James O., II, Sc.D.
*Salisbury, Stanley A.
Shuman, Jack J.
Stewart, Albert E.
*Sullivan, Joseph M.
Sutter, R.A., M.D.
**Swigert, William G.
*Talley, Kenneth R.
Wheeler, Elmer P.
Widner, Allen G.
Wright, Paul L.

*Associate Grade
**Student Grade

MONTANA (3)

Bossard, Floyd C.
Unger, Walter H.
Walker, Scott L.

NEBRASKA (3)

Cochran, David J.
Noss, Gary
Pelfrene, Alain F., M.D.

NEVADA (10)

Bevis, Darell A.
Bolton, Paul R.
Dehne, Edward J., M.D.
*Lencioni, Nathan M.
Mattick, John J.
Miller, Robert N.
Ray, Eugene M.
Foy, Terry C.
Snyder, Michael S., M.D.
Soong, Carlton S.K.

NEW JERSEY (87***)

Allen, Richard I.
Andresen, William V.
*Baker, Joseph B.
Becker, Leon R.
Beckett, William L.
Beres, Joseph J.
*Blihar, Robert W.
Bradley, William R.
Brief, Richard S.
Burtis, Evelyn G.
Caporossi, Joseph C.
Carson, Steven, Ph.D.
Charm, Joel B.
Clevenger, Wayne N.
Cohen, Irving D., Ph.D.
Confer, Robert G.
*Damiano, Joseph
Davis, Frank R., Jr.
Diakun, Robert
Doremus, K.R.
Dunham, David
Eckardt, Robert E., M.D.
Faust, Jack C.
Feasley, Charles F.,Ph.D.
Ferguson, Warren S.
Freeman, E. James

NEW JERSEY (continued)

Gerecke, Kenneth W.
Goodfriend, Lewis S.
Gregoric, Albert L.
Gresh, Joseph T.
Hall, Herbert J.
Hansen, David L.
Hatfield, Theodore R., M.D.
Hellman, Thomas M., Ph.D.
Hendricks, N.V.
Hunt, Russell S.
Jones, Allen R.
Joselow, Morris, Ph.D.
Kindsvatter, Victor H., Ph.D.
Kongsiri, Likhit
Kurusz, Henry
*Lawson, Douglas R.
Lester, David, Ph.D.
Levenstein, Irving, Ph.D.
Lorentz, Fred
Maier, Albert A.
Manganelli, Raymond M., Ph.D.
Manella, Raymond J.
McVeigh, James F.
Mehta, Dhiru
Mellor, Joseph F., Jr.
Monastyrski, Walter
Nealon, Gerald F.
O'Brien, Michael G.
Oleru, George U.
Ostergaard, Paul B.
Pfitzer, Emil A., Sc.D.
Price, Donald L.
Richmond, Nathan
Rook, James H.
Roumas, James C.
Scala, Robert A., Ph.D.
Schall, E. Lynn
Schreibeis, William J.
Shaffer, C. Boyd, Ph.D.
*Shaffer, Thomas C.
Sherr, Allen E., Ph.D.
Shimer, Preston C.
Skocypec, Wayne J.
Smith, William E., M.D.
Stanton, George B., Jr.
Stefko, Paul L.
Szymanski, Edward F.
Tobin, John S., M.D.
Toca, Frederick M.
VanPelt, Wesley R., Ph.D.
Vitale, Frederick R.

*Associate Grade
***Includes One Unlisted

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NEW JERSEY (continued)

*Waclawski, Edward J.
Wahl, Robert J.
Wallach, Abraham
Weller, Louis F.
Wilkening, George M.
Woessner, Warren W., Ph.D.
Worden, Francis X.
Yu, Wen Chuan
Zaledonis, Charles E.

NEW MEXICO (42)

Brewer, Lial W.
Burnett, William D.
Campbell, Evan E.
Cleveland, James E.
Daley, Capt, Peter S.
Defield, James D.
DeVore, Robin K.
Douglas, Darrel D.
Enders, John W.
Ettinger, Harry J.
Ferran, Gilbert H.
Garcia, Leroy L.
Geoffrion, Louis A.
Gray, Douglas C.
Hack, Alan L.
Harrison, Harry C.
Healy, John W.
Hyatt, Edwin C.
Ide, Harold M.
Johnson, William S., Sr.
Jordan, Harry S., Jr.
Kennedy, William R., Jr.
Kingsley, William H.
Lowry, Phillip L.
McKelvey, John W.
Meyer, Dean D.
Mokler, Brian V.
Moss, William D.
Parker, Donald R.
Pritchard, John A.
Raabe, Otto G., Ph.D.
Rappaport, Stephen M., Ph.D.
Reinert, Bruce D.
Schulte, Harry F.
Shurkin, Walter S.
Skillern, Clarence P.
Stocum, William E.
Talley, George M.
Thomas, Robert G., Ph.D.
Tillery, Marvin I.
Voelz, George L., M.D.
Wood, Gerry O.

*Associate Grade

NEW YORK (141)

Altshuler, Bernard, Ph.D.
Amdur, Marvin L., M.D.
Andersen, George H.
*Andrews, Leslie R.
Astill, Bernard D., Ph.D.
Averill, Edward R.
Baliff, Jack
Belcher, Albert L.
Blachman, Marvin W.
Blacker, Jerome H.
Bond, Marcus B., M.D.
Bohne, F. Karl
Bourland, P.E.M., M.D.
Braverman, M.M.
Breslin, Alfred J.
Brown, Eugene G.
*Brown, Frank O., Jr.
Brunotte, Herman
*Chang, Peter
Christensen, William D.
Cohen, Norman, Ph.D.
Cole, Jerome F., Sc.D.
Collings, Gilbeart H., Jr.,M.D.
Crossman, Germain C.
*Cullen, Critz E.
Dalton, William F.
Darmer, Kenneth I., Jr.
Davis, Joyce P.
Dernehl, Carl U., M.D.
DeVito, Joseph P.
Dixon, Ernest M.,M.D.
Dunn, James P., M.D.
Eisenbud, Merril, Sc.D.
Ely, Thomas S., M.D.
Fanney, Julius H., Jr.
Fannick, Nicholas
Farrell, John J.
Fater, Joseph J.
Feiner, Benjamin
Ferber, Kelvin H.
Ferin, Juraj
Ferry, John J.
Flato, Jerome C.
Flynn, John L.
Gallaghar, Robert G.
Garner, Charles L.
Gaudreau, Adrien L.
Gelburd, Ralph M.
Glou, Ronald S.
Greenberg, Leo, Ph.D.
Grimaldi, John V., Ph.D.
Hamilton, E. Kingdom
Houk, William M.

NEW YORK (continued)

Ingram, William T.
Issa, Abraham
Jones, Warren H., M.D.
Kaplan, Samuel A.
Keister, Forest L.
Keller, John G., Ph.D.
Killough, David T.
Kingsley, Irving
Kipp, Ronald E.
*Kirwan, Nancy Ann
Klevin, Paul B.
Kneip, Theodore J., Ph.D.
Knight, Arthur L., M.D.
Kupchik, George J., Ph.D.
LaFrance, Leo J.
Lamb, Henry G.
Lane, Kenneth S., M.D.
Larsen, O. Wesley
Laskin, Sidney
Laubly, Charles S.
Lauer, D.J.,M.D.
Levin, Lester
Licata, James P.
Lippmann, Morton, Ph.D.
Lynam, Donald R., Sr.
*Mattox, Paul
Mayers, May R., M.D.
McCarl, Warren G., M.D.
McDaniel, Paul W.
McHenry, Charles R.
Mercer, Thomas T., Ph.D.
*Miele, Michael L.
Miller, Franklin A.
*Mirowitz, Stuart R.
Mitchell, W. Fred
Morrow, Paul E., Ph.D.
Moss, Owen R.
Murray, John T.
Nelson, Kenneth W.
Nelson, Norton, Ph.D.
Oser, Bernard L., Ph.D.
Osterman, Raymond
Osti, Aldo P.
Owens, Thomas J.
Palmes, E.D,Ph.D.
Perry, Howard B.
Pickett, William E., Maj.
Ragofsky, Howard
Raleigh, Robert L., M.D.
Raybin, Harry W.
Reid, Frank H.
Reznikoff, Paul, M.D.
Richards, Ronald T.
Rimberg, David, Ph.D.
Roberts, Malcolm
Roberts, Norbert J., M.D.
Roudabush, Robert, Ph.D.
Scherberger, Richard F.
Schirripa, James T.
Schulz, Herman
Sharkey, Joseph F.
Sheinbaum, Milton
Singh, Jaswant
Slotkin, Martin
*Smith, Donald W.
Smith, Frank A., Ph.D.
Stannard, James N., Ph.D.
Steadman, Luville T., Ph.D.
Stein, Edward, Ph.D.
Sutton, William L., M.D.
Syracuse, Michael G.
Terhaar, Clarence J., Ph.D.
Thomas, Jess W.
Thompson, Harold K.
Tichauer, Erwin P., Ph.D.
Varela, Noel J.
*Venturo, Renzo
Virchow, Warren E.
*Waclawski, Edward J.
Wang, Chiu-sen, Ph.D.
Webber, Alonzo M.
Weismiller, Fred J., Jr., M.D.
White, Oliver G.
White, Otto, Jr.
Wilson, Robert H.
Wolfsie, J.H., M.D.
Yanno, Frank J.
Yoder, John D., Sc.D.

NORTH CAROLINA (43)

Arp, Earl W., Jr.
Barnard, George
Barrett, Charles D.
Belk, Harold D., M.D.
Beyer, Emil C., M.D.
*Bundy, Stephen D.
Chanlett, Emil T.
Chen, Ching Kuang
Chirico, Frank N.
Cook, Warren A.
Danchi, George
Dentler, William L.

*Associate Grade

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NORTH CAROLINA (continued)

Dickerson, Richard C.
DiPasquale, Louis C.
Drew, Robert T., Ph.D.
Fraser, David A., Sc.D.
Goldwater, L.J.,M.D.
*Hagwood, Phillip E.
Harris, Robert L., Jr.
Henning, John C.
*Hickey, John L.S.
Hill, F. Neal
Imbus, Harold R., M.D.
Ivester, Arthur L.
Kelly, Harry J., Jr.
Kenline, Paul A., Ph.D.
Lewis, Lionel
*Lubozynski, F. Thomas
Lumsden, John C.
Martin, Charles F., M.D.
*Miller, Gordon C.
Neefus, John D.
North, Ellsworth H., Jr.,M.D.
Reist, Parker C., Sc.D.
Robson, Charles D.
Stern, Arthur C.
Stopford, Woodhall, M.D.
Straughan, Steve A.
Thornton, James R.
Willhoit, Donald G.
Williams, David L.
Williams, Ted M.
Woodall, Leigh C., Jr.

NORTH DAKOTA (1)

Ruby, Darrel L.

OHIO (187)

Abell, Martin T.
Anania, Thomas L.
*Anderson, Loren A.
Ayer, Howard E.
*Bankovich, Paul W.
Beaman, Reuben, J., Jr.
Beebe, Edward R.
Beliczky, Louis S.
*Bell, R. Hays
*Bersebach, Gordon L.
Blanck, Marilyn D.
Blankenhorn, John M.

*Assciate Grade

OHIO (continued)

Blejer, H.P.,M.D.,D.I.H.
Boback, Michael W.
Bowers, Rolland G.
Bozich, Thomas A.
Bradley, John E.
*Briggs, Terry M.
*Brown, Patricia S.
Bryant, John M.
Burg, William R., Ph.D.
Burroughs, G.E.
Bynum, James R.
Caplan, Paul E.
*Caple, Rose M.
Carlson, Gordon H.
Cassady, Melvin E.
*Charman, Walter M.
Cholak, Jacob
Clark, Thomas J.
Coleman, W. Emile
*Connors, Michael G.
Coombs, Richard J.
Cox, F. Morgan
Crable, John V.
Craft, Bobby F., Ph.D.
Cralley, Lewis J., Ph.D.
Crawl, James R.
Cuddeback John E.
Cutter, Harold C.
Dauch, Jack E.
Dereniuk, Steven N.
Devitt, Gerald E.
DeWitt, Bernard J.,D.Sc.
Donaldson, Harry M.
Dukes-Dobos, Francis N.,M.D.
Engdahl, Richard B.
Engel, John D., Sc.D.
Enright, John C.
*Evans, William A.
Faud, Robert H.
Ferguson, James S.
Frank, Russell W.
Fulmer, Mary R.
Fulwiler, Richard D.,Sc.D.
Galloway, Howard L.
Georgiadis, Theodore
Gisclard, J. Brennan
*Goyda, Michael F.
*Gregory, Earl D.
Gross, Stanley B., Ph.D.
Grote, Ardith A.
Grubb, Leland L.
Haney, Donald L., Jr.
Hardin, Bryan D.

OHIO (continued)

Harris, Elliot, S., Ph.D.
Haun, Charles C.
Hazard, W.G.
Heatherton, Richard C.
Henschel, Austin F., Ph.D.
Herrick, Robert A.
Hess, Gerald L.
Hiser, Robert A.
*Hochstrasser, John M.
Hoffer, Ralph F.
Holdsworth, Charles E., Jr.
Hosey, A.D.
*Howard, James L.
Huffman, Dean Dewitt
Hull, Terry E.
Humphreys, Clark M.
*Inglis, Robert H., Jr.
*Isaacs, Fred, Jr.
Johnston, Arthur E.
Jones, James H.
Junod, Thomas L.
Kalmon, Ben
Katzenmeyer, Edwin B., Jr.
Kehoe, R.A., M.D.
Kelley, William D.
Kenney, Gary D.
Ketcham, Arthur R.
Kinkead, Edwin R.
Klein, Frank J.
Kline, Hubert S.
Knarr, Robert L.
*Kominsky, John R.
Kozuszek, Theodore K.
Kronoveter, Kenneth J.
Kupel, Richard E.
Lainhart, William S., M.D.
LaNier, Marchall E.
Laurence, James M.
**Lawrence, Clarence P.
Leininger, Edward D.
Lerner, Sidney I., M.D.
*Levy, Beth S.B.
Longley, Mars Y., Ph.D.
Ludwig, Howard R.
Lynch, Jeremiah R.
Lyon, Walter, M.D.
MacEwen, J.D., Ph.D.
Mahon, Robert D.
Marcero, Douglas H.
Maykowski, Richard M.
McConnell, Ross S., M.D.
McCormick, William E.
*McKee, Douglas
McMurrain, K.D.,Jr.,M.D.
Mekaru, Toshio
Mirti, Nicholas A.
Mitchell, Ralph I.
Modrell, Robert W.
Murray, William E.
Nachtman, Joseph P.
*Nash, Robert B., Jr.
Nord, Peter J.
*Olmstead, Gary W.
Oser, James L.
Paff, David G., M.D.
Parr, Wordie H.
*Pattee, Harry E.
Pharis, Peter W.
Pilcher, J. Mason, Ph.D.
*Price, James H.
*Pulket, Chompusakdi
Rathje, Arnold O.
Reinhard, E. Daniel, Jr.
Rentos, P.G.,Ph.D.
Richley, Barton E.
Robbins, M. Chain
Roberts, Lester B.
Rockwell, Thomas H.
Ross, Keith N.
Rosso, Albert J.
*Russell, Clyde L.
Saalwaechter, Ann T.
Sachs, Ben H., Jr.
Saltzman, B.E., Ph.D.
*Sarvadi, David G.
Schafer, Lawrence J.
**Schaub, Amy A.
Scheel, Lester D. Ph.D.
*Sebesta, W.E.
Seferian, Sam V.
*Shepler, T.W.
Sherriff, Robert E.
Sigmund, Joseph M.
Simpson, C. Wayne
*Snodgrass, Lowell E.
Sparrow, Edward
Starkey, R.H.
Stemmer, Klaus L., M.D.
Stevenson, Edward F.
Stokinger, H.E., Ph.D.
Suskind, Raymond, R., M.D.

*Associate Grade
**Student Grade

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OHIO (continued)

*Tancous, John W.
Taylor, David G., Ph.D.
Thebo, Lawrence K.
*Uhlar, Richard A.
Vandervort, Robert
Vernot, Edmond H.
Vogt, Gary D.
*Voytko, Robert A.
Wallace, Deyarman
Welker, Lloyd M., Sr.
Westendorf, William H.
Williamson, W.H.
Wilson, George L.
Yeager, David W.
Yee, Hong Ton
Young, Ronald J.
Zimber, Charles W.
Zirkes, Al
Zuzik, Joseph B.

OKLAHOMA (22)

Ausbie, Attway E.,Ph.D.
*Brown, James E.
Brown, William J., Jr.
*Cook, Dan D.
Feightner, Clarence C.
*Funk, Stanley W.
*Haning, Jack M.
Hayden, A.T., Major
Hoag, Laverne L.
Jones, Clyde W.
Konopinski, Virgil J.
Langwell, Jimmy
Lankford, David N.
Purswell, Jerry L.
Renes, Lucian E.
Stanley, Keith L., Ph.D.
Steffey, Oran D.
Swanson, John W.
Thompson, Robert N., Ph.D.
Utnage, William L.
Viet, Robert W.
*Williamson, Glen R.

OREGON (7)

Black, Robert B.
Coward, David D.
Magill, Paul L.
*Montero, Emil E.
Schink, Chester A., Ph.D.
Schoenborn, Arthur F.
Tarraglio, Frank P., Ph.D.

*Associate Grade

PENNSYLVANIA (178)

Adrounie, V. Harry
Allison, W.W.
Anderson, David M., Ph.D.
Barnes, Edgar C.
Baumann, Willard H.
Beebe, Maurice R.
Bell, Zeb G., Jr., Sc.D.
Benjamin, Charles T.
Bobkoskie, Russell L.
Bodden, Keith A.
Bonney, Thomas B.
Booth, Karroll S.
Botsford, James H.
Breslin, John A.
Brodt, Dale H.
Brown, Norman R.
Bub, Robert A.
Bumsted, Howard E.
Calhoun, J.A., M.D.
Carey, Leo
Carlitz, Irwin H.
Carpenter, Charles P., Ph.D.
Carter, Robert P.
Carter, W. Julian, Jr.
Chrostek, Walter J.
Civic, Terrence M.
Civic, Thomas J.
*Cohen, Joel M.
Coner, Charles E., Lt.Col.
Coon, Julius M., M.D.
Corn, Morton, Ph.D.
Cotabish, Harry N.
Coughlin, John J.
Davies, J. B.
Degrafenread, James E.
Deibert, Raymond H.
*DeSantis, Rudolph V.
Destafano, James T.
deTreville, R.T.P., M.D.
Devorris, Joseph T.
Dinman, Bertram D., M.D.
*Durham, Mark F.
Durkosh, Edward D.
Dyre, William H.
Elkin, Samuel, Ph.D.
Etheridge, Charles H., Jr.
Farrah, George H.
Ferber, Benjamin I.
Ferruggiaro, Alfred J.
Flickinger, Charles W.
Flumerfelt, Gene C.
Foderaro, John, M.D.
Fraust, Charles L., Ph.D.
Gabriel, Karl L., Ph.D.
Gastineau, Robert M.,Lt.Col.
Geary, Daniel L.
Gittelman, Donald H.
Goldberg, Samuel A.

PENNSYLVANIA (continued)

Goldsmith, Andrew H., Capt.
Granlund, Rodger W.
Grant, Lee B., M.D.
Grieb, Henry E.
Grunder, Fred I.
Haas, Jonathan M.
Haller, Robert B.
Hannon, J.W.G.,M.D.
Hebb, Jerry L.
Hemeon, Wesley C.L.
Henson, Edward V., M.D.
Herr, Howard F.
Hess, Paul W., Ph.D.
Hlavaty, E.J.
Hoffman, Clair A.
Jackson, James O.
Janes, William S.
Johnson, William S.
Kamon, Eliezer
Keenan, Richard R., Ph.D.
Keller, Lawrence W.
*Kelton, Stanton C., Jr.
Kingsley, Lt.Col.,Willard E.
Kitzer, R.G. Jr.
Kloos, Edwin J.
Knauber, John W.
Kobrick, Thomas E.
Kreichelt, Thomas E.
Kreischer, Jerold B.
*Labbauf, Abbas
Lee, Terry C.
Lieberman, Jesse
Linch, Adrian L.
MacFarland, H.N., Ph.D.
Mammarelli, Andrew A., Jr.
Mancuso, Thomas F., M.D.
Manekshaw, Sarosh, J.H.
Masaitis, John B.
*Mattiolo, Leon A.
Mawhinney, Warren C.
Merkle, C.R.E.,Jr.
Michael, Paul L., Ph.D.
Miller, Henry T.
Miller, Joseph W.
Miller, Roy H.
Moffitt, Augustine E., Jr., Sc.D.
Morse, George L.
Myers, Samuel A.
Neilson, Arthur
*Ng, Richard
Novak, John C.
**Nusbaum, Victor A.
Ornosky, Martin
Ortlip, Willard L.

*Associate Grade
**Student Grade

Pallies, William M.
Parobeck, Paul S.
Pearce, S.J.
Petruska, Edward M.
Phillips, Milo W.
Piros, Wesley E.
Pletz, Leroy O.
Plunkett, John M.
Polito, Louis D.
Porter, Sidney W., Jr.
Prieve, Claudia S.
Purdom, P.W., Ph.D.
Quealy, James F.
Rakow, Alexander P., D.O.
*Ranken, Emily A.
Renshaw, Frank M.,
Richardson, Lewis F., Jr.
Rosendahl, Thomas E.
Rozas, C. John
Rubino, Robert L.
Ruhf, Russell C.
Runion, Howard E.
Sabo, Andrew T.
Sataloff, Joseph, M.D.
Schlager, Keith A., Ph.D.
Schreibeis, Lee, Jr.
Schrenk, H.H., Ph.D.
Sentz, Frank C., Jr.
Shoemaker, William E.
Skendall, John V.
Smyth, Henry F., Jr., Ph.D.
Snyder, John P.
Snyder, Paul J.
Snyder, Richard
Sowinski, Edward J.,Ph.D.
Speicher, H.W.
Spritzer, Albert A., M.D.
Stanko, James J.
Stein, Felix L.
Stevens, Charles H.
*Stockton, Steven D.
*Strelecki, Ronald R.
Stubblefield, Jere D.
*Swanson, Frank A.
Swift, Richard L.
Todd, Alan S.
Tomb, Thomas F.
Toothman, Edwin H.
Tyler, Dennis A.
Venable, Emerson
Vought, Virginia M.
Wagner, Stanley T.
Webster, Donald L.

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PENNSYLVANIA (continued)

Weil, Carrol S.
Weyel, Dietrich A.
Whitaker, Paul J., M.D.
Whitman, Newton E.
Willard, Frank J.
Williams, Norman, M.D.
Williams, Robert A.
Wilner, Stephen M.
*Wilson, James C.
Witman, Ronald L.
Wood, William S.
Zatek, Joseph E.
Zullo, Philip

RHODE ISLAND (7)

Fusco, Serafino J.
Hickey, James E.
Mandell, Leonard C.
Matheson, James N.
Northrup, Joseph A., Jr.
Revoir, William H., Jr.
Wuraftic, Joseph

SOUTH CAROLINA (13)

Anderson, Charlie J.
Boone, Francis W.
Callison, H. Grady, Jr.
Childress, Emory R.
Croley, James J., Jr.
Goodman, Joseph L., M.D.
Hook, Marion B., Jr.,
Oakley, Herbert R.
*Roberts, John T., Jr.
Seifert, Harry E.
Siebert, George W., III
Slone, Allen R., M.D.
Waligora, Stanley J., Jr.

SOUTH DAKOTA (3)

Feusner, LeRoy C., Capt.
Salazar, Alex, Jr.
Wisehart, Donovan E.

TENNESSEE (35)

Arnold, Gerald A.
Blake, Charles L.
Bolton, Newell E.
Boone, Charles W.
Burnett, Thomas J.
Covert, Roy J.

*Associate Grade

TENNESSEE (continued)

Davis, Doyle M.
*Dufour, James T.
Ealy, James A.
Garrett, Jasper T.
*Gill, H. Brent
*Harbison, Joe G., Jr.
Higdon, Herbert F.
*Hunt, Christopher L.
Jung, Francis P.
Ketchen, Eugene E.
*Landis, Stevan D.
Lawrence, E. Fred
McAlduff, Harold J., Jr.
McGee, William A.
Miller, Lee H., M.D.
Morehead, James F., Jr.
Murrey, William S., Jr.
Oglesby, Frank L.
Oppold, James A., Ph.D.
Porter, Walter E.
Ress, John F.
Roberts, Donald P.
Schultz, Neil B.
Smith, R.C.
Stoddard, David L.
Whitson, Thurman C.
Winckler, Leonid E.
Wing, Jerome F.
Wolle, Robert H.

TEXAS (104)

Abersold, John N., Ph.D.
Adrian, Horace F.
*Anderson, Stanley E.
Atwood, David
Ayoub, Mohamed N., Ph.D.
Banner, Edwin C., III
Beatty, Maj. David C.
Bergtholdt, Charles P.
Birch, Sheldon R.
Boyle, John P.
Brasch, Jerome K.
Brown, Robert D.
Byrne, James F.
Carroll, Clinton C.
Clapp, Raymond E.
Collins, Eddie B.
Collins, Raymond J., Major
Combi, John V.
Comstock, Eric G., M.D.
*Covan, James P.
*Dabney, Tom E.
Deese, Donald E.
Dierens, Alton H.
*Donahue, MIchael R.

TEXAS (continued)

Eastes, Jessie D.
*El-Maguid, Ahmed A.
Fallon, Paul F., Maj.
Fontaine, Jack H.
Fox, John E.
Furr, Robert J.
Garcia, Meliton M.
Gibeau, John K.
Glorig, Aram, M.D.
*Godfrey, Edwin K.
Good, Merrill R., Major
Griffin, Ralph G., Jr.
Guinn, Ronald L.
Hammond, James W.
*Hester, Carolyn R.
Hobson, Herschel L., Ph.D.
Horvath, Bruce S.
Hyde, Donald L.
Konzen, Richard P., Ph.D.
*Kortla, Claren J.
Krehbiel, Delmar D., Ph.D.
Kusnetz, Howard L.
Lauderdale, Jerry F.
Laugenour, D.P., M.D.
LeBrocq, Eric F., Jr.
Ledbetter, Joe O., Ph.D.
LeFebvre, E.E., Major
*Leiner, Ronald S.
Love, Alan C.
*Lutts, William L., Jr.
Marcie, Frank J.
McNamara, David E.
Melvin, Walter W., Jr., M.D.
Meyer, William H.
Morman, Donald H.
Murphy, Patrick
Nau, Carl A., M.D.
Nelson, Gary S.
Paganini, Otto
Parker, Frank M.,III
Paschal, Frank L., Jr.
Penney, Floyd L.
*Persky, William H.
Phillippe, Maurice M., Ph.D.
*Pickle, Joe D.
Pringle, Donald G.
Quigley, Joseph A.
Ramsey, Jerry D., Ph.D.
*Ransdell, Jerry D.
Reed, Charles W.
Regula, John M.
Reisenweber, Richard L., Sc.D.
*Richardson, Carl D.
Roberts, Thomas L.
Ross, James K., M.D.
Roy-Chowdhury, Anil K.
Rudmose, Wayne, Ph.D.
Schaeffer, Edward H.
Schiltz, John O.
*Schmidt, Richard R.
Schwindt, Philip C., Jr.,Maj.
*Schulz, Harvey R.
Severs, Richard K., Ph.D.
Shatterly, Luther W.
*Shoop, David T.
Shreve, Richard J.
*Skinner, Raymond L.
*Smahlik, Henry J.
Solook, John T.
*Spencer, Howard W.
Stallings, Billy J.
Suggs, Lt.Col. Harry J.
Townsend, Kirkby G.
Vernon, Ralph J., Ph.D.
Vos, Grover A.
Warren, Edward L.
White, Norman G., Ph.D.
Witzke, Russel L.
Wukasch, Martin C.
*Yin, Nick D.

UTAH (31)

*Adler, Robert G.
Archer, Victor E., M.D.
Barg, Don C.
Berghout, C. Fred
Burton, David J.
Butler, George J.
Coleman, Richard D.
Comboy, Robert L.
Dalley, Dennis R.
Dixon, Willard C.
Dungey, Curtis E.
Dyke, Maurice
Heaney, Robert J., Ph.D.
Heins, Allan P.
Hendricks, Russel H., Ph.D.
Knudsen, John F.
Larsen Lee B.
Lee, Jeffrey S.
Madsen, Floyd A.
Nackowski, Sandra B.

*Associate Grade

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J-MA
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UTAH (continued)

*Nelson, James H.
Norman, Gary R.
Peterson, Robert L.
Putnam, Robert D.
Richardson, John B.
Sieverson, James P.
Smith, Thomas J.
Varner, Michael O.
Wagner, William L.
Winn, Grant S., Ph.D.
Yeager, M.A.

VERMONT (3)

Ashe, Harry B.
Keenan, Robert G.
Laitinen, Donald O.

VIRGINIA (48)

Barboo, Samuel H., Cdr., USN
Bayer, Maj. Johan E.
Beliles, Robert P., Ph.D.
Benton, Ronald E.
Brinkerhoff, Gail M.
Busey, William M.
*Cacciotti, Joseph J.
Caesar, George E., Jr.
*Carr, Thomas B., Jr.
Cole, Homer M.
Cure, John W., III
DiLustro, Salvatore
Dodge, William B.
Doptis, Leigh E.
Eggleston, Tony E.
Frazier, Phillip M.
Giever, Paul M.
Gioiello, David M., Jr.
Golz, Harold H., M.D.
Hanen, Sherry J.
*Hartmann, Kipp W.
Hilcken, John A., Ph.D.
Hollingsworth, Richard L.
Jacobson, Murray
Jessee, Charles R.
Johnston, Hassel
Jordan, Charles J.
Kwan, Byung K.
Levinson, Seymour
Lewis, John B.,III
Mabson, William E., Maj.
Maccioli, John T.

*Associate Grade

VIRGINIA (continued)

Mansur, Richard H.
Marr, William T.
Mundy, Charles B., M.D.
*Phillips, Stanleigh W.
*Pouliot, Stuart H.
Ryer, Flo H.
Salmon, Eliahu, Ph.D.
Shultz, Jerry E.
Smith, Raymond
Teske, John W.
*Veigel, C. Harding, Ph.D.
Walker, Robert H., Jr.
Walsh, Ralph J., Col.
Wood, Eugene, G.
Worsham, Herbert J.
*Wright, Usha

WASHINGTON (46)

Anderson, Aage B.
Anderson, Bernhardt V.
Anderson, Donald E.
Anderson, Ralph G.
Apol, Arvin G.
Bailey, Gerald E.
Bessmer, D.J.
Blair, Austin W., Jr.
Breysse, Peter A.
*Cant, Stephen M.
Carpenter, George D.
Cothrin, Stanley G.
Craig, Douglas K., Ph.D.
Darcy, Felix J.
DeRousseau, Phil J.
Fergin, G.S.
Fuqua, Philip A., M.D.
*Grant, Robert K.
Hansen, L.A., Ph.D.
*Harrison, Jose R.
Hipp, M.J.
Horstman, Sanford W., Jr., Ph.D.
Kniseley, John M.
Kooiman, Abraham M.
Kusian, Ross N.
Lake, James W.
Lichtenstein, Michael E.
Liukonen, Larry R.
*Locke, Daniel K.
McArthur, Billy R.
Mangold, Carl A.
McJilton, Charles E.
Mills, Roy O.
Noble, Wesley M.
Novak, N.P.
O'Brien, Michael J.
Olson, Theodore C.
Ridge, Michael C.

WASHINGTON (continued)

Rossano, August T., Jr.,Sc.D.
Ruch, Walter E., Ph.D.
Sandell, Ken
Selby, John M.
*Shurts, James A.
Wang, David U.
Wendlick, Joseph D.
Wilson, William L.

WASHINGTON, DC (30)

Burnett, Maj.Ronald D.
Carter, Maj. Donald I.
Cohn, James R.
Doyle, Henry N.
Drozd, Joseph J., Jr.,LCDR
Gilbert, Harry
Glauberman, Harold
*Godette, Edith S.
Grose, Carl B.
Janous, John A.
Johnson, Kenneth D., Ph.D.
Kay, John H., Ph.D.
Kittilstad, Owen H., Lt.Col.
Krop, Stepehn, Ph.D.
Levin, Arthur A.
Maher, Joseph R.
Marrazzo, Rudolph M.
McClure, C. Ray
McNerney, James M., Jr.
Rector, Douglas E., LCDR
Rhoden, Richard A., Ph.D.
Ross, Donald M., Sc.D.
Seabaugh, Van M.
Stanley, Fred L.
VanAtta, F.A., Ph.D.
Wands, Ralph C.
Ward, Wendell L.
Weinstein, Martin S.
Welty, Carl G., Jr.
Wrenn, Grover C., Jr.

WEST VIRGINIA (21)

*Adams, William C.
Bare, Ben S.
Clarke, Charles C.
Cope, Robert W.
Dermit, John N.
Kasberger, Robert E.
Ketcham, Newton H.
Linsky, Benjamin
*Lunn, Jerry D.
McShane, William P.

*Associate Grade

WEST VIRGINIA (continued)

Murray, Bert L.
Neff, Joe E.
*Niemann, Jeffrey K.
Peele, Robert E.
Qazi, Abdul Hamid
Shoub, Earle P.
Smith, William M.
Suitlas, John R.
Vining, John F., III
Williams, Fred
Young, William C.

WISCONSIN (28)

Baretta, Edward D.
Berg, Byron A.
Biancardi, Michael F.
*Breuer, Jerry A.
**Brown, Roger L.
Gregory, Jerome P.
*Green, Jeffrey D.
Hawkinson, Robert E.
Kennebeck, Marvin E., Jr.
Kukla, Joseph F.
Kupfer, George A.
Lange, Paul
Lundquist, Marjorie A.
Mims, Albert
Otterson, Edward J.
Peck, Robert C., Jr.
Peterson, J.E., Ph.D.
**Pollock, Richard A.
Racic, Milan
Robinson, Ray M.
Rowe, Donald M., M.D.
Sadenwasser, John L.
Stavros, Thomas G.
Uber, William J.
*Voborsky, Robert C.
Wasko, Peter E.
Young, Robert L.
Zenz, Carl, M.D.

WYOMING (2)

Cleaver, Robert E.
Harms, Gale D.

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MEMBERS IN FOREIGN COUNTRIES

ARGENTINA (1)

Marafioti, Hugo

AUSTRALIA (2)

Cumpston, A.G., Med.
Erkins, John H.J.

BELGIUM (1)

Brunier, Robert

BRAZIL (3)

Fonseca, Alcyr de A., M.D.
Tsuchida, Koiti
VanDeursen, Felix

CANADA (67)

Adley, Frank E.
Bithel, Leonard
Bolduc, Jacques
Boucher, Bernard D.
Bourdages, M. Raoul
Brown, John R., Ph.D.
Buchwald, H., Ph.D.
Budlovsky, Joseph G., M.D.
Cimon, M. Gaston
Chmara, Peter
Dallinger, John A.
*Eilers, Annete J.
Farant, Jeane-Pierre
Fliegl, Rudy J.
*Franklin, Alexander
Gibbs, G.W.
Gibson, David E.
*Gresham, Ralph B.
Hui, Hubert Y-T.
Ife, Donald A.
Jegier, Sigmund, Ph.D.
Johnston, John H.
Katz, Morris, Ph.D.
Knight, Geoffrey
LaChance, Maurice J.
Laham, Souheil, Ph.D.
Lee, Robert K.
*Lockington, John N.
MacEachen, Wilbert L.
MacPherson, Finlay J.
*Maidment, Howard
Majzner, T.A.

CANADA (continued)

Menzies, George E.
Monkman, J.L.
Murray, Neil
Nelson, Hugh M.,P.Engr.
Patrick, Allen N.
Pelnar, Premysl, M.D.
Plamondon, Sarto R.
Pullen, Peter F.
Rajhans, G.S.
Raouf, Abdul, Ph.D.
Rennicks, Robert A.
Riegert, Alfred L.
Rispler, Lawrence O.
Ross, Charles R.
Rozovsky, Human
Rutherford, James G.
Sanderson, H.P., Ph.D.
Saunders, Gerald A.
Scattergood, George
Schrag, Kenneth R.
Smith, Leonard K.
Stephenson, John
Stopps, Grodon J., M.D.
Sullivan, John L.
To, James C.
Todd, Henry
Verma, Devendra K.
Vitols, Valentin, Ph.D.
Ward, William M.
White, John M.
Windish, John P.
*Wong, Kenneth K.C.
Wood, Gerald P., Ph.D.
Yourt, G.R.
Ziegler, Lester W.

CANAL ZONE (2)

Baskin, William K.
*Gauger, George W.

COLUMBIA (1)

Bernal, Jorge R.

DENMARK (1)

Grut, Aage, M.D.

*Associate Grade

EGYPT (2)

El-Dakhakhny, A., Ph.D.
Noweir, Madbuli H., Sc.D.

ENGLAND (16)

Adam, John A.
Blair, Derek
Coles, Gerald V.
Davies, Morgan H.
Duck, Bertram W., M.D.
*Eyres, Alan R.
Hickish, David E., Ph.D.
Jansen, J.D., Ph.D.
Langley, Edward W.
Luxon, Stuart G.
Pocock, K.N.J.,D.I.H.
Sanderson, James T.
Sherwood, Robert J.
Steel, John, Ph.D.
Thompson, David B.
Turner, D., Ph.D.

FRANCE (2)

Marliac, Jean-Pierre, Ph.D.
Truhaut, Rene

GERMANY (6)

DeGesoro, Roy A.
Eich, Jacob, M.D.
Immendoerfer, Martin
Leichnitz, Kurt
Lentge, Horst K.
Oettel, Heinz, M.D.,Ph.D.

INDIA (1)

Chakraborty, M.K.,D.Phil.

IRAN (2)

Samimi, Behzad, Ph.D.
Sanai, G.H.

ISRAEL (1)

Dror, Klaus, M.D.

ITALY (6)

Alonzo, Enrico, M.D.
Giovanardi, Vittorio
Parmeggiani, Luigi, M.D.
Peyton, Mary Fouse
Rubino, Giovanni F.
Salvini, Michele, M.D.

JAPAN (1)

Toyama, Toshio

KOREA (2)

Chung, Kyou Chall, M.D.
Paik, Nam W.

NETHERLANDS (1)

Blok, Aart C., M.D.

NIGERIA (1)

Enrinoso, Adebola Ore-Olorun

PERU (2)

Alvarez, Horacio A.
Bloomfield, J.J.

PUERTO RICO (5)

Amaro, Ulpiano
Aponte, Maria del R.
Castro, Fernando J.
*Garcia-Sharp, Frank
Villares, Enrique J.

SAUDI ARABIA (1)

Davis, Quentin J.

SINGAPORE (1)

*Lee, Martin Chee Kong

SPAIN (15)

Albesa-Vilalta, Antonio
*Bahima, Jose T.
Blazquez Martinez, Manual
*Die Goyanes, Carlos
Cobos, Pedro D.
Elejalde, Mariano de Leitaola
*Flores-Pereita, Pedro

*Associate Grade

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SPAIN (continued)

Gonzales, Enrique F.
*Marti, Antonio V.
Matas, Ricardo D.
*Ribot-Sanchez, Luis
*Riveira, Vincent
*Rodriguez-Acosta, Jose F.
*Rodriguez, Jose M.
*Vila, Ramon V.

SWEDEN (6)

Ahlmark, Axel
Gerhardsson, Gideon
Ivergard, Toni B.K.
Johansson, Mats T., Sc.D.
Lindgren, Gunnar O., M.D.
Lundgren, K.D., M.D.

SWITZERLAND (5)

El Batawi, Mostafa A., M.D.,Sc.D.
Goelzer, Berenice, I.F.
Guillemin, Michel F.
Kratel, Rudi E., Dr.
Mastromatteo, Ernest, M.D.

THAILAND (1)

Noiphan, Visith

TRANSVAAL (1)

Page-Shipp, Roy J.

VENEZUELA (4)

Asuaje, Fernando, Ph.D.
Mayz, Eusebio
Paoli, Marcos J.
Smith, Erich

SUSTAINING MEMBERS (216)
(As of June 30, 1975)

The American Industrial Hygiene Association acknowledges with appreciation the Sustaining Members who by their membership demonstrate their support of the objectives of the Association.

Abbott Laboratories, N. Chicago, IL
Aetna Insurance Company Hartford, CT
Aetna Technical Service, Inc. Hartford, CT
Air Products & Chemicals, Inc. Wayne, PA
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Alabama Dry Dock & Shipbuilding Co., Mobile, AL
Allied Chemical Corp. Morristown, NJ
Alnor Instrument Co. Niles, IL
Aluminum Co. of America Pittsburgh, PA
AMAX, Inc., Greenwich, CT
American Air Filter Co. Louisville, KY
American Can Co. Greenwich, CT
American Mutual Insurance Alliance, Chicago, IL
American Mutual Liability Insurance Co.,Wakefield, MA
American Optical Co. Southbridge, MA
AMETEK, Inc., Los Angeles, CA
The Anaconda Co.,Anaconda, MT
The Anaconda Co.,Tucson, AZ
The Anaconda Co. Columbia Falls, MT
Analytical Instruments Development, Inc. Avondale, PA
Analytical Research Laboratories, Monrovia, CA
Arabian American Oil Co. Dhahran, Saudi Arabia
Armco Steel Corp. Middletown, OH
ARO, Inc., Arnold Air Force Stn., TN
ASARCO, New York, NY
Asbestos Information Association/N. America, Washington, DC
Atlantic Richfield, Los Angeles, CA
Autosonics, Inc., Norristown, PA
Averill Equipment Co. Troy, MI
Ball Corp., Muncie, IN
BASF Wyandotte Corp. Geismar, LA
Battelle Pacific NW Labs., Richland, WA
Beckman Instruments, Inc. Fullerton, CA
Bell Telephone Labs., Murray Hill, NJ
Bendix Corp.,Baltimore,MD
Bendix Process Instruments Div., Lewisburg, WV
Bethlehem Steel Corp. Bethlehem, PA
Bituminous Casualty Corp. Rock Island, IL
The Boeing Co.,Seattle,WA
Boeing Vertol Company, Philadelphia, PA
The Borden Co.,Columbus,OH
Brusnwick Corp.,Skokie,IL
Brush Wellman, Inc. Cleveland, OH
E.D.Bullard Company Sausalito, CA
Burlington Industries, Inc. Greensboro, NC
Canadian Labour Congress, Ottawa, Ontario
Cassiar Asbestos Corp.,Ltd. Cassiar, British Columbia
Caterpillar Tractor Co. Peoria, IL
Centro de Investigacion de Ingenieria, Ambiental, Buenos Aires, Argentina

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Chicago Transit Auth., Chicago, IL
Chrysler Corp. Detroit, MI
Cities Service Co., Tulsa, OK
Geo. D. Clayton & Assoc., Southfield, MI
Colgate-Palmolive Jersey City, NJ
Colt Industries, Midland Div.,Midland, PA
Cominco, Ltd., Trail, British Columbia
Compania Shell de Venezuela, Ltd.,Maracaibo, Zulia, Venezuela
The Continental Ins. Co. New York, NY
H.S.Cover Co., Buchanan, MI
Creole Petroleum Corp., Caracas, Venezuela
Deere & Co., Moline, IL
Detrex Chem. Industries,Inc., Detroit, MI
Detroit Edison Co., Detroit, MI
Diamond Shamrock Chem.Co., Cleveland, OH
The Dow Chem. Co., Midland, MI
Dow Chem. USA, Michigan Div., Midland, MI
Dow Corning Corp., Midland,MI
Dravo Corp., Pittsburgh,PA
Duo-Aire, Inc.,Kalamazoo,MI
E.I.DuPont de Nemours & Co., Inc., Wilmington, DE
Eastman Kodak Co., Rochester, NY
Eastman Kodak Co., Windsor,CO
Eckel Industries, Inc. Cambridge, MA
Eli Lilly & Co., Indianpolis, IN
Employers Mutual of Wausau, Wausau, WI
Engelhard Industries Div. of Engelhard Minerals & Chem. Corp., Murray Hill, NJ
Environmental Compliance Corp., Venetia, PA
Esso Brasileria de Petroleo S.A., Rio de Janeiro, Brazil
Esso S.A.P.A.,Buenos Aires Argentina
Exxon Co., USA, Houston,TX
Exxon Corp., New York,NY
Farmland Industries, Inc. Kansas City, MO
Ferris State College Big Rapids, MI
Fieldcrest Mills, Eden,NC
Fireman's Fund American Insurance Companies, San Francisco, CA
Ford Motor Co.,Dearborn,MI
Fundacao Centro Nacional de Seguaranca, Higiene e Medicina do Trabalho, Sao Paulo, Brazil
General Adjustment Bureau, Inc., Chicago, IL
General Electric Co., Fairfield, CT
General Motors Corp., Detroit, MI
The General Tire & Rubber Co., Akron, OH
GenTex Corp., Carbondale,PA
Georgia Power Co. Atlanta, GA
Glendale Optical Co., Inc., Woodbury, NY
Go-Jo Industries, Inc., Akron, OH
B.F.Goodrich Co., Akron,OH
Goodyear Tire & Rubber Co., Akron, OH
GTE Automatic Electric, Northlake, IL
GTE Sylvania, Danvers, MA
Guardian Safety Equipment Co., Philadelphia, PA
Gulf Group Co's., Dallas,TX
Gulf Oil Canada, Ltd., Toronto, Ontario
Gulf Oil Corp., Houston,TX
Hazelton Labs., Inc., Vienna, VA
Hitchcock Industries, Inc., Minneapolis, MN
H.J.Heinz Co., Pittsburgh,PA
Hoffmann-LaRoche,Inc., Nutley, NJ
Honeywell, Inc. Minneapolis, MN
Hooker Chemical & Plastics Corp., Niagara Falls, NY

Hughes Aircraft Co., Los Angeles, CA
Hydro, Quebec, Montreal
ICI United States, Inc. Wilmington, DE
Industrial Bio-Test Labs., Inc., Northbrook, IL
Industrial Health Foundation, Pittsburgh, PA
Inland Steel Co., Harbor Works, E.Chicago, IN
Internatl. Business Machines Corp., Armonk, NY
Internatl. Harvester Co., Chicago, IL
Internatl. Res. & Dev.Corp., Mattawan, MI
Internatl. Safety Academy Macon, GA
ITT Corp., New York, NY
Johns-Manville Corp., Denver, CO
Kaiser Alum. & Chem.Corp., Oakland, CA
Kaiser Industries Corp., Oakland, CA
Kawecki-Berylco Industries Reading, PA
Komyo Rikagaku Kogo, K.K., Meguro-ku, Tokyo, Japan
The Lab. for Chromatography, Flushing, NY
Lear Seigler, Inc. Anaheim, CA
Liberty Mutual Ins. Co., Boston, MA
London Schl of Hygiene & Tropical Medicine, London, England
Lone Star Steel Co., Lone Star, TX
Love's Bakery, Honolulu, HI
Lumbermen's Mutual Casualty Co., Long Grove, IL
Mallinckrodt, Inc., St. Louis, MO
Marathon Oil Co., Findlay,OH
Martin-Marietta Corp., Rockville, MD
MDA Scientific, Inc., Park Ridge, IL
Michigan Mutual Liability Co., Detroit, MI
Millipore Corp., Bedford, MA
Mine Safety Appliances Co., Pittsburgh, PA
3M Co., St. Paul, MN
Mobay Chem. Co., Pittsburgh, PA
Mobil Oil Corp., NY, NY
Monsanto Co., St. Louis,MO
Motorola, Inc.,Chicago,IL
McClouth Steel Corp., Trenton, MI
Natl. Environmtal Instrumts Inc., Warwick, RI
Natl. Institutes of Health, Bethesda, MD
Natl. Mine Service Co., Pittsburgh, PA
Natl. Safety Council, Chicago, IL
Newport News Industrial Corp. Newport News, VA
Niagara Mohawk Power Corp., Syracuse, NY
N.L.Industries, Magnesium Div. Salt Lake City, UT
Norton Co., Worcester, MA
Olin Corp., Lake Charles, LA
Olin Corp., New Haven,CT
Owens-Corning Fiberglas Corp. Toledo, OH
Owens-Illinois, Toledo, OH
Pennsylvania Mfgs. Assoc. Ins. Co., Philadelphia, PA
Phillips Petroleum Co., Bartlesville, OK
Pneumafil Corp., Charlotte, NC
Procter & Gamble Co., Cincinnati, OH
Pulmosan Safety Equipmt Corp., Flushing, NY
Ramcon, Inc., Memphis, TN
Raybestos-Manhattan,Inc., Trumbull, CT
RCA Corp., Camden, NJ
Republic Steel Corp., Cleveland, OH
Research Appliance Co., Gibsonia, PA
Reynolds Metals Co., Richmond, VA
Rockwell Internatl., Pittsburgh, PA

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Rohm & Hass Co., Pittsburgh, PA
Safety Supply Co., Toronto, Ontario
St. Regis Paper Co., NY,NY
Schweizehische Unfallversicherungsanstalt Suva, Luzern, Switzerland
Scientific Assoc's., Inc., St. Louis, MO
Scott Aviation, S.Haven,MI
G.D.Searle & Co., Skokie,IL
Sentry Ins.,A Mutual Co., Stevens Pt., WI
Shell Canada Ltd., Toronto, Ontario
Shell Oil Co., Houston, TX
The Sherwin-Wms. Co., Cleveland, OH
Anatole J. Sipin Co., NY,NY
Sociedad Minera El Teniente, Rancagua, Chile
S.Carolina Dept. of Health & Environmtal Control, Columbia, SC
Southern Peru Copper Corp., Tacna, Peru
SW Foundation for Res. & Education, San Antonio,TX
Sperry Rand Corp., Shreveport, LA
Standard Oil Co.(Indiana) Chicago, IL
The Standard Oil Co., Cleveland, OH
Standard Oil Co. of Calif., San Francisco, CA
State Compensation Ins. Fund, San Francisco, CA
Stauffer Chem. Co., Richmond, CA
Stewart-Todd Assoc's., Inc. Wayne, PA
Sugar Beet Prod.Co., Saginaw, MI
Sun Oil Co., Marcus Hook, PA
Swift & Co., Chicago, IL
Tenneco, Inc., Houston, TX
Texas Instrumts, Inc., Dallas, TX
Tribune Co., Chicago, IL
Twin City Testing & Eng. Lab., St. Paul, MN
Uniroyal, Inc., Middlebury, CT
United Nuclear Industries, Inc. Richland, WA
U.S.Steel Corp., Pittsburgh, PA
Univ. of Hawaii, Honolulu, HI
Univ. of Washington, Seattle, WA
The Upjohn Co., Kalamazoo, MI
OSHA Training Institute, US Dept. of Labor, Rosemont, IL
US Testing Co., Inc., Hoboken, NJ
Viking Pump Div., Houdaille Industries, Inc., Cedar Falls, IA
Virginia Chem., Inc., Portsmouth, VA
Welsh-A Textron Co., Providence, RI
Western Electric Co., Inc. New York, NY
Westinghouse Electric Corp., Buffalo, NY
Westpoint Pepperell, Westpoint, GA
Wilks Scientific Corp., S. Norwalk, CT
Wilson Prod., Div.,ESB, Inc. Reading, PA
Witco Chem. Co., Inc. NY,NY

The following laboratories have been accredited under the Laboratory Accreditation Program of the American Industrial Hygiene Association, through June 30, 1975..

Abex Corporation
Industrial Hygiene Analytical Laboratory
4550 W. 26th Street
Chicago, Illinois 60623
C.C.Blackwell,Jr.,M.D.,Director

Aerojet Solid Propulsion Co.
Environmental Data Laboratory
P.O.Box 13400
Sacramento, California 95813
P.J.Klass,Ph.D.,Director

Aetna Life & Casualty Company
Engineering Industrial Hygiene Laboratory
151 Farmington Avenue
Hartford, Connecticut 06115
John M. Robinson,Director

American Can Co.
Safety & Industrial Hygiene Laboratory
U.S.Highway 22
Union, New Jersey 07083
J.F.McVeigh, Manager

American Metal Climax, Inc.
AMAX Laboratory
400 Middlesex Ave.
Carteret, New Jersey 07008
R.G.Ernst, Director

American Smelting & Refining Co.
Dept. of Environmental Sciences Laboratory
3422 South 700 West
Salt Lake City, Utah 84119
Robert D. Putnam, Ph.D., Director

Anderson-Nichols & Company, Inc.
Air Quality & Industrial Hygiene Laboratory
150 Causeway Street
Boston, Massachusetts 02114
John Chapin, Ph.D., Director

Bethlehem Steel Corporation
Environmental Quality Control
Homer Research Laboratories
Bethlehem, Pennsylvania 18016
A.E.Moffitt,Sc.D.,Director

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Hanford Environmental Health Foundation
Environmental Health Sciences Laboratory
P.O.Box 100
Richland, Washington 99352
Ralph G. Anderson, Director

Hartford Insurance Group
Environmental Sciences Unit Laboratory
Hartford Plaza
Hartford, Connecticut 06115
William G. Meade, Director

Honeywell, Inc.
Materials Engineering Laboratory
2701 4th Avenue South
Minneapolis, Minnesota 55408
Thomas N. Zenk, Director

Interlake, Inc.
Interlake Technical Center
Environmental Control Laboratory
150 West 137th St.
Riverdale, Illinois 60627
Fred G. Krikau, Director

International Safety Academy
Environmental Health Laboratory
1021 Georgia Ave.
Macon, Georgia 31201
John G. Etheridge, M.D.,Director

Kaiser Aluminum and Chemical Corp.
Center for Technology
6177 Sunol Blvd.
Pleasanton, California 94556
H.J.Seim,Ph.D.,Director

LFE Corporation
Environmental Analysis Laboratories Div.
2030 Wright Avenue
Richmond, California 94804
Marcel Nathans,Ph.D.,Director

Liberty Mutual Insurance Co.
Industrial Hygiene Laboratory
71 Frankland Road
Hopkinton, Massachusetts 01748
Russell W. VanHouten,Director

Maryland State Dept. of Health & Mental Hygiene
Occupational Health & Air Quality Lab.
Laboratories Administration-Howard & Biddle Sts.
Baltimore, Maryland 21202
Emanuel Kaplan, Sc.D., Director

Massachusetts Institute of Technology
Industrial Hygiene Laboratory
77 Massachusetts Avenue
Cambridge, Massachusetts 02139
Richard I. Chamberlin, Director

National Institute for Occupational Safety & Health
DLCD, Physical & Chemical Analysis Branch
Analytical Services Section
1014 Broadway
Cincinnati, Ohio 45202
John V. Crable, Director

National Institute for Occupational Safety & Health
Western Area Occupational Health Laboratory
P.O.Box 8137
Salt Lake City, Utah 84108
Russell H. Hendricks, Ph.D., Director

National Loss Control Services Corp.
Environmental Sciences Laboratory
Long Grove, Illinois 60049
Mrs. Betty O'Shea, Director

Ohio State Div. of Public Health Laboratories
Industrial Chemistry Section
1571 Perry Street
Columbus, Ohio 43201
C.C.Croft, Sc.D., Director

Oregon State Dept. of Human Resources
Occupational Health Laboratory
1400 Southwest 5th Avenue
Portland, Oregon 97201
Olav Merilo, Director

Pedco Environmental Specialists
Suite 13 Atkinson Square
Cincinnati, Ohio 45238
Lawrence A. Elfers, Director

Pennsylvania Dept. of Environmental Resources
922 Health And Welfare Bldg.
Harrisburg, Pennsylvania 17120
Virginia M. Vought, Director

PPG Industries
Barberton Technical Center
P.O.Box 31
Barberton, Ohio 44203
Bernard DeWitt, D.Sc., Director

Radiation Detection Company
162 Wolfe Road
P.O.Box 1414
Sunnyvale, California 94088
Stuart L. Adelman, Ph.D., Director

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Chrysler Corporation
Industrial Hygiene Services Laboratory
P.O.Box 1919
Detroit, Michigan 48231
L.P.Gendernalik, Ph.D., Director

Clayton Environmental Consultants, Inc.
25711 Southfield Road
Southfield, Michigan 48075
Robert D. Soule, Director

Eastman Kodak Company
Health and Safety Laboratory
Industrial Hygiene Section
1669 Lake Avenue
Rochester, New York
Robert L. Raleigh, M.D., Director

Employers Insurance of Wausau
Environmental Health Laboratory
2000 Westwood Drive
Wausau, Wisconsin 54401
Robert E. Hawkinson, Director

Environmental Sciences Associates, Inc.
Industrial Hygiene Analytical Laboratory
175 Bedford Street
Burlington, Massachusetts 01803
Reginald M. Griffin, Ph.D., Director

General Electric Company
Environmental Health Support Laboratory
1285 Boston Avenue
Bridgeport, Connecticut 06602
Dale A. Culp, Director

General Motors Corporation
Industrial Hygiene Department Laboratory
G.M.Technical Center
12 Mile & Mound Roads
Warren, Michigan 48090
Walter H. Konn, Director

Gulf Oil Corporation
Industrial Hygiene Laboratory
P.O.Box 3240
Pittsburgh, Pennsylvania 15230
James O. Jackson, Ph.D., Director

St. Louis County Health Dept.
Div. of Laboratories
Air Pollution Industrial Hygiene Lab.
801 S. Brentwood Blvd.
Clayton, Missouri 63105
Wayne E. Black,Ph.D., Director

St. Paul Fire & Marine Ins. Co.
Environmental Services Analytical Lab.
494 Metro Square Bldg.
7th & Robert Streets
St. Paul, Minnesota 55101
Donald J. Larsen, Director

Sandia Laboratories
Environmental Health Laboratory
Division 3311
Albuquerque, New Mexico 87115
Lial W. Brewer, Director

South Carolina Dept. of Health &
Environmental Control
Div. of Environmental Health
Occupational Health Laboratory
2600 Bull Street
Columbia, South Carolina 29201
Edward R. Williams, D.P.H.,Director

State of Washington
Dept. of Labor & Industries
Industrial Hygiene Laboratory
P.O.Box 207
Olympia, Washington 98501
Charles E. McJilton, Ph.D., Director

Union Carbide Corporation
Chemicals & Plastics Res. & Dev. Dept.
P.O.Box 8361
South Charleston, West Virginia 25303
N.H.Ketcham, Director

Union Carbide Corporation
Ferroalloys Division Laboratory
P.O.Box 299
Marietta, Ohio 45750
Paul W. McDaniel, Director

Union Carbide Corporation
Industrial Hygiene Laboratory
Gulf Coast Area
P.O.Box 471
Texas City, Texas 77590
Donald E. Deese, Director

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Union Carbide Corporation
Parma Technical Center
Industrial Hygiene Lab. Facility
12900 Snow Road
Parma, Ohio 44101
George Jackson, Director

University of Cincinnati
Kettering Laboratory, Analytical Section
3223 Eden Avenue
Cincinnati, Ohio 45219
B.E.Saltzman,Ph.D.,Director

University of Iowa
State Hygienic Laboratory
Medical Laboratories Bldg.
Iowa City, Iowa 52242
W.J.Hausler,Ph.D.,Director

University of Missouri
Environmental Trace Substances Res. Ctr.
Columbia, Missouri 65201
James O. Pierce,II,Sc.D.,Director

U.S.Army Environmental Hygiene Agency
Laboratory Services Directorate
Aberdeen Proving Ground, Maryland 21010
Marshall Steinberg,Ph.D.,Col.,Director

West Allis Memorial Hospital
Industrial Toxicology Laboratory
8901 West Lincoln Ave.
West Allis, Wisconsin 53227
Harold J. Conlon,M.D.,Director

LOCAL SECTIONS
Meeting Plans and Officers

ARIZONA-

Officers

President: Walter C. Holberg
Vice Pres: William T. Keane, Sc.D.
Secretary-Treas: Marge P. Smith
1724 Bridalwreath
Tempe, AZ 85281

CAROLINAS-

Officers

President: John C. Lumsden
President-elect: Robert W. McCollum
Secretary-Treas: Ms. Gloria B. Cann, R.N.
Parke, Davis & Co.
P.O.Box 368
Greenwood, SC 29646

CHICAGO-

Meets the first Wednesday of each month f[illegible]er through June (except May and December) at the Courts Restaurants, 401 N. Michigan Avenue, Illinois, with dinner at 6:15 P.M.

Officers:

President: Betty O'Shea
President-elect: Kenneth A. Phillipo
Secretary: John S. Shockley, Jr.
American Foundrymen's Society
Golf and Wolf Rds.
Des Plaines, IL 60016
Treasurer: Robert S. Kassriel, M.D.

CONNECTICUT RIVER VALLEY SECTION-

Meetings at least three times per year. No definite dates established.

Officers:

President: Louis Press
President-elect: Janet Kapish
Treasurer: Steven K. Wheeler
Secretary: Eileen Stephenson
Aetna Life and Casualty
151 Farmington Avenue
Hartford, CT 06156

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DEEP SOUTH-

Three meetings each year, one of which will coincide with the annual meeting of the Louisiana Safety Conference held the 2nd week in December.

Officers:

President: Beverly Pancamo
President-elect:
Secretary-Treas: J.C.Schonberg
Union Carbide Corp.
P.O.Box 50
Hahnville, LA 70057
504-783-6861

DELAWARE VALLEY-

Meets second Tuesday of alternate months from September to May.

Officer:

President: Samuel Elkin, Ph.D.
President-elect: Walter J. Chrosten
Secretary: Edward M. Petruska
American Mutual Liability Ins. Co.
67 Long Lane
Upper Darby, PA 19082
Treasurer: Martin Ornosky

FLORIDA-

Two-three meetings per year.

Officers:

President: Jack McKichan
President-elect: Roland Byrd
Secretary-Treas: Bob Hebblethwaite
2626 Leonid Rd.
Jacksonville, FL 32218

GEORGIA-

At least one meeting per year.

Officers:

President: James L. Burson
President-elect: Holmes E. Pyles
Secretary: Jerry L. Copper
Treasurer: Alic C. Farrar
International Safety Academy
1021 Georgia Avenue
Macon, GA 31201

GULF COAST-

Meets the third Tuesday of January, March, May, September, and November.

Officers:

President: Donald E. Deese
President-elect: Bruce Horvath
Secretary-Treas: Lee Silverthorne
Dow Chemical Co.
P.O.Box K B-101
Freeport, TX 77541

HAWAII-

Meets four times per year, normally in January, April, July, and October.

Officers:

President: Arthur Alper
Vice-President: Carl J. Souza
Secretary-Treas: Dennis Chew
Directors: Jerry Johnson
Richard Yawata
Charles Regan
U.S. Dept. of Labor
Honolulu Area Office
331 Queen St. Suite 505
Honolulu, HI 96313

I. & I. (ILLINOIS & IOWA)-

Meets four times per year. No definite dates established.

Officers:

President: Ward W. Bickford
President-elect: Thomas A. Selders
Secretary-Treas: Thomas M. Snyder
Deere & Company
1231 - 13th Street
E. Moline, IL 61244

INDIANA-

Meets three times a year, on the fourth Tuesday of October, January and April.

Officers:

President: Carl S. Ray, M.D.
President-elect: Robert E. Gangstead
Secretary-Treas: Michael W. Heminger
General Electric Co.
1635 Broadway, Bldg. 21
Fort Wayne, IN 46804

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LAS VEGAS, NEVADA-

Minimum of two meetings per year, held at the Southwest Radiological Health Lab. USPHS, Las Vegas, Nevada.

Officers:

President: Terry C. Roy
President-elect: Carlton Soong
Secretary-Treas: Dorothy Morgan
612 Digger St.
Las Vegas, NV 89107

METROPOLITAN NEW YORK-

Usually four meetings per year, between September and May.

Officers:

Chairman: Donald R. Lynam, Ph.D.
Chairman-elect: John D. Yoder, Sc.D.
Secretary-Treas: Ronald T. Richards
Texaco, Inc.
135 E. 42nd St.
New York, NY 10017

MICHIGAN(Detroit Area)-

Six dinner meetings in Detroit metropolitan area plus one all-day conference during active season of September through May.

Officers:

President: Robert S. Ajemian
President-elect: Paul A. Jankowski
Secretary-Treas: Norman Brusk
22130 Church
Oak Park, MI 48237

MID-AMERICA-

Officers:

President: John C. Irwin
President-elect: David R. Hackathorn
Secretary-Treas: David O. Smart
101 W. 11th St.
Kansas City, MO 64114

NEW ENGLAND-

Five meetings a year, usually on the third Thursday of January, March, May, September, and November. Meetings are dinner meetings with an all-day meeting in November.

Officers:

President: Leon D. Horowitz
President-elect: Phillip LaTorre
Secretary-Treas: Correspond with the President
Leon D. Horowitz
Chief, Indus. Hygiene Section
Home Office Engineering
American Mutual Liability Ins. Co.
Wakefield, MA 02880

NEW JERSEY-

Meets the third Thursday of alternate months from October through April, and on the first Thursday in June, for dinner at various restaurants in the metropolitan New Jersey area.

Officers:

President: Ralph M. Gelburd
President-elect: George B. Stanton, Jr.
Secretary-Treas: Preston C. Shimer
2271 Hill Rd.
Westfield, NJ 07090

NORTH TEXAS-

Meets four times a year, on the last Monday of January, March, September, and November.

Officers:

President: Mrs. Karen Jean Rice
Vice-president: John Regula
Secretary-Treas: Charles W. Reed
Director of Indus. Hygiene
Texas Employers' Ins. Assoc.
P.O.Box 2759
Dallas, TX 75221

NORTHEASTERN OHIO-

At least three meetings annually.

Officers:

President: Douglas Marcero
President-elect: Edwin B. Katzenmeyer, Jr.
Secretary-Treas.: Harold C. Cutter
24201 Yosemite Dr.
Euclid, OH 44117

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SUPERIOR COURT OF THE STATE OF CALIFORNIA

FOR THE COUNTY OF LOS ANGELES

FILE COPY

WALTER C. RIGSBY, JOSEPH K. KLOSE and SHELDON H. MANNING,

Plaintiffs,

vs.

JOHNS-MANVILLE, etc., et al.,

Defendants.

No. C 151 947

EXHIBIT YY

EXHIBITS TO THE DEPOSITION OF SHELDON H. MANNING, VOLUME VI, taken Tuesday, March 6, 1979, at Los Angeles, California, before Lucia Moskal, CSR, a Notary Public.

2 OF 2

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Reported by:
Lucia Moskal, CSR 1222

No. LA-788-79

RENDEL B. HUTCHINGS
Certified Court Reporters

LOS ANGELES 90065 3436 N. Figueroa 223-1191

WEST LOS ANGELES 90049 654 N. Sepulveda 472-9578

SANTA ANA 92701 523 N. Grand 547-6169

SAN DIEGO 92101 326 Broadway 233-6227

MT-PWHD-004419

NORTHERN CALIFORNIA(San Francisco Area)-

Joint meeting with the Health Physics Society in September and five dinner meetings on the second Tuesday of odd-numbered months from November to July.

Officers:

President: Alfredo Salazar
President-elect: Thomas Walker
Secretary-Treas: Henry J. McDermott
Shell Oil Company
Walnut Creek, CA 94956

OHIO VALLEY(Cincinnati Area)-

Meets fourth Tuesday of the month from October to April at the Engineering Society of Cincinnati Building, 1349 E. McMillan Street, Cincinnati, Ohio.

Officers:

President: William Westendorf
President-elect: Richard Coomes
Secretary: John Kominsky
6808 Leeds Lane W.
Cincinnati, OH 45215
Treasurer: Barbara Halterman

OTTAWA, CANADA (Inactive)-

Meetings are normally held in Ottawa at irregular intervals as occasion permits.

PACIFIC NORTHWEST (Alaska, British Columbia, Idaho, Montana, Oregon and Washington)-

Meets several times annually.

Officers:

President: Ralph G. Anderson
President-elect: A.F.Schoenborn
Secretary-Treas: R.J.Hollingsworth
Intalco Aluminum Corp.
Box 937
Ferndale, WA 98248

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PITTSBURGH-

Five meetings per year at locations and times as the program committee directs.

Officers:

President: Robert G. Gallaghar
President-elect: William Janes
Secretary-Treas: Mary Ann Babyak
Industrial Health Foundation
5231 Centre Ave.
Pittsburgh, PA 15232

QUEBEC-

Officers:

President: Paul A. Belanger
President-elect: J.F.Perron

Services de Protection de l'Environnement
Environnement Industriel
9310 St.Laurent, 11e estage
Montreal H2N 1N4

ROCKY MOUNTAIN(Colorado, New Mexico, Wyoming, and El Paso and Amarillo, Texas areau)-

Meets several times annually.

Officers:

President: Ronald J. Uhle
President-elect: Donald R. Parker
Secretary-Treas: John Hanschy
7037 Dudley Dr.
Arvada, CO 80004

SOUTHERN CALIFORNIA(Los Angeles Area)-

Dinner meetings at 7:00 P.M. at Taix French Restaurant 1911 Sunset Blvd., Los Angeles, on the second Thursday of January, March, May, September and November.

Officers:

President: James M. Bachman
President-elect: Prem Notani-Sharma, Dr. P.H.
Secretary: Daniel J. Gorberg
Republic Indemnity Co. of America
1220 N. Highland
Los Angeles, CA 90038
Treasurer: Richard C. Kenen

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SOUTHERN ONTARIO-

Officers:

Chairman: G.E.Menzies
Chairman-elect: John H. Johnston
Secretary-Treas: Perc Pritchard
Dominion Foundries Ltd.
P.O.Box 460
Hamilton, Ontario

ST. LOUIS-

Meetings in October, December, and March.

Officers:

President: Denver L. Holt
President-elect: Dr. John J. Manda
Secretary-Treas: Thomas C. Linck
417 Iron Lantern Dr.
Ballwin, MO 63011

TENNESSEE VALLEY(Tennessee and portions of southwestern Virginia, western North Carolina, northern Alabama, northern Mississippi, and southwestern Kentucky)-

Meets semi-annually, various locations.

Officers:

President: T.C.Whitson
President-elect: David M. Trayer
Secretary-Treas: Ronald J. Young
2910 Scioto St.
513 Sawyer Hall
Cincinnati, OH 45221

UPPER MIDWEST(Minnesota, N. Dakota, S. Dakota, and portions of Iowa and that portion of Wisconsin within a 100-mile radius of the Minneapolis -St.Paul region)-

Four meetings per year.

Officers:

President: Owen D. Lien
President-elect: Donald Larsen
Secretary-Treas: Henry Makino
Honeywell, Inc.
Honeywell Plaza
Minneapolis, MN 55408

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UTAH-

Meetings will be held bi-monthly at different locations.

Officers:

President: Thomas J. Smith, Ph.D.
President-elect: William L. Wagner
Secretary-Treas: Ilmar Lusis
Utah International, Inc.
P.O.Box 9289
Salt Lake City, UT 84109

WASHINGTON-BALTIMORE-

Four meetings during the year at a convenient site between Washington and Baltimore.

Officers:

President: David Staples
President-elect: David Gioiello
Secretary: Ed Radden
Treasurer: Paul Stearn
340 Ayrhill Ave., N.E.
Vienna, VA 22180
Directors: Erroll Hay
James Beegan

WESTERN NEW YORK-

Four meetings per year; one each during the fall, winter, spring, and summer. Two meetings are in Bufflao, and two are in Rochester.

Officers:

President: Joseph Fater
President-elect: Forest L. Keister
Secretary-Treas: Denese A. Deeds
Westinghouse Electric Corp.
Box 225
Buffalo, NY 14240

YUMA-PACIFIC SOUTHWEST-

Meets annually, February or March.

Officers:

President: Ruth B. Patty
President-elect: Herbert T. Walworth
Secretary: Florence Clayton
P.O.Box 425
Fallbrook, CA 92808
Treasurer: Gertrude Cralley

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Manpower and Career Development

1973–Ralph J. Vernon, Ph.D., Chairman
1975–Mary O. Amdur, Ph.D.
1974–Clyde M. Berry, Ph.D.
1975–Walter J. Chrostek
1975–Donald F. Deese
1973–Lawrence W. Hecker, Ph.D.
1973–Edward R. Hermann, Ph.D.
1973–Philip LaTorre
1974–Edward D. Leininger
1973–Robert D. Mahon
1975–Edward D. Palmes, Ph.D.
1974–Thomas C. Purcell, Ph.D.
1974–Frank M. Renshaw, Ph.D.
1973–John P. Sapia
1975–Robert E. Sherriff
1973–Joseph B. Zuzik

This committee was inadvertently omitted from the membership directory. Please insert following page 25.

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Roster
of
THE AMERICAN ACADEMY OF INDUSTRIAL HYGIENE

1970-1971

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American Board of Industrial Hygiene, Incorporation

421

MT-PWHD-004423

Roster
of
THE AMERICAN ACADEMY OF INDUSTRIAL HYGIENE

1970-1971

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American Board of Industrial Hygiene, Incorporated

422

MT-PWHD-004424

American Academy of Industrial Hygiene

OFFICERS AND COUNCIL

(Terms begin May 1970)

EDWARD D. PALMES, PH.D., *President* (1971)

DOHRMAN H. BYERS, *Vice President* (1971)

PAUL F. WOOLRICH, *Secretary* (1971)

ANDREW D. HOSEY, *Treasurer* (1972)

BERNARD D. BLOOMFIELD, *Councillor* (1973)

ANNA M. BAETJER, SC.D., *Councillor* (1972)

H. F. SCHULTE, *Councillor* (1971)

W. G. FREDRICK, SC.D., *Past President* (1971)

HERBERT T. WALWORTH, Councillor (1972)
(appointed by ABIH)

REDACTED
FOIA
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History

In 1956, the Board of Directors of the American Industrial Hygiene Association appointed an *ad hoc* Committee on Certification in the Field of Industrial Hygiene. Under the chairmanship of Lewis J. Cralley, Ph.D., this Committee reported to the Board on October 10, 1957, recommending that the Association endorse and initiate the establishment of a voluntary certification program for qualified industrial hygienists.

In November 1957 the Board of Directors appointed an *ad hoc* Committee on Certification Standards, under the chairmanship of Henry F. Smyth, Jr., Ph.D. In February 1958 this Committee recommended to the Executive Committee of the Association that the American Conference of Governmental Industrial Hygienists should be invited to join with the Association in initiating a certification program, and should be invited to delegate six members to join with the *ad hoc* Committee in planning. Early in 1958 these ACGIH delegates were named, and the resulting Joint Committee on Certification Standards with thirteen members held its first meeting in April 1958, under the chairmanship of Henry F. Smyth, Jr., Ph.D.

In March 1959 the Joint Committee recommended to the two Associations that voluntary certification should be conducted by an independent incorporated Board, that the two Associations should sponsor the Board and advance monies for its initial expenses, that the Joint Committee should be discharged, and that each Association should delegate six of its members to join in organizing the independent Board. During the summer of 1959 the memberships of the two Associations approved the principle of voluntary certification, the outline of plans and proposed qualifications for certification which had been prepared by the Joint Committee, and the advance of money for initial expenses. Each organization thereupon delegated six of its members to join in organizing the Board.

The twelve delegates held their initial meeting in Rochester, New York on April 24, 1960. A petition for a charter as a nonprofit corporation under the laws of the Commonwealth of Pennsylvania was approved by the Court of Common Pleas of Allegheny County September 12, 1960, and certified by the Prothonotary of that County September 26, 1960. The American Board of Industrial Hygiene held its first annual meeting in Pittsburgh on October 28, 1960.

All diplomates of the American Board of Industrial Hygiene become members of the American Academy of Industrial Hygiene. They remain members in good standing so long as they pay the annual dues assessed by the Board. Those who have retired from professional activity will remain members in good standing without the payment of annual dues. During 1966 the diplomates activated the American Academy of Industrial Hygiene as a voluntary professional society.

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American Board of Industrial Hygiene, Incorporated

Nominated by American Conference of Governmental Industrial Hygienists

Allan L. Coleman	1970
William G. Fredrick, Sc.D.	1972
Andrew D. Hosey	1974
Alan C. Love	1974
E. Lynn Schall	1972
Charles D. Yaffe	1970

Nominated by American Industrial Hygiene Association

James W. Hammond	1974
Willis G. Hazard	1970
Nathan V. Hendricks	1972
Henry F. Smyth, Jr., Ph.D.	1972
Herbert T. Walworth	1974
Jack H. Wolfsie, M.D.	1970

Past Members

Edgar C. Barnes (AIHA)	1960-61
William R. Bradley (AIHA)	1962-68
Lester V. Cralley, Ph.D. (AIHA)	1960-66
Hervey B. Elkins, Ph.D. (ACGIH)	1962-68
Louis F. Garber (ACGIH)	1962-68
Thomas F. Mancuso, M.D. (ACGIH)	1960-64
Kenneth M. Morse (AIHA)	1960-66
Harry F. Schulte (AIHA)	1961-64
John C. Soet (ACGIH)	1960-66
James H. Sterner, M.D. (AIHA)	1960-64

BOARD OF DIRECTORS

(All members of the American Board of Industrial Hygiene, Incorporated are members of the Board of Directors)

OFFICERS 1968-1970

CHARLES D. YAFFE, *Chairman*

JACK H. WOLFSIE, M.D., *Vice-Chairman*

E. LYNN SCHALL, *Secretary-Treasurer*

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LIMITED
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Bylaws

American Academy of Industrial Hygiene

Preamble

The American Board of Industrial Hygiene Incorporated under the laws of the Commonwealth of Pennsylvania in 1960 as a non-profit corporation has as a primary purpose improvement in the practice and educational standards of the profession of industrial hygiene. The American Board of Industrial Hygiene in carrying out its objectives certifies individuals as to education, experience and professional ability in the comprehensive practice of industrial hygiene or specialized aspects of the profession.

The American Board of Industrial Hygiene by legal action duly recorded in the minutes of the Corporation has indicated that successful candidates for certificates shall attain the status of Diplomate in the American Academy of Industrial Hygiene subject to compliance with requirements established by the American Board of Industrial Hygiene. Further, the American Board of Industrial Hygiene by legal action duly recorded in the minutes of the Corporation has activated the American Academy of Industrial Hygiene into a non-incorporated, voluntary, non-profit, professional society, under the sponsorship of the Corporation to attain the Purpose and Objectives outlined in the Bylaws of the Academy.

Article I. Name

The name of the organization shall be "American Academy of Industrial Hygiene."

Article II. Purpose and Objectives

Section 1. The purpose of the Academy is to provide leadership in advancing the professional field of industrial hygiene, by raising the level of competence of industrial hygienists and by securing wide recognition of the need for high quality industrial practice to insure healthful work conditions in the various occupations and industries. To meet this central purpose the Academy must work both within and ouside its own professional group. Its activities shall include but not be limited to:

(a) Recruitment and training—develop and conduct programs of recruitment of graduates in the sciences and in engineering into the field; promote programs of graduate training in industrial hygiene and consult with the universities and other training programs, entrance requirements, curricula and methods of instruction to insure a firm base on which to build professional competence; encourage the development of programs of continuing education and training for practicing industrial hygienists through refresher courses and advanced seminars.

(b) Promotion of industrial hygiene—promote recognition by all individuals and organizations concerned with health maintenance in industry of the need for the highest level of competence in industrial hygiene practice; participate actively in governmental planning committees and hearings and in the parallel efforts of industrial management groups and labor organizations to improve and extend occupational health activities; collaborate with other professional groups in occupational health in pursuit pf common aims and objectives.

(c) Advancement of Board Certification—work with the appropriate governmental and private agencies to secure the widest acceptance and adoption of Certification by the American Board of Industrial Hygiene as a basic qualification for employment in both public and private industrial hygiene organizations.

(d) Code of Ethics—establish guidelines for ethical conduct in the practice of industrial hygiene.

Section 2. The Academy is organized as a non-profit association. Its officers shall serve without pay and upon dissolution of the Academy, its assets shall revert to the American Board of Industrial Hygiene.

Section 3. Subject to specific approval by the American Board of Industrial Hygiene, the Academy is empowered to accept grants, gifts and monies from foundations, government, industry and individuals to implement specific objectives within the purpose of the Academy or to implement the objectives of grants made to the American Board of Industrial Hygiene.

Article III. Membership

All individuals who are certified by the American Board of Industrial Hygiene are eligible for membership in the Academy and will maintain active membership by regular payment of dues.

Article IV. Officers and Council

Section 1. The officers of the Academy shall be the President, the Vice-President, the Secretary, and the Treasurer.

Section 2. The Council will consist of the officers plus four Councilors, one of whom shall be appointed by the American Board of Industrial Hygiene for a three year term from the membership of the American Board of Industrial Hygiene, and the immediate Past President and will act as the governing body of the Academy.

Section 3. Term of office. The President and the Vice-President shall serve for one year. At the expiration of their terms the Vice-President shall automatically become the President. The Secretary and the Treasurer will serve for three years. The Councilors will serve for three years and one new Councilor will be elected each year so that a completely new Council is not installed in any year.

Section 4. Executive Committee. The Executive Committee will consist of all four officers and will be given such duties as the Council desires. In general, the Executive Committee will report any of its actions to the next scheduled meeting of the Council.

Section 5. Meetings. The Council shall meet at least once a year at the call of the President. A quorum will consist of five Council Members.

Section 6. Mail Ballot. In the interval between meetings of the Council, action may be taken by ballots mailed to each Council Member by the Secretary or President, provided a majority of Council Members return their ballots marked within the time stated in the ballot.

Article V. Elections

Section 1. Nominations of officers and elective directors shall be made by a nominating committee of three members of the Academy to be proposed by the President and appointed by the Council. At least 90 days before the annual meeting the nominating committee shall select two nominees for each elective office. Names of candidates will be submitted to the Academy Members for action by mail. In case of a tie vote, the tie shall be resolved by vote of the Council.

Section 2. Installation of officers and directors shall take place at the last business session of the annual meeting.

Article VI. Duties of Officers

Section 1. The President shall be the principal administrative officer of the Academy and of the Executive Committee and Council, and shall preside at all meetings of these groups. He shall perform such other duties as may be directed by the Council.

Section 2. The Vice-President shall carry out the duties of the President when the latter is absent from a meeting or is incapacitated.

Section 3. The Secretary shall keep accurate record of the transactions of all meetings of the Academy, Council and Executive Committee. He shall carry on correspondence of the Academy, the Council, and the Executive Committee.

Section 4. The Treasurer shall be custodian of all monies of the Academy. He shall receive monies due the Academy and pay all authorized bills against the Academy. He shall submit his accounts for audit in advance of the annual meeting of the Council. He shall be bonded at the expense of the Academy.

Article VII. Meetings

Section 1. There shall be an annual meeting of members of the Academy to conduct such business as shall be brought before it.

Section 2. The Council may call special meetings of the members of the Academy.

Section 3. For all meetings of the Academy a quorum shall consist of 10% of the Members.

Article VIII. Dues

Dues for membership in the Academy shall be that portion of monies assessed by the American Board of Industrial Hygiene and as allocated by mutual agreement between the American Board of Industrial Hygiene and the Directors of the Academy to the Academy by the American Board of Industrial Hygiene.

Article IX. Amendments

Section 1. No amendment to the Bylaws shall change the qualifications for membership.

Section 2. No amendment to the Bylaws shall result in pecuniary gain or profit, indirect or otherwise, to a member of the Academy.

Section 3. Any proposed amendment to the Bylaws must be submitted in writing to the Council and must be signed by five Members. The Council shall also have the power to initiate amendments to the Bylaws. The Council shall consider all such amendments and shall submit them to Academy Members for action by mail ballot. Approval shall be given by favorable vote of two-thirds of the ballots returned within 30 days.

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Members of the
American Academy of Industrial Hygiene
July 1, 1970

Ackerman, Harry H., (M.A.)
Comprehensive Practice
109 Fairmount Drive
Bel Air, Md. 21014
(U.S. Army Environmental Hygiene Agency)

Adley, Frank E.
Comprehensive Practice
407 Cullum St.
Richland, Wash. 99352
(Hanford Occupational Health Foundation, Inc.)

Adrounie, V. Harry
Comprehensive Practice
Reeds Road
Downingtown, R.D. 2, Pa. 19335

Allan, Ralph E., (M.S.)
Comprehensive Practice
660 Wedgewood Ave. Apt. 11
Upland, Calif. 91786

Alpaugh, Edwin L.
Comprehensive Practice
International Harvester Co.
401 N. Michigan Ave.
Chicago, Ill. 60611

Amdur, Marvin L., (M.D.)
Comprehensive Practice
Buffalo Industrial Medical Center
755 Tonawanda St.
Buffalo, N. Y. 14207

Amdur, Mary O., (Ph.D.)
Toxicological Aspects
Harvard School of Public Health
665 Huntington Ave.
Boston, Mass. 02115

Anderson, David M. (Ph.D.)
Comprehensive Practice
Bethlehem Steel Co.
Bethlehem, Pa. 18016

Anderson, Darrell E., (M.S.)
Comprehensive Practice
Minnesota Dept. of Health
University Campus
Minneapolis, Minn. 55440

Anderson, Floyd G.
Engineering Aspects
Branch of Health Research
U.S. Bureau of Mines
4800 Forbes Ave.
Pittsburgh, Pa. 15213

Anderson, Russell K.
Comprehensive Practice
P. O. Box 197
Rutherford, N.J. 07070
(R. K. Anderson Associates, Inc.)

Andresen, William V.
Comprehensive Practice
489 Pepperidge Tree Ter.
Smoke Rise
Butler, N.J. 07405
(American Cyanamid Co.)

Ashe, Harry B.
Comprehensive Practice
Vermont State Department of Health
P. O. Box 607
Barre, Vt. 05641

Atkins, Dowis C.
Comprehensive Practice
204 Crestmont Drive
Alvin, Texas 77511

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Averill, Edward R.
Comprehensive Practice
Mobil Oil Corp.
150 East 42nd St.
New York, N.Y. 10017

Ayer, Howard E. (S.M.)
Engineering Aspects
U.S. Public Health Service
Div. of Occupational Health
1014 Broadway
Cincinnati, Ohio 45202

Baetjer, Anna M., (D.Sc.)
Toxicological Aspects
The Johns Hopkins
School of Hygiene
615 North Wolfe St.
Baltimore, Md. 21205

Baier, Edward J. (M.P.H.)
Comprehensive Practice
17 Hickory Lane
Mechanicsburg, Pa. 17055
(Pennsylvania Department
of Health)

Baldry, George S., (M.D.)
Comprehensive Practice
1450 South Miami Ave.
Miami, Fla. 33130

Bales, Ronald E.
Comprehensive Practice
9722 Fernwood Road
Bethesda, Md. 20034
(U.S. Public Health Serv.)

Baliff, Jack
Comprehensive Practice
Div. of Industrial Hyg.
N.Y. State Dept. of Labor
80 Centre St.
New York, N.Y. 10013

Ballard, Stanley Conant
Engineering Aspects
Route 4, Box 86A
Easton, Md. 21601
(Retired)

Banks, Oneil Mays (Ph.D.)
Comprehensive Practice
American Petroleum Inst.
1271 Ave. of Americas
New York, N. Y. 10020

Barnes, Edgar C.
Comprehensive Practice
Westinghouse Electric Corp.
3 Gateway Center, Box 2278
Pittsburgh, Pa. 15230

Barnes, John R. (Ph.D.)
Toxicological Aspects
E. I. du Pont de Nemours &
Co.
Haskell Laboratory
Newark, Del. 19711

Barrett, Harry (M.S.)
Comprehensive Practice
IBM—Dept. 413
Monterey and Cottle Roads
San Jose, Calif. 95114

Barrett, James C.
Comprehensive Practice
Div. of Occupational Health
Michigan Dept. of Health
Old Dewitt Rd.
Lansing, Mich. 48914

Baumann, Willard H.
Comprehensive Practice
United States Steel Corp.
Gary Steel Works
Gary, Ind. 46402

Bavley, Harold
Engineering Aspects
Div. of Occupational Hyg.
Mass. Dept. of Labor & Ind.
39 Boylston St.
Boston, Mass. 02116

Beaman, Reuben., Jr.
Engineering Aspects
Ivorydale Technical Center
Proctor and Gamble Co.
Cincinnati, Ohio 45217

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MAR 23 1973

Beard, Rodney Rau, (M.D.)
Comprehensive Practice
Stanford Medical Center
Stanford, Calif. 94305

Beegan, James A.
Engineering Aspects
3912 Beech Avenue
Baltimore, Md. 21211
(Maryland St. Health Dept.)

Benjamin, Charles T.
Comprehensive Practice
R.D. 1, Chestnut Tree Rd.
Honey Brook, Pa. 19344
(U.S. Dept. of Labor)

Berg, Byron A.
Comprehensive Practice
Allis-Chalmers
Manufacturing Co.
Box 512
Milwaukee, Wis. 53201

Berghout, Christian F.
Engineering Aspects
405 Foster Knoll Dr.
Joppa, Md. 21085
(U.S. Army Environmental
Hygiene Agency)

Bergtholdt, Charles P.,
(M.P.H)
Comprehensive Practice
Chief Occupational Med.
Branch (DC3)
NASA Manned Spacecraft
Center
Houston, Tex. 77058

Berry, Clyde., (Ph.D.)
Comprehensive Practice
Inst. of Agricultural Med.
State University of Iowa
Iowa City, Iowa 52240

Bessmer, Daniel J., (M.A.)
Comprehensive Practice
Ind. Hyg. Div., Code 730
Puget Sound Naval Shipyd.
Bremerton, Wash. 98314

Bianconi, William O.
Engineering Aspects
7760 Bluebird Drive
Jenison, Mich. 49428

Birmingham, Donald J. (M.D.)
Comprehensive Practice
Wayne State University
School of Medicine
Dept. of Dermatology and
Syphilology
1400 Chrysler Freeway
Detroit, Mich. 48207

Blankenhorn, John M.
Comprehensive Practice
Chemical Aspects
Occupational Health
Research and Training
Facility
U. S. Public Health Service
1014 Broadway
Cincinnati, Ohio 45202

Blocker, Hyman
Comprehensive Practice
2451 Janet Lee Drive
La Crescenta, Calif. 91214
(Univ. of California,
Los Angeles)

Bloomfield, Bernard D. (M.S.)
Comprehensive Practice
Michigan Dept .of Health
Div. of Occupational Health
3500 North Logan St.
Lansing, Mich. 48914

Bloomfield, John J.
Comprehensive Practice
Casilla 2117
Lima, Peru
(Pan American Health
Organization)

Bohl, Carl D. (Sc.D.)
Comprehensive Practice
Monsanto Co., Medical Dept.
St. Louis, Missouri 63166

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MT-PWHD-004428

Bolton, Paul R.
Comprehensive Practice
4516 Lilliput Lane
Las Vegas, Nev. 89102
(Reynolds Electrical and Engineering Co., Inc.)

Bonney, Thomas B.
Chemical Aspects
Aluminum Company of America
1501 Alcoa Building
Pittsburgh, Pa. 15219

Boone, Francis W. (M.S.)
Comprehensive Practice
Pan-Am World Airways
Health & Safety Dept.
P.O. Box 2057
Jackass Flats, Nev. 89023

Borawski, Edward
Chemical Aspects
Medical Department
U.S. Naval Propellant Plant
Indian Head, Md. 20640

Borcherding, Charles H., Jr.
Comprehensive Practice
Abex Corp., Medical Dept.
4550 W. 26th St.
Chicago, Ill. 60623

Bossard, Floyd C.
Comprehensive Practice
2901 Edwards
Butte, Mont. 59701

Bovee, Clifton W. (M.P.H.)
Comprehensive Practice
World Health Organization
P.O. Box 242
Saigon, Vietnam

Bovee, H. H. (Ph.D.)
Comprehensive Practice
F461 Health Sciences Bldg.
University of Washington
Seattle, Wash. 98105

Boylen, George W., Jr.
Comprehensive Practice and Chemical Aspects
2 Ledgewood Rd.
Wilmington, Mass. 01887
(Massachusetts Institute of Technology)

Bradley ,William R., (M.S.)
Comprehensive Practice
William R. Bradley and Associates
72 County Road
Tenafly, N. J. 07670
(Consultant)

Brady, John P.
Comprehensive Practice
Edel Laboratories
18 Green St.
Newark, N. J. 07102

Brandt, Allen D., (Sc.D.)
Engineering Aspects
Bethlehem Steel Co.
Bethlehem, Pa. 18016

Brasch, Jerome K. (M.S.)
Engineering Aspects
1905Williamsburg Ct. S.
League City, Tex. 77573
(Brown and Root, Inc.)

Breysse, Peter A. (M.P.H.)
Comprehensive Practice
University of Washington
Env. Health Div.
Dept. of Prev. Med.
Seattle, Wash. 98105

RECEIVED
JUN 83

Brief, Richard S.
Comprehensive Practice
Esso Research and Engineering Co.
P. O. Box 45
Linden, N. J. 07036

Brieger, Heinrich, (M.D.)
Toxicological Aspects
2031 Locust St.
Philadelphia, Pa. 19103
(Jefferson Medical College)

Brodsky, Allen, (Sc.D.)
Radiological Aspects
2047 Brookfield Drive
Pittsburgh, Pa. 15243
(Dept. of Occupational Health, University of Pittsburgh)

Brower, John F., (M.S.)
Comprehensive Practice
Standard Oil Co. (Indiana)
910 S. Michigan Ave.
Chicago, Ill. 60680

Brown, Carlton E., (Sc.D.)
Chemical Aspects
629 Biggs Avenue
Frederick, Md. 21701
(Retired)

Brown, Harold V. (Dr.P.H.)
Comprehensive Practice
6008 Chariton Ave.
Los Angeles, Calif. 90056
(University of California, Los Angeles)

Buchwald, Herbert (Ph.D.)
Comprehensive Practice
10437 - 135th St.
Edmonton, Alberta, Canada
(Alberta Dept. of Health)

Bulmer, Frederick M. R. (M.B.)
Comprehensive Practice
100 Eastbourne Ave.
Toronto, Ontario, Canada
(Retired)

Bumford, Forrest H.
Comprehensive Practice
New Hampshire Dept. of Health and Welfare
Div. of Public Health
61 South Spring St.
Concord, N. H. 03301

Bumsted, Howard E., (M.Ch.E.)
Comprehensive Practice
303 McElheny Road
Glenshaw, Pa.
(United States Steel Corp.)

Burgess, William A., (M.S.)
Engineering Aspects
Harvard School of Public Health
665 Huntington Ave.
Boston, Mass. 02115

Burk, Chapman (M.S.)
Radiological Aspects
2716 Del Monte Ave.
El Cerrito, Calif. 94530
(Mare Island Naval Shipyard)

Butler, George J. (M.P.H.)
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Brown, Harold V.
Burk, Chapman (M.S.)
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Feldstein, Milton (M.A.)
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Flinn, Robert H. (M.D.)
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James, Henry R.
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DeSimone, Charles J. (M.S.)
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Morgan, James F.
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O'Shea, Betty S.
Peterson, Charles A.
Retzer, William R.
Satterfield, Robert W. (S.M.)
Schulz, Howard N.
Siedlecki, Jerome T. (M.S.)
Spiegl, Charles J., (Ph.D.)
Walworth, Herbert T., (M.S.)
Weber, Herbert J., (M.S.)
Wyman, Charles W.

INDIANA
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Edwards, Albert
Keppler, J. Fred

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Fanney, Julius H., Jr., (M.P.H.)
Luckens, Mark M. (Ph.D.)
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Chew, F. Freeland, Jr.
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Devitt, Gerald E. (M.S.)
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Lynch, Jeremaih R. (M.S.)

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MacEwen, James D. (Ph.D.)
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Mountain, John T., (M.S.)
Pring, Robert T.
Robson, Charles D.
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Saltzman, Bernard E., (Ph.D.)
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Scheel, Lester D. (Ph.D.)
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Stokinger, Herbert E., (Ph.D.)
Svirbely, Joseph L. (Ph.D.)
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Zavon, Mitchell R., (M.D.)

OKLAHOMA
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Douglas, Darrel D.
Schoenborn, Arthur F.
Sears, Thomas E.

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Anderson, David M. (Ph.D.)
Anderson, Floyd G.
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Bonney, Thomas B.
Brandt, Allen D., (Sc.D.)
Brieger, Heinrich, (M.D.)
Brodsky, Allen, (Sc.D.)
Bumsted, Howard E., (M.Ch.E.)
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Lieberman, Jesse (M.S.)
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Mancuso, Thomas F. (M.D.
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Mawhinney, Warren C.
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Pearce, Selden J.
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Sansone, Eric B. (Ph.D.)
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RHODE ISLAND
Di Lustro, Salvatore
Mandell, Leonard C., (M.S.)
Wuraftic, Joseph, M.S.)

SOUTH CAROLINA
Gabis, Max S.
Patterson, C. Maurice
Reinig, William C.

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Wisehart, Donovan E.

TENNESSEE
Davis, Doyle M.
Goddard, Frank L., Jr.
Hart, James C.
Jung, Francis P., (M.S.)
McAlduff, Harold J.
Oglesby, Frank L.
Roberts, Donald P., (M.P.H.)

TEXAS
Atkins, Dowis C., (B.S.)
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Mason, Morton, F., (Ph.D.)
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Rudmose, H. Wayne (Ph.D.)
Sterner, James H., (M.D.)
Tyler, D. A., (M.Ed.)
Wukasch, Martin C., (M.S.)

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Bales, Ronald E., (M.S.)
Hendricks, Russel H., (Ph.D.)
Holladay, Duncan A., (M.A.)
Jensen, Carl R. (M.S.)
Nelson, Kenneth W., (M.S.)
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VERMONT
Ashe, Harry B.
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VIRGINIA
Daubenspeck, G. Walker, (M.S.)
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Herrick, Robert A.
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WEST VIRGINIA
Ketcham, Newton H., (M.S.)
Linsky, Benjamin (M.S.E.)
McQuary, William A.,(M.S.E.)

WISCONSIN
Berg, Byron A.
Lange, Paul (M.P.H.)
Meiter, Edward G., (Ph.D.)
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APO SAN FRANCISCO
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Silva, Donald G., (M.S.)
Smead, Phillip E. Maj. (M.S.) (M.P.H.)

BOLIVIA
Gumiel, Alberto B. (M.D.)

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Buchwald, Herbert, (Ph.D.)
Bulmer, Frederick M. R., (M.B.)
Johnston, John H. (M.A.)
Laham, Souheil, (Ph.D.)
Leppard, Leon B., (Ph.D.)
MacFarland, Harold N., (Ph.D.)
Monkman, J. Lloyd
Moore, David E.
Nelson, Hugh M.
Plamondon, Sarto R. (M.S.)
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Ross, Charles R. (M.S.)
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Marr, William T. (M.S.P.H.)

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Dizon, Gregorio D., (M.D.)

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Gerhardsson, Gideon (M.S.)

VIETNAM
Bovee, Clifton W., Col., (M.P.H.)

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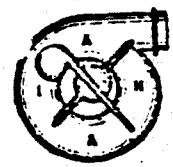
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AMERICAN INDUSTRIAL HYGIENE ASSOCIATION

SOUTHERN CALIFORNIA SECTION



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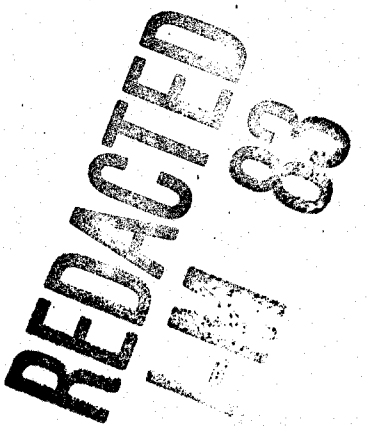
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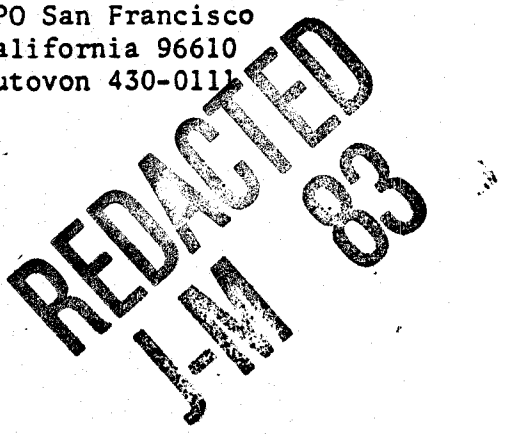
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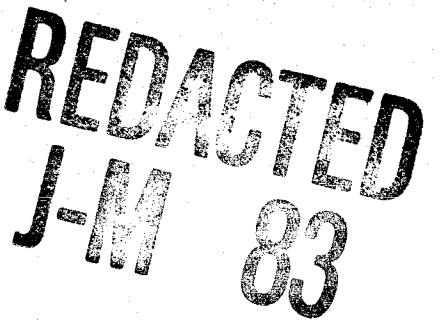
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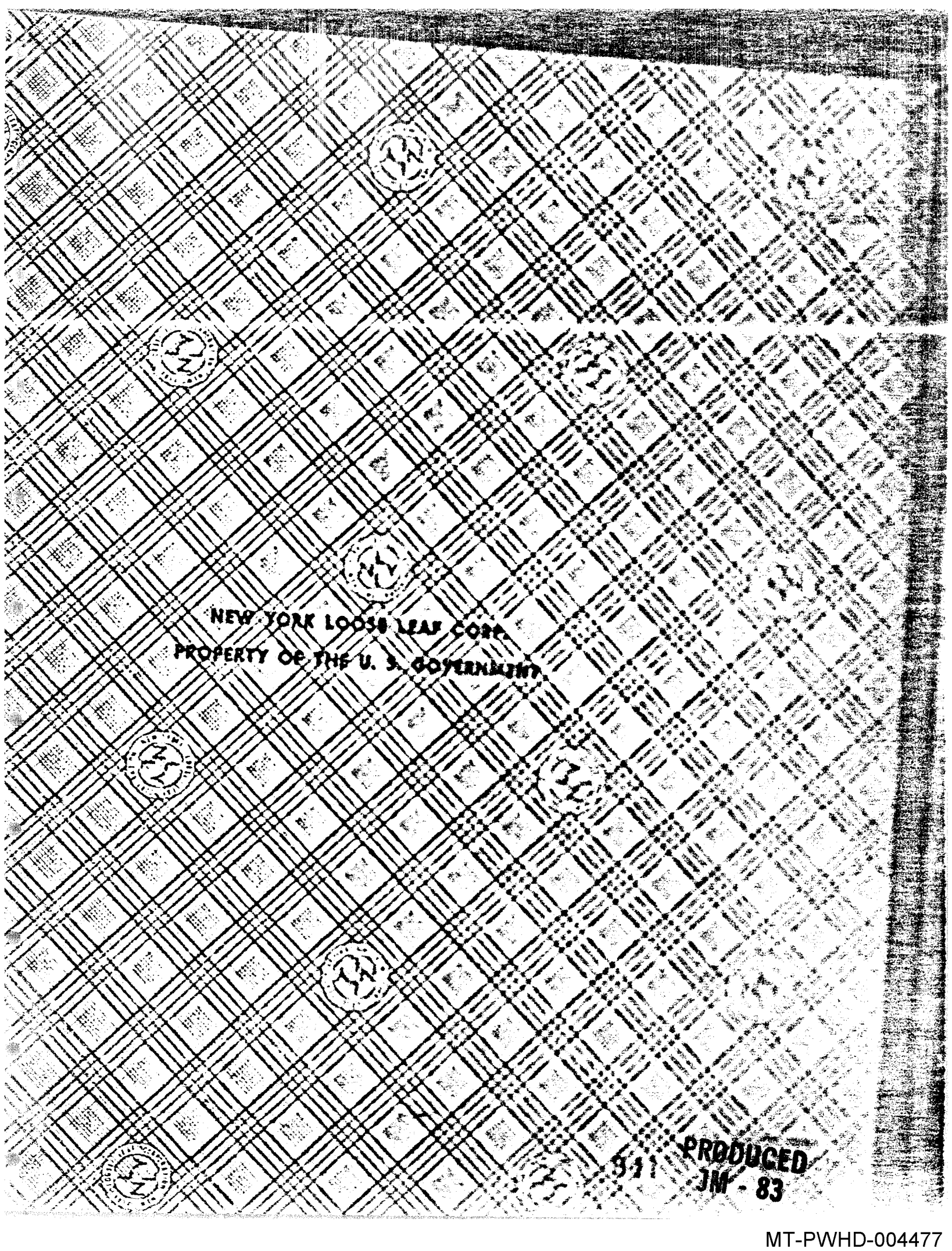
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FOREWORD

In this revision for the Twelfth Edition, the Committee on Industrial Ventilation, American Conference of Governmental Industrial Hygienists, has attempted to keep abreast of new developments and standards for industrial ventilation systems. A critical review has been made of the previous edition, modifying and rewriting certain portions for improved clarity and accuracy.

The committee continues its policy of presenting the material in a practical, concise, easy-to-understand manner. Theoretical discussions and complex equations are not given. The manual is sufficiently complete so that an industrial ventilation system can be designed without reference to other texts.

New material and revisions include:

SECTION 3 - Ventilation for Heat Control

The information relating to radiant heat as a factor in calculating effective temperature has been revised to clarify the procedure.

SECTION 4 - Hood Design Data

Additional information is given explaining the proper selection of exhaust Capture Velocity. Slot hood design factors and limitations are discussed.

SECTION 5 - Specific Operations

Specific design data with new drawings is presented for Low Volume-High Velocity exhaust systems. The open surface tank design data has been up-dated to correspond to the new Federal Occupational Safety and Health Act. Nineteen other drawings of exhaust hood designs have been revised.

SECTION 6 - Duct Design Procedure

The method for evaluating duct velocity changes and the corresponding static pressure corrections has been rewritten for better comprehension. A detailed explanation of Fan Static Pressure and Fan Total Pressure is presented. Air density correction data has been extended. Design data for duct expansions and evase discharges has been revised.

SECTION 7 - Oil and gas fuels data and calculations have been extended to include flue gas composition by weight and density.

SECTION 10 - Fans

New material illustrates fan performance in series and parallel operation. Revised discussion of fan selection for non-standard air.

APPENDIX - Current Threshold Limit Values for Airborne Contaminants are presented.

Currently available separately are:

1. The new Ventilation System Testing Guide describes the standard test method for testing an industrial ventilation system and includes the necessary charts, tables, data sheets and formulae.
2. The Metric Supplement comprises a set of tables, graphs and charts in metric units which can be used to replace the English charts in the Standard ventilation manual to enhance its use worldwide.
3. Computer decks and programs for designing industrial exhaust systems are available.

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ACKNOWLEDGMENTS

Industrial Ventilation is a true Committee effort, bringing into focus in one source useful, practical ventilation data from all parts of the country. The Committee membership of industrial ventilation and industrial hygiene engineers represents a diversity of experience and interest that insures a well-rounded cooperative effort.

From the 1st Edition in 1951 this effort has been successful, as witnessed by the acceptance of the "Ventilation Manual" throughout industry, by governmental agencies and as a world-wide reference and text.

The present Committee is grateful for the faith and firm foundation provided by past Committees and members enumerated elsewhere in these pages.

Special acknowledgment is made to the Division of Occupational Health, Michigan Department of Health for contributing their original field manual which was the basis for the 1st Edition, and to Mr. Knowlton Caplan who supervised the preparation of that manual.

The Committee is grateful also to those consultants who have contributed so greatly to the preparation of this and previous editions of Industrial Ventilation and to Mrs. Norma Donovan, Secretary to the Committee for her untiring zeal in our efforts.

To many other individuals and agencies who have made specific contributions and have provided support, suggestions and constructive criticism, our special thanks.

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INTRODUCTION

The importance of clean uncontaminated air in the industrial work environment is well known. Modern industry with its complexity of operations and processes uses an increasing number of chemical compounds and substances, many of which may be highly toxic. The use of such materials may result in a dissemination of fumes, gases, vapors and mists into the workroom air. Effective, well designed ventilation offers a solution where protection to workers is needed under such environmental exposure.

In recent times the application of local exhaust ventilation has been accepted as the preferred method for an effective means of control. The smaller exhaust air volume results in lower heating costs, compared to high volume general exhaust air requirements. The present emphasis on air pollution control stresses the need of air cleaning devices on industrial ventilating systems. From the capital cost standpoint, the smaller air volumes of the local exhaust system are of great advantage on the price of air cleaning devides.

The unsatisfactory past practices of providing exhaust ventilation without giving thought as to how the outdoor replacement air is to be provided has resulted in worker discomfort, exposures to combustion gases from backdrafting flues and impaired ventilation. A present day awareness of this considers the need of providing suitable make-up air systems as well as efficiently designed local exhaust ventilation. The consideration of both these factors will result in personnel comfort as well as a safe, controlled atmosphere.

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DEFINITIONS

Aerosol: An assemblage of small particles, solid or liquid, suspended in air. The diameter of the particles may vary from 100 microns down to 0.01 micron or less, e.g., dust, fog, smoke.

Air Cleaner: A device designed for the purpose of removing atmospheric air-borne impurities such as dusts, gases, vapors, fumes and smokes. (Air cleaners include air washers, air filters, electrostatic precipitators and charcoal filters.)

Air Filter: An air cleaning device to remove light particulate loadings from normal atmospheric air before introduction into the building. Usual range: Loadings up to 3 grains per thousand cubic feet (0.003 grains per cubic foot). Note: Atmospheric air in heavy industrial areas and in-plant air in many industries have higher loadings than this and dust collectors are then indicated for proper air cleaning.

Air Horsepower: The theoretical horsepower required to drive a fan if there were no losses in the fan, that is, if its efficiency were 100%.

Air, Standard: Dry air at 70 F and 29.92 in (Hg) barometer. This is substantially equivalent to 0.075 lb/cu ft.

Aspect Ratio: The ratio of the width to the length. $AR = \frac{W}{L}$

Aspect Ratio of an Elbow: The width (W) along the axis of the bend divided by depth (D) in plane of bend. $AR = \frac{W}{D}$

Blast Gate: Sliding damper.

Blow (throw): In air distribution, the distance an air stream travels from an outlet to a position at which air motion along the axis reduces to a velocity of 50 fpm. For unit heaters, the distance an air stream travels from a heater without a perceptible rise due to temperature difference and loss of velocity.

Brake Horsepower: The horsepower actually required to drive a fan. This includes the energy losses in the fan and can be determined only by actual test of the fan. (This does not include the drive losses between motor and fam.)

Capture Velocity: The air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.

Coefficient of Entry: The actual rate of flow caused by a given hood static pressure compared to the theoretical flow which would result if the static pressure could be converted to velocity pressure with 100% efficiency. It is the ratio of actual to theoretical flow.

Comfort Zone (Average): The range of effective temperatures over which the majority (50 per cent or more) of adults feel comfortable.

Convection: The motion resulting in a fluid from the differences in density and the action of gravity. In heat transmission this meaning has been extended to include both forced and natural motion or circulation.

Density: The ratio of the mass of a specimen of a substance to the volume of the specimen. The mass of a unit volume of a substance. When weight can be used without confusion, as synonymous with mass, density is the weight of a unit volume of a substance.

Density Factor: The ratio of actual air density to density of standard air. The product of the density factor and the density of standard air (0.075 lb/cu ft) will give the actual air density in lbs per cu ft.
d x 0.075 = actual density of air, lbs per cu ft.

Dust: Small solid particles created by the breaking up of larger particles by processes such as crushing, grinding, drilling, explosions, etc. Dust particles already in existence in a mixture of materials may escape into the air through such operations as shoveling, conveying, screening, sweeping, etc.

Dust Collector: An air cleaning device to remove heavy particulate loadings from exhaust systems before discharge to outdoors. Usual range: Loadings 0.003 grains per cubic foot and higher.

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Entry Loss: Loss in pressure caused by air flowing into a duct or hood. (Inches H_2O).

Fumes: Small solid particles formed by the condensation of vapors of solid materials.

Gases: Formless fluids which tend to occupy an entire space uniformly at ordinary temperatures and pressures.

Gravity, Specific: The ratio of the mass of a unit volume of a substance to the mass of the same volume of a standard substance at a standard temperature. Water at 39.2 F is the standard substance usually referred to. For gases, dry air, at the same temperature and pressure as the gas, is often taken as the standand substance.

Hood: A shaped inlet designed to capture contaminated air and conduct it into the exhaust duct system.

Humidity, Absolute: The weight of water vapor per unit volume, pounds per cubic foot or grams per cubic centimeter.

Humidity, Relative: The ratio of the actual partial pressure of the water vapor in a space to the saturation pressure of pure water at the same temperature.

Inch of Water: A unit of pressure equal to the pressure exerted by a column of liquid water one inch high at a standard temperature.

Lower Explosive Limit: The lower limit of flammibility or explosibility of a gas or vapor at ordinary ambient temperatures expressed in per cent of the gas or vapor in air by volume. This limit is assumed constant for temperatures up to 250 F. Above these temperatures, it should be decreased by a factor of 0.7 since explosibility increases with higher temperatures.

Manometer: An instrument for measuring pressure; essentially a U-tube partially filled with a liquid, usually water, mercury or a light oil, so constructed that the amount of displacement of the liquid indicates the pressure being exerted on the instrument.

Micron: A unit of length, the thousandth part of 1 mm or the millionth of a meter, (approximately 1/25,000 of an inch).

Mists: Small droplets of materials that are ordinarily liquid at normal temperature and pressure.

Plenum: Pressure equalizing chamber.

Pressure, Atmospheric: The pressure due to the weight of the atmosphere. It is the pressure indicated by a barometer. Standard Atmospheric Pressure or Standard Atmosphere is the pressure of 29.92 inches of mercury.

Pressure, Static: The potential pressure exerted in all directions by a fluid at rest. For a fluid in motion it is measured in a direction normal to the direction of flow. Usually expressed in inches water gauge when dealing with air. (The tendency to either burst or collapse the pipe.)

Pressure, Total: The algebraic sum of the velocity pressure and the static pressure (with due regard to sign).

Pressure, Vapor: The pressure exerted by a vapor. If a vapor is kept in confinement over its liquid so that the vapor can accumulate above the liquid, the temperature being held constant, the vapor pressure approaches a fixed limit called the maximum or saturated, vapor pressure, dependent only on the temperature and the liquid. The term vapor pressure is sometimes used as synonymous with saturated vapor pressure.

Pressure, Velocity: The kinetic pressure in the direction of flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches water gauge.

Radiation, Thermal (Heat) Radiation: The transmission of energy by means of electromagnetic waves of very long wave length. Radiant energy of any wave length may, when absorbed, become thermal energy and result in an increase in the temperature of the absorbing body.

Slot Velocity: Linear flow rate of contaminated air through slot, fpm.

Smoke: An air suspension (aerosol) of particles, usually but not necessarily solid, often originating in a solid nucleus, formed from combustion or sublimation.

Temperature, Effective: An arbitrary index which combines into a single value the effect of temperature, humidity and air movement on the sensation of warmth or cold felt by the human body. The numerical value is that of the temperature of still, saturated air which would induce an identical sensation.

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Temperature, Wet-Bulb: Thermodynamic wet-bulb temperature is the temperature at which liquid or solid water. by evaporating into air, can bring the air to saturation adiabatically at the same temperature. Wet-bulb temperature (without qualification) is the temperature indicated by a wet-bulb psychrometer constructed and used according to specifications.

Threshold Limit Values (TLV): The values for air borne toxic materials which are to be used as guides in the control of health hazards and represent time weighted concentrations to which nearly all workers may be exposed 8 hours per day over extended periods of time without adverse effects. (See Appendix)

Transport (Conveying) Velocity: Minimum air velocity required to move the particulates in the air stream, fpm.

Vapor: The gaseous form of substances which are normally in the solid or liquid state and which can be changed to these states either by increasing the pressure or decreasing the temperature. Vapors diffuse.

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ABBREVIATIONS

A	Area
AHP	Air horsepower
acfm	actual cfm
AR	Aspect ratio
B	barometric pressure
bhp	Brake horsepower
btu	British thermal unit
btuh	btu/hr
C_e	Coefficient of entry
cfm	Cubic feet per minute
cu ft	Cubic foot
d	Density factor
D	Diameter
ET	Effective temperature
F	Degree, Fahrenheit
fpm	Feet per minute
fps	Feet per second
g	Gravitational force, ft/sec/sec
gpm	Gallons per minute
gr	Grains
h_e	Hood entry loss
hp	Horsepower
hr	Hour
in	Inch
LEL	Lower explosive limit
ME	Mechanical efficiency
mg	milligram
MRT	Mean radiant temperature
mm	Millimeter
min	Minute
MW	Molecular Weight
ppm	Parts per million
lb	Pound
psi	Pounds per square inch
Q	Quantity of air, cfm
RH	Relative humidity
ρ	Density of air in lb/cu ft
rpm	Revolutions per minute
SFM	Surface feet per minute
sq ft	Square foot
sq in	Square inch
SP	Static pressure
SP_h	Hood static pressure
scfm	Cfm at standard air conditions
sp. gr	Specific gravity
STP	Standard temperature and pressure
TLV	Threshold Limit Values
TP	Total pressure
V	Velocity, fpm
VP	Velocity pressure
wg	Water gauge

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Section 1

GENERAL PRINCIPLES OF VENTILATION

Principles of Air Flow

The flow of air between two points is due to the occurrence of a pressure difference between the two points. This pressure difference results in a force on the air, causing air flow from the high pressure zone to the low pressure zone. The quantity of air flow (Q) and the velocity of flow (V) are related according to the equation

$$Q = AV$$

where: Q = volume, cubic feet per minute
A = cross sectional area through which the air flows in square feet
V = velocity in lineal feet per minute

This basic relationship describes the flow of air under all conditions.

Air traveling at a specific velocity will create a definite pressure which is known as the Velocity Pressure. There is a definite relationship between the velocity of air and the Velocity Pressure. The basic statement of this relationship is

$$v = \sqrt{2gh}$$

where: v = velocity, feet per second
g = gravitational acceleration, feet per second per second
h = head of air, feet

When g = 32.2 ft/sec^2 and air density is 0.075 pounds per cubic foot, this formula converts to

$$V = 4005\sqrt{VP}$$

where: V = air velocity, feet per minute
VP = velocity pressure, inches of water

It should be emphasized that Velocity Pressure is always exerted in the direction of air flow.

Air confined within an enclosure, whether in motion or not, creates another type of pressure which exerts itself perpendicularly to the walls of the enclosure. This pressure is known as Static Pressure and it is normally independent of the velocity of the air.

When Static Pressure is below atmospheric pressure it is negative. When it is above atmospheric pressure it is positive. Velocity Pressure is always positive.

The algebraic sum of Static Pressure and Velocity Pressure is Total Pressure. This may also be written in the form of an equation—the symbols are those used throughout this book:

$$TP = SP + VP$$

The significance of these pressures can be demonstrated under actual conditions. For example, assume a rectangular chamber (sealed) containing air pressure of 0.05 pounds per square inch. This 0.05 psi pressure is entirely due to static pressure. If a small hole is drilled into this chamber and a U-tube is used, a reading of 1.39 inches of water will result. (1 psi = 27.7 inches of water.) Since there is no air flow, the velocity pressure will be zero and the total pressure will be 1.39 inches of water. This is shown in Figure 1-1.

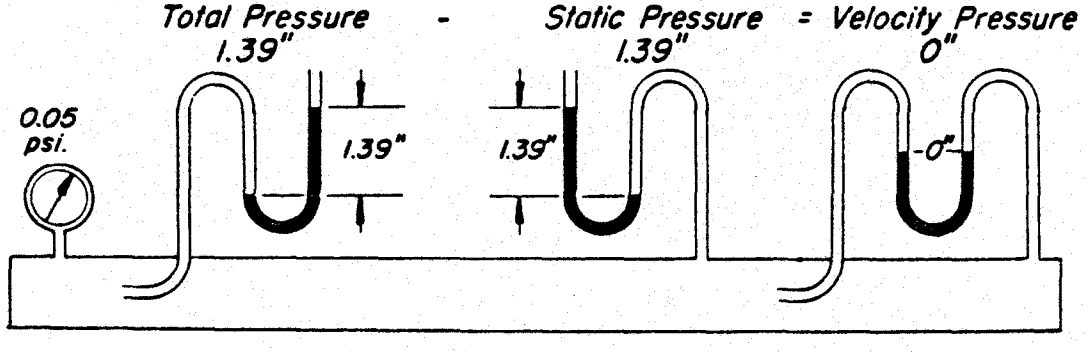


Fig. 1-1

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If the ends of this chamber are opened, it becomes a duct through which air may flow. With air flowing through this duct there are now two distinct pressures, namely, static pressure and velocity pressure. The algebraic sum of these two pressures is called total pressure. If a fan is placed so that air is blown through the duct, the pressures shown in Figure 1-2 could result.

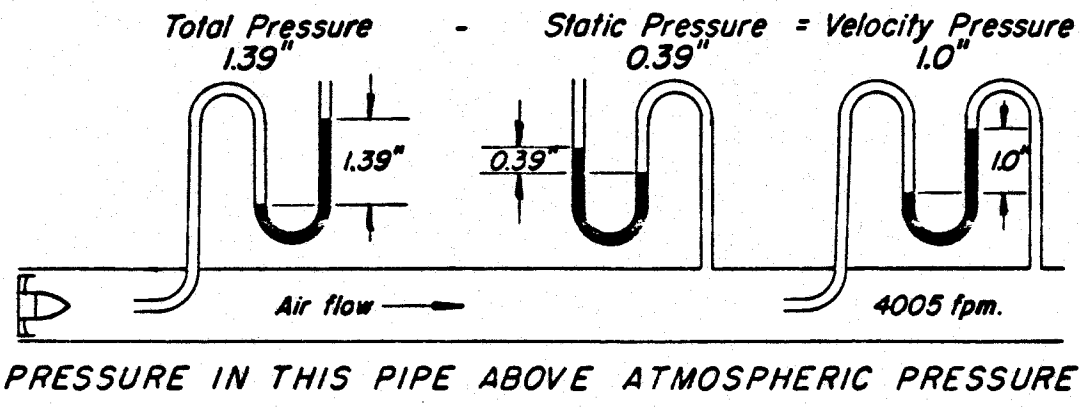


Fig. 1-2

If a fan is placed so that air is drawn through the duct, the pressures indicated in Figure 1-3 could result.

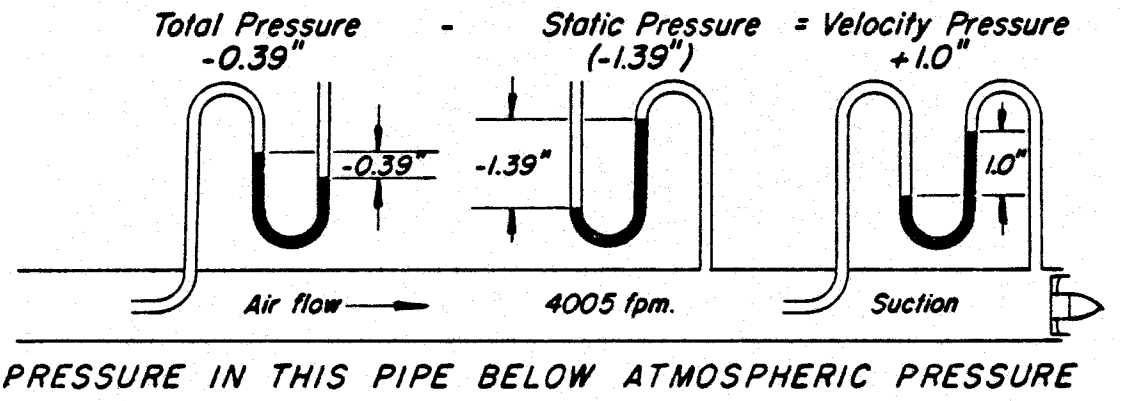


Fig. 1-3

In Figure 1-4 typical static and velocity pressures are shown in a long section of exhaust duct equipped with a defined hood.

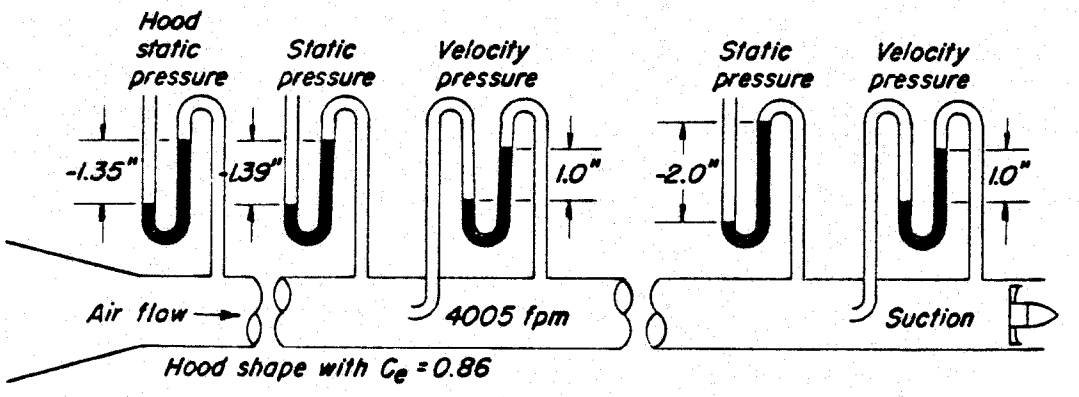


Fig. 1-4

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Acceleration of Air and Hood Entrance Losses

The pressure difference required to move air into an opening must be sufficient to both accelerate the air from rest to a velocity and to overcome the turbulence losses at the opening.

For acceleration, the energy required is equal to the Velocity Pressure corresponding to the velocity.

Turbulence losses are caused by the opening and vary with the shape of opening. The coefficient of entry (C_e) indicates the extent of turbulence losses. In a theoretically perfect hood with no turbulence loss, $C_e = 1.0$.

Hood Static Pressure (SP_h) is a direct measurement, in inches of water, of both the acceleration energy and turbulence losses. For a perfect hood with no turbulence loss, $C_e = 1.0$ and $SP_h = VP$ (See Section 4). In this case:

$$V = 4005\ C_e \sqrt{SP_h} = 4005 \sqrt{SP_h}$$

For the hood shown in Figure 1-4 where $C_e = 0.86$ this becomes:

$$V = 4005\ C_e \sqrt{SP_h} = 4005 \times 0.86 \sqrt{SP_h} = 3444 \sqrt{SP_h}$$

To obtain the desired velocity, 4005 fpm, the required SP_h can be calculated from the above formula:

$$\sqrt{SP_h} = \frac{V}{3444} = \frac{4005}{3444}$$

$$SP_h = \left(\frac{4005}{3444}\right)^2 = 1.35 \text{ inches of water}$$

As previously stated, the hood static pressure indicates both the acceleration (VP) and turbulence losses (h_e). This may be expressed as

$$SP_h = VP + h_e$$

For design purposes the entry loss (h_e) is often designated as a decimal fraction (F_h) of the velocity pressure (VP). In this form it applies to all velocities.

$$h_e = F_h VP$$

(See Section 4, Figure 4-5; Section 5; Section 6, Figure 6-10.)

Pressure Drop Through Ductwork

Air flowing through ducts encounters resistance to flow due to (1) friction losses and (2) dynamic (turbulence) losses. Friction losses are caused by the actual rubbing of the air against the surfaces of the duct. Dynamic losses result due to air turbulence which takes place whenever air flow through a duct changes direction or velocity; i.e., whenever the duct changes direction or varies in cross-sectional area. The result of the friction and dynamic losses is to cause a pressure drop to occur as the air flows through a duct.

The well known Bernoulli's Theorem frequently used in flow of fluids is merely a statement of the laws of conservation of energy. Bernoulli's Theorem as applied to air is: static pressure plus velocity pressure at a point upstream in direction of air flow is equal to the static pressure plus velocity pressure at a point downstream in direction of air flow plus the friction and dynamic losses:

$$SP_1 + VP_1 = SP_2 + VP_2 + \text{losses}$$

For practical purposes, the total amount of friction through any round duct varies directly as the length, inversely as the diameter of the duct and directly as the square of the velocity of air flowing through the duct. The pressure drop through a duct system due to dynamic losses depends upon (1) number and type of elbows present and (2) the frequency with which the velocity of air changes as it flows through the duct system.

In order to overcome the resistances of a duct system, it is necessary to expend energy in maintaining a pressure differential between the two ends of the system. This is usually accomplished by the use of a fan. The fan delivers air at a static pressure great enough to overcome the resistance of the system. Figure 1-5 gives a graphical description of actual pressure changes in a simple exhaust system.

Effective Specific Gravity

Frequently, the location of exhaust hoods is mistakenly based on a supposition that the contaminant is "heavier than air" or "lighter than air." In most health hazard applications, this criterion is of little value. Hazardous dust, fumes, vapors and gases are truly air-borne, following air currents and are not subject to appreciable motion either upward or downward because of their own density. For example, consider the

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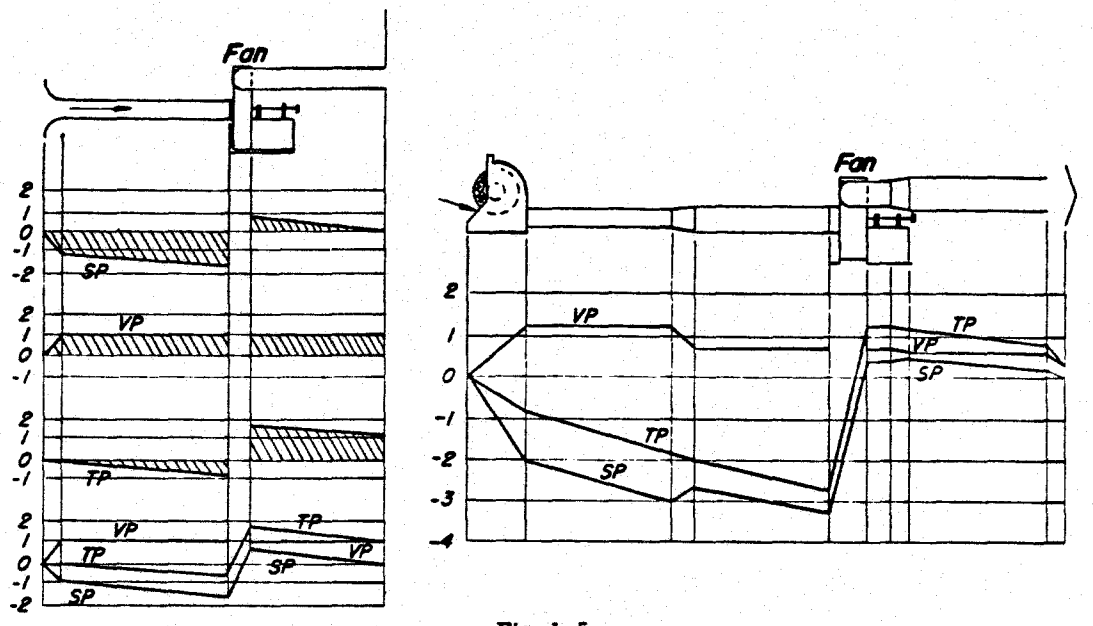


Fig. 1-5

degreasing solvent, perchloroethylene (tetrachloroethylene). Assuming the perchloroethylene vapor is well mixed with air, the following calculations indicate the effective specific gravity of a 10,000 ppm perchloroethylene-air mixture.

Specific gravity of air = 1
Specific gravity of C_2Cl_4 = 5.7
10,000 ppm = 1 part C_2Cl_4 : 99 parts of air
0.01 x 5.7 = 0.057
0.99 x 1.0 = 0.990
1.047 = effective specific gravity of mixture

Since 10,000 ppm is 100 times the TLV value of perchloroethylene, the mixture normally encountered would contain much less than 10,000 ppm. By a similar calculation a 100 ppm perchloroethylene-air mixture has an effective specific gravity of 1.0005.

Therefore, the perchloroethylene-air mixtures compared to clean air would have a tendency to move downward expressed by the ratio of 105/100 in the case of the 10,000 ppm mixture or 10005/10000 in the case of the 100 ppm mixture and not by the ratio of 5.7/1 as is frequently implied. Thus the effects of window ventilation, cross currents, traffic and heat can dwarf into insignificance the effect of specific gravity. A vapor of high specific gravity has been chosen for illustration; obviously the influence of specific gravity will be even less in the case of those gases and vapors whose specific gravity is closer to the specific gravity of air.

Air Flow Characteristics of Blowing and Exhausing

Air blown from a small opening retains its directional effect for a considerable distance beyond the plane of the opening. However, if the flow of air through the same opening were reversed so that it operated as an exhaust opening handling the same volume of air, the flow would become almost completely non-directional and its range of influence would be greatly reduced. For this reason, local exhaust hoods must not be contemplated for any process which cannot be conducted in the immediate vicinity of the hood. Figure 1-6 illustrates the fundamental difference between blowing and exhausting.

Make-Up Air

Many exhaust systems will require a mechanical system of supplied air to offset the air exhausted. For a more complete discussion of design, refer to Section 7, "Make-Up and Recirculated Air."

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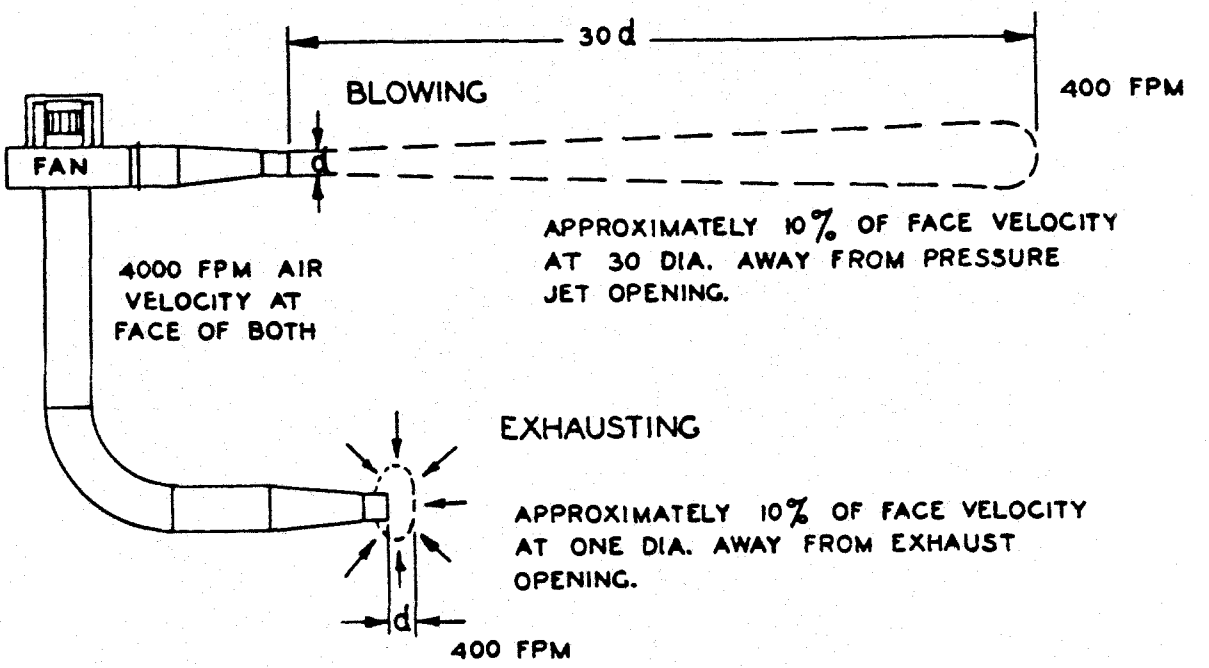


Fig. 1-6

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Section 2

DILUTION VENTILATION

The terms general ventilation and dilution ventilation are often used interchangeably. In this manual general ventilation refers to the removal (or supply) of air from a general area, room or building for the purpose of comfort control, and is covered under "Ventilation for Heat Control," Section 3. Dilution ventilation, as the name implies, refers to dilution of contaminated air with uncontaminated air in a general area, room or building for the purpose of health hazard or nuisance control.

Dilution Ventilation for Health

In general, dilution ventilation is not as satisfactory for health hazard control as is local exhaust ventilation. There are, however, occasional circumstances in which dilution ventilation must be used because the operation or process prohibits local exhaust. Circumstances may be found in which dilution ventilation provides an adequate amount of control more economically than a local exhaust system. One should be careful, however, not to base the economical considerations entirely upon the first cost of the system since dilution ventilation frequently exhausts large volumes of heat from a building and can easily be a troublesome factor.

The use of dilution ventilation has four limiting factors: (1) the quantity of contaminant generated must not be too great or air volume necessary for dilution will be impractical; (2) workers must be far enough away from contaminant evolution, or evolution of contaminant must be in sufficiently low concentrations so that workers will not have an exposure in excess of the established TLV value; and (3) the toxicity of the contaminant must be low; (4) the evolution of contaminants must be reasonably uniform.

Dilution ventilation is very seldom successfully applied to fumes and dusts because (1) the high toxicities often encountered require too great quantities of dilution air; (2) velocity and rate of evolution are usually very high; and (3) data on the amount of fumes and dust production are very difficult if not impossible to obtain.

Dilution ventilation is most often used to advantage to control the vapors from organic liquids such as the less toxic solvents. In order to successfully apply the principles of dilution to such a problem, factual data are needed on the rate of vapor generation or on the rate of liquid evaporation. Usually such data can be obtained from the plant if they keep any type of adequate records on material consumption.

Example

Suppose a cementing operation contaminates the air of a workroom with methyl ethyl ketone vapors, the solvent portion of the cement.

It is necessary to determine how much solvent vapor is being formed every minute and this can be done by determining the amount of cement consumed and the proportion of methyl ethyl ketone contained therein. Assume that four gallons of solvent are used in eight hours or four pints per hour.

The next step is to select a K value. K serves as a multi-purpose safety factor to maintain air concentrations well below the TLV. In selecting K one consideration is the toxicity of the material:

Slightly toxic material:	TLV $\geq$ 500 ppm
Moderately toxic:	TLV 100 - 500 ppm
Highly toxic:	TLV $\leq$ 100 ppm

Another consideration is the evolution rate of the contaminant; usually this is non-uniform. A third aspect is the effectiveness of the ventilation. See Figure 2-1.

The K value selected can vary from 3 to 10 depending on these considerations. Since several employees are scattered throughout the workroom and since the only possible location of fans in an outside wall is a considerable distance from some of the points of evolution of solvent, assume a K value of 6.

$$\text{Cu. ft. dilution per hour} = \frac{403 \times \text{specific gravity of solvent} \times 1{,}000{,}000 \times \text{pints solvent/hr.} \times K}{\text{molecular weight solvent} \times \text{TLV}}$$

$$= \frac{403 \times 0.805 \times 1{,}000{,}000 \times 4 \times 6}{72.06 \times 200} = 540{,}000 \text{ or } 9{,}000 \text{ cfm dilution air.}$$

Table 2-1 lists the dilution air volumes for several of the solvents often encountered. Formulas are also given for calculating dilution air volumes for liquids not specifically listed.

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Table 2-1. DILUTION AIR VOLUMES FOR VAPORS

The following values are tabulated using the TLV values shown in parentheses, parts per million. TLV values are subject to revision if further research or experience indicates the need. If the TLV value has changed, the dilution air requirements should be calculated from the following formulae.

$$\text{Cu ft air per pint evaporated} = \frac{403 \times \text{sp. gr. liquid} \times 1{,}000{,}000 \times K}{\text{molecular weight liquid} \times \text{TLV}}$$

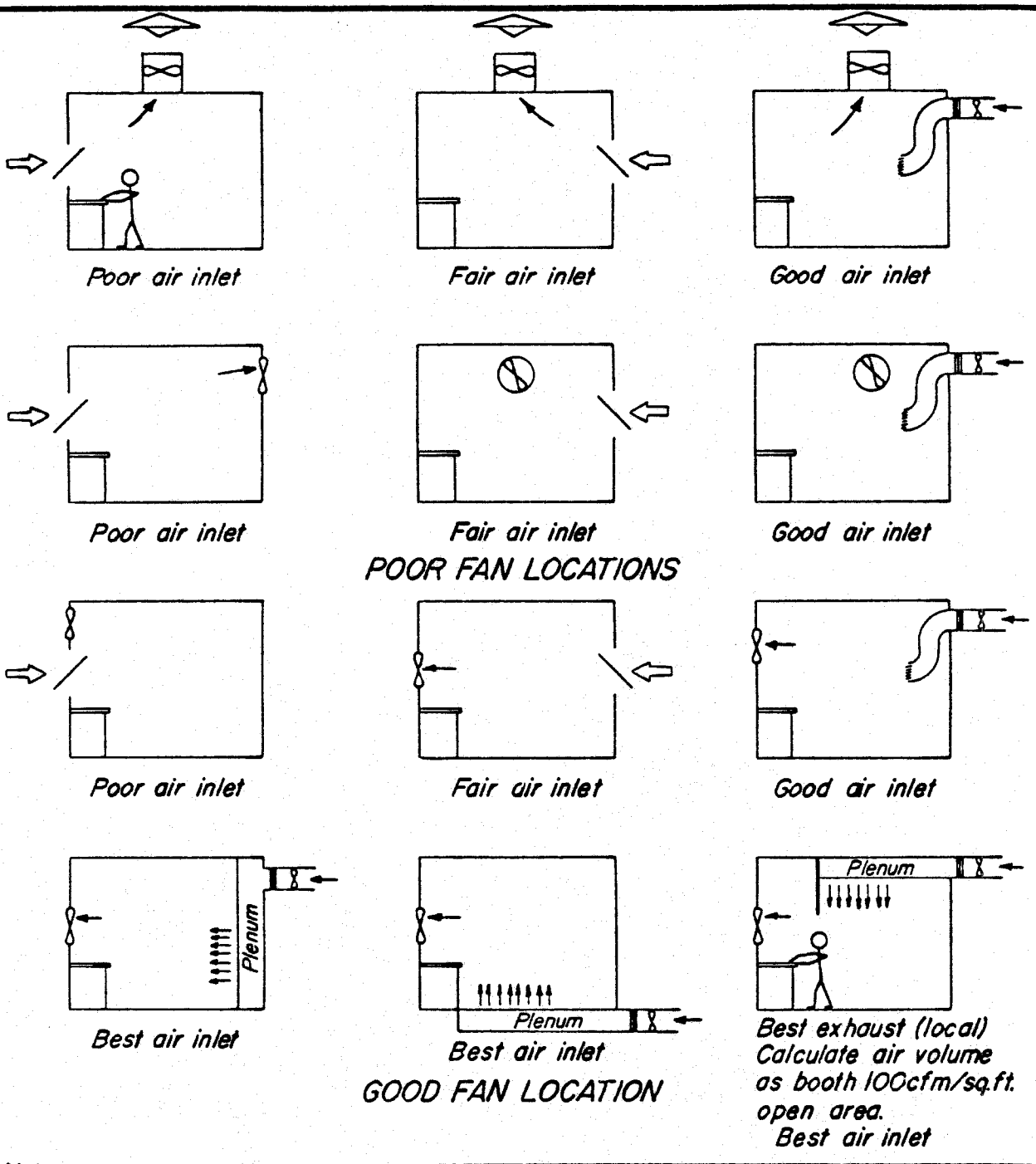
$$\text{Cu ft air per lb evaporated} = \frac{387 \times 1{,}000{,}000 \times K}{\text{molecular weight liquid} \times \text{TLV}}$$

Liquid	Cu ft of air (STP) required for dilution to TLV*	
	Per Pint Evaporation	Per Pound Evaporation
Acetone (1000)	5,500	6,650
n-Amyl acetate (100)	27,200	29,800
Isoamyl alcohol (100)	37,200	43,900
Benzol (25)	Not Recommended	
n-Butanol (butyl alcohol) (100)	44,000	52,200
n-Butyl acetate (150)	20,400	22,200
Butyl cellosolve (50)	61,600	65,600
Carbon disulfide (20)	Not Recommended	
Carbon tetrachloride (10)	Not Recommended	
Cellosolve (2-Ethoxyethanol) (200)**	20,800	21,500
Cellosolve acetate (2-ethoxyethyl-acetate)(100)	29,700	29,300
Chloroform (50)**	Not Recommended	
1-2 Dichloroethane (50)** (ethylene dichloride)	Not Recommended	
1-2 Dichloroethylene (200)	26,900	20,000
Dioxane (100)	47,300	43,900
Ethyl acetate (400)	10,300	11,000
Ethyl alcohol (1000)	6,900	8,400
Ethyl ether (400)	9,630	13,100
Gasoline	Requires special consideration	
Methyl acetate (200)	25,000	26,100
Methyl alcohol (200)	49,100	60,500
Methyl butyl ketone (100)	33,500	38,700
Methyl cellosolve (25)	Not Recommended	
Methyl cellosolve acetate (25)	Not Recommended	
Methyl ethyl ketone (200)	22,500	26,900
Methyl isobutyl ketone (100)	32,300	38,700
Methyl propyl ketone (200)	19,000	22,400
Naptha (coal tar) (100)	30,000-38,000	40,000-50,000
Naptha (petroleum) (500)	Requires special consideration	
Nitrobenzene (1)	Not Recommended	
n-Propyl acetate (200)	17,500	18,900
Isopropyl alcohol (400)	13,200	16,100
Isopropyl ether (500)**	5,700	7,570
Stoddard solvent (200)	15,000-17,500	20,000-25,000
1,1,2,2-Tetrachloroethane (5)	Not Recommended	
Tetrachloroethylene (100)	39,600	23,400
Toluol (Toluene) (200)**	19,000	21,000
Trichloroethylene (100)	45,000	29,400
Xylol (xylene) (100)	33,000	36,400

* The tabulated dilution air quantities must be multiplied by the selected K value.
** See Threshold Limit Values for 1971 in Appendix.
See Appendix for additional TLV and for LEL values.

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Note:
Inlet air requires tempering during winter months.
See Section 7

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

PRINCIPLES OF DILUTION VENTILATION

DATE 1-66 | Fig. 2-1

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The principles to be applied to a dilution ventilation system are as follows:

1. Select from factual data the amount of air required for satisfactory dilution of the contaminant. The values tabulated on Table 2-1 assume perfect distribution and dilution of the air and solvent vapors. These values must be multiplied by the proper K value.
2. Locate the exhaust openings near the sources of contaminant, if possible, in order to obtain the benefit of "spot ventilation."
3. In order for dilution methods to be effective, the exhaust outlet and air supply must be so located that all the air employed in the ventilation passes through the zone of contamination.
4. Replace exhausted air by a make-up air system. Make-up air should be heated during cold weather. Dilution ventilation systems usually handle large quantities of air by means of propeller fans. Make-up air usually must be provided if the ventilation is to be adequate and the system to operate satisfactorily.
5. The general air movements in the room should keep the source between the operator and the exhaust opening.
6. A combined supply and exhaust system is preferred with a slight excess of exhaust if there are adjoining occupied spaces and a slight excess of supply if there are no such spaces.
7. Avoid re-entrance of the exhausted air by discharging the exhaust high above the roof line or by assuring that no window, outside air intakes or other such openings are located near the exhaust discharge.

Dilution Ventilation for Fire and Explosion

Another function of dilution ventilation is to reduce the concentration of vapors within an enclosure to below the lower explosive limit. It should be stressed that this concept is never applied in cases where workers are exposed to the vapor. In such instances, dilution rates for health hazard control are always applied. The reason for this will be apparent when comparing TLV's and lower explosive limits (LEL's).

The TLV of xylol is 100 ppm. The LEL of xylol is 1% or 10,000 ppm. An atmosphere of xylol safeguarded against fire and explosion will usually be kept at 25% of the LEL or 2500 ppm. Exposure to such an atmosphere may cause severe illness or death. However, in baking and drying ovens, in enclosed air drying spaces, within ventilation ductwork, etc., dilution ventilation for fire and explosion is used to reduce the vapor concentration to below the LEL.

The formulas listed on page 2-2 may be modified to yield air quantities to dilute to below the LEL. By substituting LEL for TLV:

$$\text{Cu ft per pint evaporated} = \frac{(403)\ (\text{sp. gr. liquid})\ (100)\ (C)}{(\text{Mol. wt liquid})\ (\text{LEL})\ (B)} \quad \text{(For Standard Air)}$$

Note:
1. Since LEL is expressed in %(parts per 100) rather than ppm (parts per million as for the TLV), the factor of 1,000,000 becomes 100.
2. C is a safety factor which depends on the percentage of the LEL necessary for safe conditions. In most ovens and drying enclosures it has been found desirable to maintain vapor concentrations at not more than 25% of the LEL at all times in all parts of the oven. In properly ventilated continuous ovens, a C factor of 4 is used. In batch ovens, with good air distribution, the existence of peak drying rates requires a C factor of 10 or 12 to maintain safe concentrations at all times. In non-recirculating or improperly ventilated batch or continuous ovens, larger C factors may be necessary.
3. B is a constant which takes into account the fact that the lower explosive limit of a solvent vapor-air mixture decreases at elevated temperatures. B = 1 for temperatures up to 250 F; B = 0.7 for temperatures above 250 F.

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Example I

A batch of enamel dipped shelves is baked in a recirculating oven at 350 F for one hour. The volatiles in the enamel applied to the shelves consist of two pints of xylol. What oven ventilation rate, in cfm, is required to dilute the xylol vapor concentration within the oven to a safe limit at all times?

For xylol, the LEL = 1%; Sp. gr. = 0.88; Mol. Wt. = 106; C = 10; B = 0.7. From the above formula:

$$\text{cu ft per pint evaporated} = \frac{(403)(0.88)(100)(10)}{(106)(1)(0.7)}$$

For two pints of xylol evaporated in one hour:

$$\text{cfm}_{(STP)} = \frac{(2)(403)(0.88)(100)(10)}{(106)(1)(60)(0.7)} = 158$$

Since the above formula is at standard conditions, the air flow rate must be converted from 70 F to 350 F (operating conditions).

$$\text{acfm}_{350\ F} = (\text{cfm}_{STP})\ \text{(Ratio of Absolute Temperatures)}$$

$$= (\text{cfm}_{STP})\ \frac{(460\ F + 350\ F)}{(460\ F + 70\ F)}$$

$$\text{acfm}_{350\ F} = (158)\ \frac{(810)}{(530)} = 242$$

Example II

In many circumstances, solvent evaporation rate is non-uniform due to the process temperature or the manner of solvent use.

A 6 ft diameter muller is used for mixing resin sand on a 10 minute cycle. Each batch consists of 400 pounds of sand, 19 pounds of resin and 8 pounds of ethyl alcohol. What ventilation rate is required?

For ethyl alcohol: LEL = 3.28%; mol wt = 46.07; C = 4; B = 1

$$\text{cu ft per pound evaporated} = \frac{(387)\ (100)\ (C)}{\text{Mol wt x LEL x B}} = \frac{(387)\ (100)\ (4)}{(46.07)\ (3.28)\ (1)} = 1022$$

For 8 pounds of ethyl alcohol evaporated in 2 minutes:

$$\text{cfm}_{(STP)} = \frac{8}{2} \times 1022 = 4088$$

To convert to operating conditions, 200 F

$$\text{acfm}_{(200\ F)} = 4088\ \frac{(460\ F + 200\ F)}{(460\ F + 70\ F)} = 5100$$

Another source of data is the National Board of Fire Underwriters' Pamphlet #86, "Standard for Class A Ovens and Furnaces". This contains a more complete list of solvents and their properties. In addition it lists and describes a number of safeguards and interlocks which must always be considered in connection with fire dilution ventilation. See also Reference 81.

Mixtures

In many cases the parent liquid for which dilution ventilation rates are being designed will consist of a mixture of solvents. The common procedure used in such instances is as follows.

Health Dilution Ventilation

When two or more hazardous substances are present, their combined effect, rather than that of either individually, should be given primary consideration. In the absence of information to the contrary, the effects of the different hazards should be considered as additive. That is, if the sum of the following fractions,

$$\frac{C_1}{TLV_1} + \frac{C_2}{TLV_2} + \ldots + \frac{C_n}{TLV_n}$$

exceeds unity, then the threshold limit of the mixture should be considered as being exceeded. C indicates the observed atmospheric concentration and TLV the corresponding threshold limit.

Exceptions to the above rule may be made when there is good reason to believe that the chief effects of the different harmful substances are not in fact additive but independent, as when purely local effects on different

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organs of the body are produced by the various components of the mixture. In such cases, the threshold limit ordinarily is exceeded only when at least one member of the series $\left(\frac{C_1}{TLV_1} \text{ or } \frac{C_2}{TLV_2}, \text{ etc.}\right)$ itself has a value exceeding unity.

Where two or more hazardous substances are present, the dilution ventilation should be therefore calculated in the absence of information to the contrary on the basis that the effect of the different hazards is additive. The air quantity required to dilute each component of the mixture to the required safe concentration is calculated and the sum of the air quantities is used as the required dilution ventilation for the mixture.

Where two or more hazardous substances are present and it is known that the effects of the different substances are not additive but act independently on the different organs of the body, the required dilution ventilation for each component of the mixture should be calculated and the highest cfm thus obtained used as the dilution ventilation rate.

Example III

A paint stripping operation is being performed; methylene chloride (dichlormethane) and methyl alcohol (methanol) are being released. Both of these have narcotic properties and the effects are considered additive. Air samples disclose concentrations of 300 ppm methylene chloride and 100 ppm methyl alcohol. Using the equation given, the sum of the fractions $\left(\frac{300}{500} + \frac{100}{200} = 1.1\right)$ is greater than unity and the TLV of the mixture is exceeded. The volume of air at standard temperature and pressure required for dilution of this mixture to the TLV would be as follows.

Assume that 2 pints of each is being released each hour. Select a "K" value of 4 for methylene chloride and a "K" value of 6 for methyl alcohol.

$$\text{Dilution rate for methylene chloride} = \frac{403 \times 1.336 \times 1{,}000{,}000 \times 4 \times 2}{84.94 \times 500 \times 60} = 1700 \text{ cfm (STP)}$$

$$\text{Dilution rate for methyl alcohol} = \frac{403 \times 0.792 \times 1{,}000{,}000 \times 6 \times 2}{32.04 \times 200 \times 60} = 9950 \text{ cfm (STP)}$$

Dilution rate for the mixture = 1700 + 9950 = 11,650 cfm

Fire Dilution Ventilation

There is a formula for determining the lower explosive limit of mixtures of gases which is usually correct but which frequently shows a marked discrepancy between calculated and observed values, particularly for mixtures of solvent vapors. This formula is useful when its applicability to a particular mixture of solvent vapors can be demonstrated but it cannot be applied indiscriminately.

In such instances, it is common practice to regard the entire mixture as consisting of the components requiring the highest amount of dilution air per unit liquid volume and to calculate the required air quantity on that basis. (This component would be the one with the highest value for $\frac{\text{sp. gr}}{(MW)(LEL)}$).

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Section 3

VENTILATION FOR HEAT CONTROL

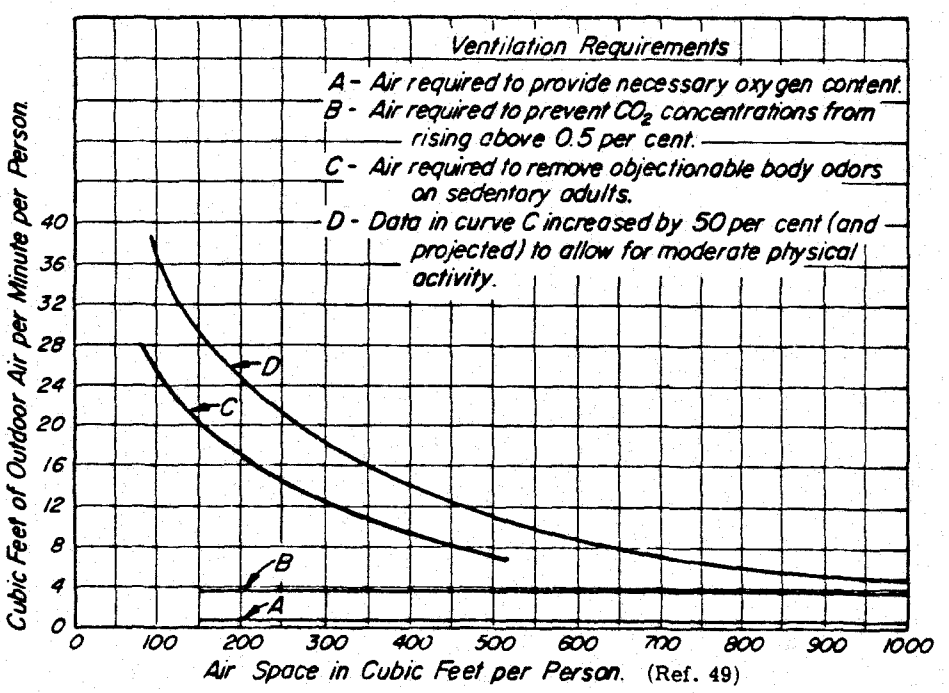
Ventilation for heat relief may include certain phases of air conditioning, the design details of which are outside the scope of this manual. Air conditioning is defined as the process of treating air so as to control simultaneously its temperature, humidity, cleanliness and distribution to meet the requirements of the conditioned space. In most residential, office and commercial systems the requirements are comfort for the occupants. In many industrial situations, however, comfort conditions cannot be maintained and the function of ventilation and air conditioning, along with other control methods such as isolation, shielding and insulation is to prevent acute discomfort or actual physiological damage. Specific installations may require cooling and/or dehumidification of supply air or the supply and exhaust of considerable quantities of untreated air. The following gives some criteria for evaluating hot conditions and suggests applicable methods of control. Although exposures to cold occur in many industries, control by heating and suitable clothing is usually attained easily and cold exposure will not be further mentioned.

PHYSIOLOGICAL PRINCIPLES

Respiratory Requirements

The need for outside air for respiration, that is, to remove carbon dioxide produced by the body and provide oxygen, is self-evident. In most situations, sufficient air for this purpose will enter by infiltration. Examples of some exceptions to this are the following:

1. Sealed spaces such as vaults and underground shelters.



(Ref. 49)

Fig. 3-1

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2. Tanks, wells, sewers, silos, fermentation vats, etc., where oxygen may have been displaced by organic decomposition products such as methane, hydrogen sulfide, carbon dioxide. In some other cases a toxic residual gas or vapor may be present even though sufficient oxygen for respiration is available.

3. Spaces where special effort has been made to isolate the area from outside air (e.g., clean rooms), particularly when inert gases are used and the ventilating system is set for 100% recirculation of the clean air or in processes where an excess of inert gas is used.

Other needs for fresh air ventilation in enclosed spaces are for odor removal and removal of tobacco smoke. In actual practice, oxygen requirements and carbon dioxide removal needs are met when odor and tobacco smoke are controlled. The values shown on Curve D represent current design standards. (For detailed information, see Reference 2.) However, the prime need for ventilation is to maintain heat balance in the body.

Heat Balance

Environmental conditions within a space must be consistent with the body's heat balance. The problem is physical, not chemical, and the main part of the body involved is the skin, not the lungs. The heat balance may be expressed as an equation: $M = \pm S + E \pm R \pm C$

where M = rate of metabolism
S = rate of heat storage in the body
E = rate of evaporative heat loss
R = rate of radiative heat loss or gain
C = rate of convective heat loss or gain

In this equation, M is a positive number; R and C may be either positive or negative, depending on whether the body is losing or gaining heat by these methods. For example, if the body is losing heat by radiation to cold walls, R is positive. S is either positive, negative or zero to balance the equation.

The rate of metabolism and the rate of heat losses from the body vary with both environmental and organism factors as shown in Table 3-1. The standard rate of metabolism for sedentary adults is taken as 400 btu/hr. Under heavy exertion this may be increased to as much as 3000 or 4000 btu/hr. Metabolism is the rate at which the body produces heat. In order to maintain thermal equilibrium, the body must lose heat at exactly this same rate.

TABLE 3-1. FACTORS INVOLVING HEAT BALANCE EQUATION

FACTOR	ENVIRONMENT	HUMAN
Metabolism (M)	Little effect	Activity Weight Surface Area Age Sex
Evaporation (E)	Wet Bulb Temperature Dry Bulb Temperature Velocity	Ability to produce sweat Surface area Clothing
Radiation (R)	Temperature difference between bodies Emissivity of surfaces	Surface area Clothing
Convection (C)	Dry Bulb Temperature Velocity	Clothing Mean body surface temp. Surface area

The rate of evaporative heat loss is always positive; that is, the body can only lose heat by this means. It cannot gain heat by evaporation. The radiative and convective heat loss or gain should need no explanation.

The storage factor S, which is needed to balance the equation is always small. The body cannot adapt itself to large storage effects of either warmth or cold. It is this storage effect, chiefly in the large muscle areas of the body, which produces the feeling of chill or uncomfortable warmth. Figure 3-2 shows these factors for a clothed subject at rest for varying dry bulb temperatures and constant relative humidity.

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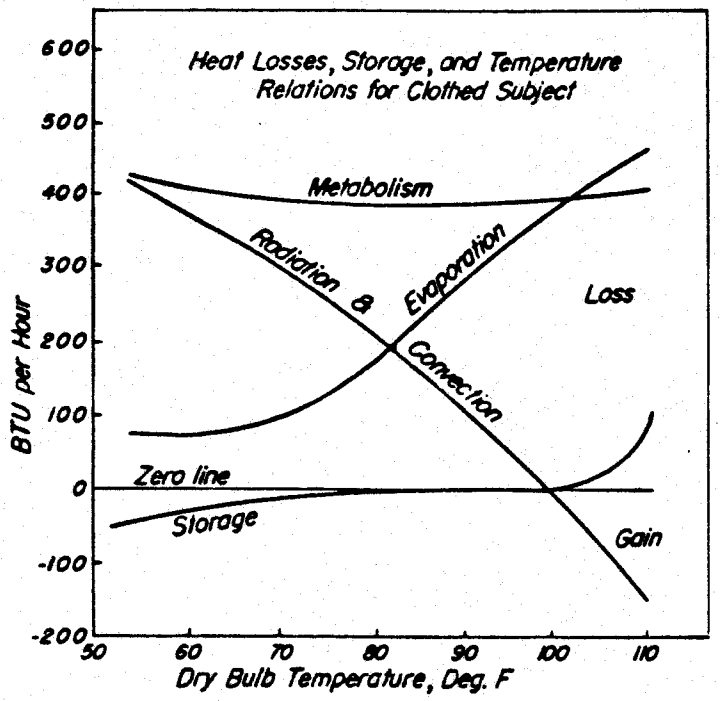


Fig. 3-2

Adaptive Mechanism of the Body

The human body, by a very complex mechanism, can attain perfect adaptation to environmental conditions through a narrow range. When this is true the storage factor is zero and optimum comfort is attained. The chief adaptive mechanisms of the body are peripheral blood circulation, sweating and change in metabolism.

In cold environments the skin surface has reduced blood circulation while in a warm environment the blood circulation to the skin is increased. This increase in blood at the skin surface is at the expense of the internal organs and brain and, if excessive, can result in heat exhaustion.

Sweating increases sharply in warm environments. However, in order to have a cooling effect, the humidity must be low and/or the air velocity must be high since the cooling effect is due to the evaporation of the liquid content of the sweat. Profuse sweating depletes the body salt content of unacclimatized persons and extra salt may be given when heavy work must be carried out under hot dry conditions.

The rate of metabolism is fairly constant in a temperate environment. There is an increase, however, in metabolism at low temperatures and at high temperatures. At elevated temperatures a sharp increase in metabolism denotes the beginning of the breakdown of the regulative process. See Figure 3-2.

Acclimatization

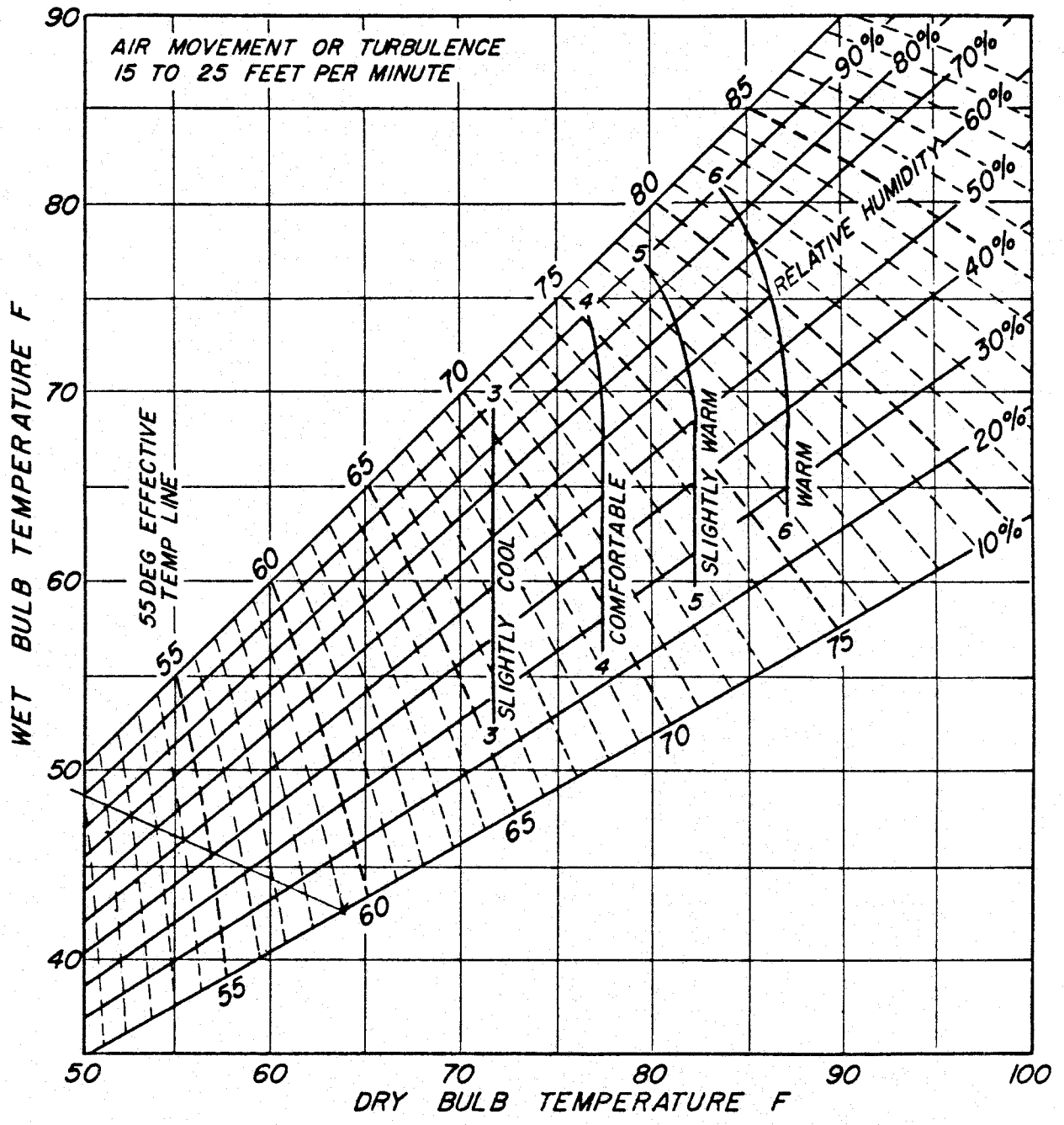
Acclimatization of personnel exposed to heat for extended periods of time is well demonstrated. Over a period of two weeks or so, the capacity of the individual to withstand heat is considerably increased. The acclimatization starts with a decrease in heat production as the individual adjusts by using energy more efficiently and relaxing when the work situation permits. During the first few days an increase in sweating develops. The heat regulating mechanism apparently becomes more sensitive, enabling the individual to better react to rapidly changing environmental conditions. The blood volume is increased, as is the volume of extracellular fluid; at the same time there is a marked drop in pulse rate response. The concentration of salt in the sweat decreases to a point where it is virtually impossible for a chloride deficit to be produced even by hard work in a hot dry environment.

Effective Temperature

Effective temperature (ET) is an index of relative comfort determined by successive comparison of different combinations of temperature, humidity and air movement and gives the relative impression of persons immediately upon entering a space. The numerical value of the ET for any given air condition is fixed by the

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Notes

1. Effective Temperature (dashed) lines indicate sensation of warmth immediately after entering conditioned space.
2. Solid lines 3, 4, 5, and 6 indicate sensations experienced after three hour occupancy.
3. Both sets of curves apply to people at rest and normally clothed.

Fig. 3-3. Comfort chart for still air. Courtesy of the American Society of Heating, Refrigeration and Air Conditioning Engineers.

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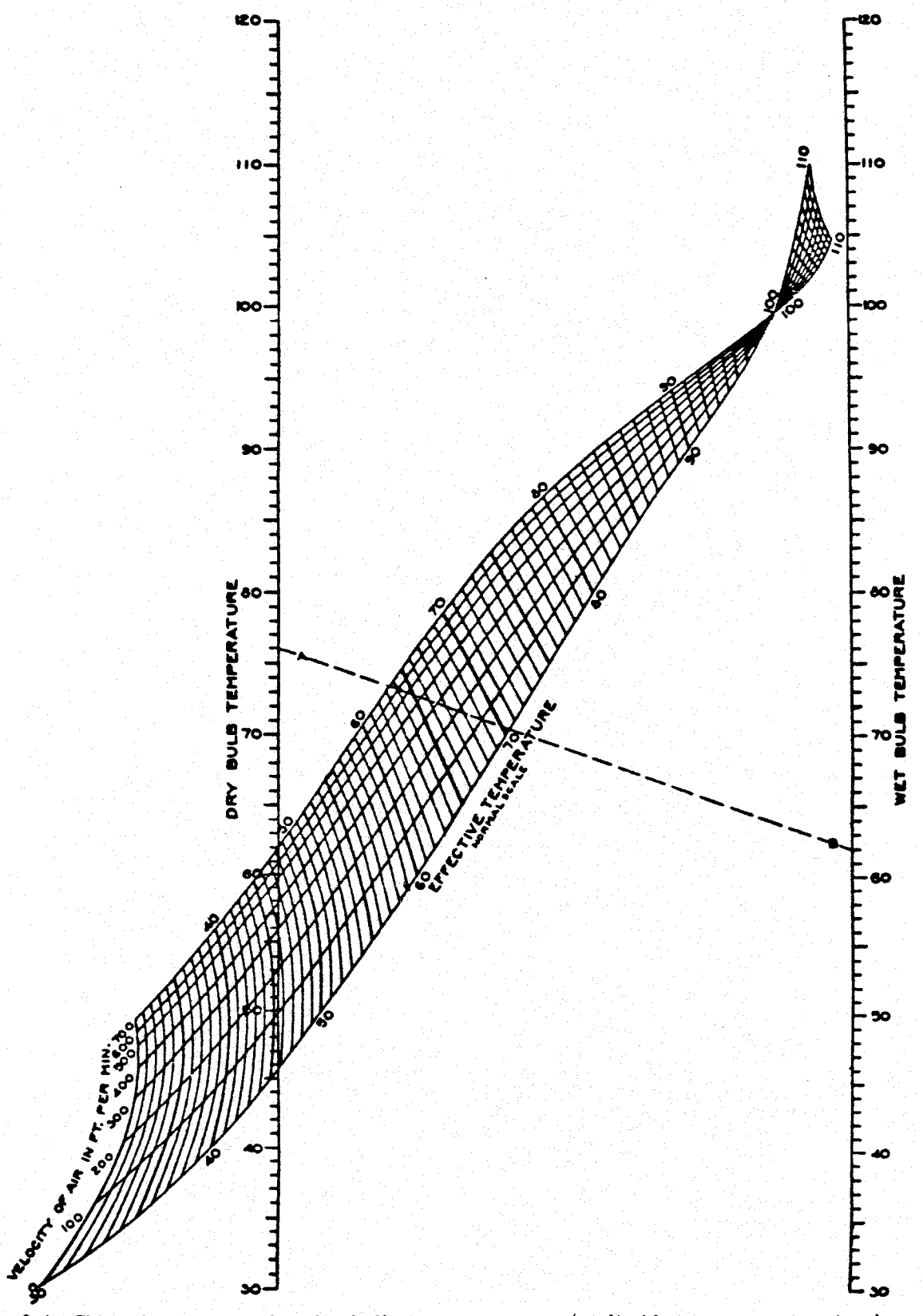


Fig. 3-4. Chart showing normal scale of effective temperature (applicable to persons at rest and normally clothed). Courtesy of the American Society of Heating and Ventilation Engineers. For application of this chart, see text.

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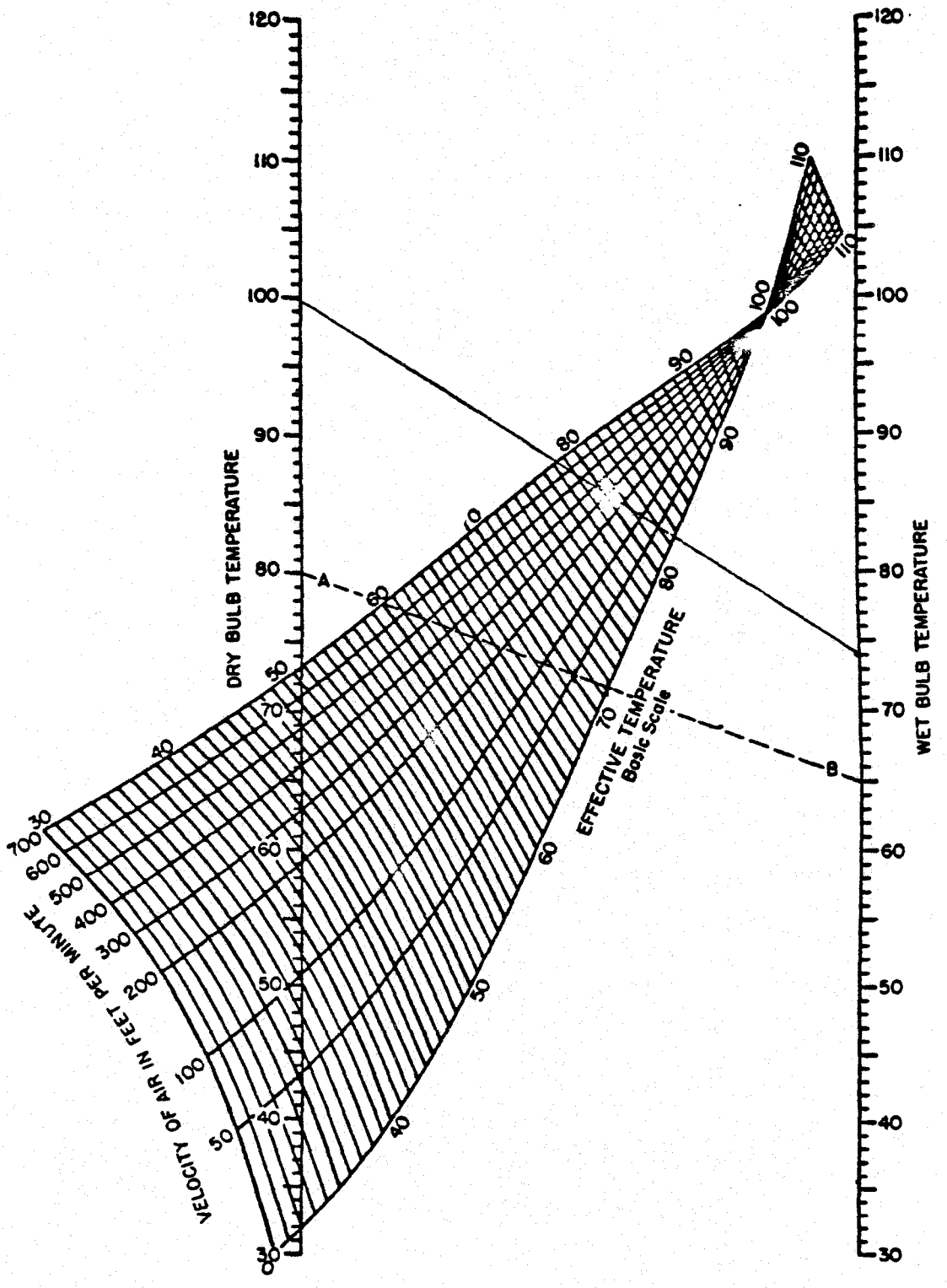


Fig. 3-5. Effective Temperature. Basic scale of effective temperature applicable to men stripped to the waist. (Courtesy American Society of Heating and Ventilating Engineers.) For application of this chart, see text.

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temperature of slowly moving saturated air which gives a like immediate sensation of warmth or coolness. The ET is determined by referring measured dry bulb temperature, wet bulb temperature and air velocity to a chart.

For persons at rest or engaged in light activity, over periods of several hours, it has been determined that the effect of humidity is much less than indicated by the effective temperature. Presently accepted criteria for comfort of normally clothed, sedentary Americans are shown on the revised ASHRAE comfort chart, Figure 3-3, along with the effective temperature lines for still (less than 25 fpm) air.

Effective temperatures are still valid criteria when sweating occurs and in the absence of a radiative heat load may be used to specify permissible thermal conditions. Figure 3-4 shows the effective temperature chart for persons normally clothed, engaged in moderate activity and includes the effect of air velocity. To determine effective temperature from this chart, a line is drawn connecting dry bulb and wet bulb temperatures. The intersection of this line with the air velocity line determines the effective temperature.

Globe Temperature

Effective temperature does not consider the effect of radiant heat although radiation from hot surfaces is often a major heat load on the body. One measure of the radiation effect is the globe temperature. The globe temperature is determined by means of a thermometer placed inside a six-inch copper sphere, matte black inside and out (a copper toilet tank float similarly treated may be substituted). The globe thermometer ordinarily requires 20 minutes to come to equilibrium. If the globe temperature is 20 F or more above the temperature determined in the same location by a shielded thermometer, then radiation shielding should be considered as it will reduce the heat load on an individual considerably more than will additional ventilation. Globe temperatures may be used to determine effective temperature corrected for radiation as described later.

Where air velocities are more than 200 fpm and/or when the radiation is such that opposite sides of the globe have very different surface temperatures, globe readings will be inconsistent and radiation on a person may be calculated from measured surface temperatures and solid angles as described in Reference 70.

Effective Temperature Corrected for Radiation

Effective temperature for an environment involving radiant heat load may be determined by use of dry bulb, wet bulb and globe thermometer readings in the following manner:

1. Determine the absolute humidity of the air by the use of wet bulb and dry bulb temperatures and psychrometric chart (See Appendix).
2. Determine a pseudo wet bulb temperature represented by the absolute humidity and a dry bulb temperature the same as the globe thermometer reading.
3. Determine the effective temperature represented by the pseudo wet bulb reading and the globe thermometer reading by use of the effective temperature chart.

Example:

Given: Workers normally clothed, doing light work, are exposed to a radiant heat condition in which the following measurements were made:

Dry bulb temperature	70 F
Wet bulb temperature	55 F
Globe Thermometer	95 F
Air Velocity	100 fpm

Determine effective temperature to which workers are subjected.

Determine absolute humidity from the psychrometric chart by locating the point where the dry bulb temperature line, 70 F, crosses the wet bulb temperature line, 55 F (see Figure 3-6). Project this point horizontally to the right and read 40 grains water vapor per pound dry air, absolute humidity.

Determine the pseudo wet bulb reading by putting the globe temperature, 95 F, on the dry bulb scale of the chart and projecting it vertically until it crosses the previously determined absolute humidity line (40 gr) (— see Figure 3-6). Project this point along the wet bulb temperature line to the dew point temperature or 100% humidity line. Read 64 F; this is the pseudo wet bulb temperature.

To determine the effective temperature, use chart Figure 3-4. On the left (dry bulb temperature scale) locate the globe thermometer temperature, 95 F; on the wet bulb temperature scale locate the pseudo wet bulb temperature, 64 F. Draw a line between the two points. At the point where this line crosses the 100 fpm velocity line read the effective temperature, 78 F.

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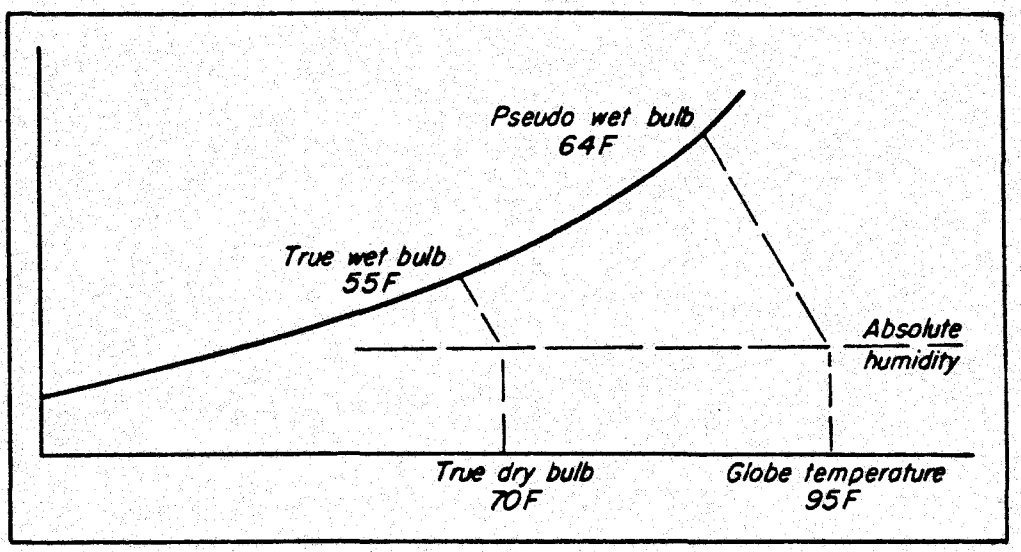


Fig. 3-6

Tolerance to Hot Atmospheres

Various laboratory and field studies have indicated the temperature and humidity limits for continuous work in hot industries shown in Table 3-2. The effective temperatures correspond approximately to those obtained from Figure 3-5 which is based on at-rest subjects stripped to the waist. Thus either Table 3-2 or Figure 3-5 may be used in determining effective temperatures for use with the effective temperature toler-

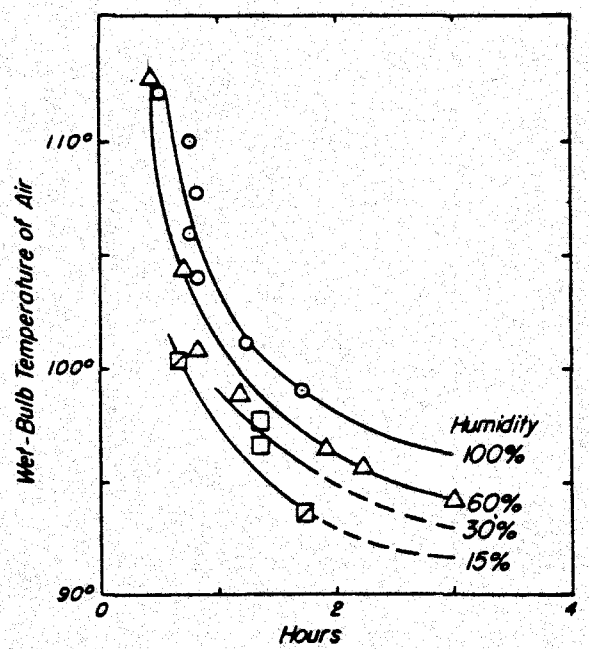


Fig. 3-7. Tolerance times for men at rest in still air of diverse wet-bulb temperatures and four relative humidities. Times are averaged for the three or four men, nude to the waist, who sat simultaneously through each test. The consistency of the results is represented by the fact that points of diverse humidities do not overlap. The temperature ceiling is reduced about 1 F for each 20% of relative humidity.

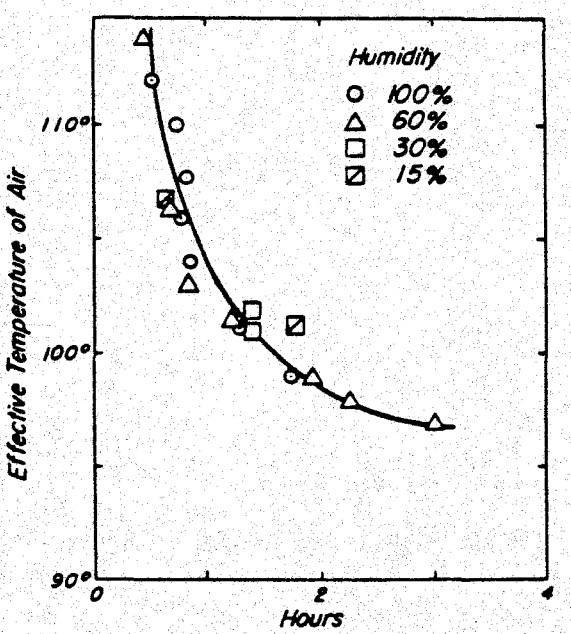


Fig. 3-8. Tolerance times at diverse effective temperatures. Same data as in Figure 3-7. It is evident that the scale of effective temperatures makes the times identical regardless of humidities.

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ance limits for various work conditions given in Table 3-2. The limitation of temperature and humidity to the perspiration threshold of 75 ET in cold weather is desirable in order to reduce excessive sweating and consequent chilling of workers during rest or in post work periods. In all cases where a significant radiant heat load is involved, the effective temperature corrected for radiation should be used.

Where exposure to heat beyond the limits of Table 3-2 becomes necessary, short periods of work in the heat should be alternated with rest periods in a cooler environment. Thus while it is generally concluded that a wet-bulb temperature of 88 F to 90 F is the upper limit which men can endure for long periods, wet-bulb temperatures of over 110 F can be tolerated for a few minutes. Figure 3-7 relates tolerance time to wet-bulb temperature at different humidities for subjects at rest, stripped to the waist, and Figure 3-8 presents the same data in terms of effective temperature. For higher rates of metabolism the tolerance would be greatly reduced. Thus an increase in metabolism of 2 1/2 times decreases the wet-bulb temperature of tolerance for one hour by 13 F.

CONTROL METHODS

This manual will deal only with engineering methods for the control of abnormally hot atmospheres. However, an accepted industrial hygiene method other than actual control will first be mentioned. This method is to limit the time of exposure as well as the total number of employees exposed. If control cannot be achieved by other methods it may prove necessary to limit the time of exposure, with periods of rest or other work in cooler atmospheres. Baffles, shields or partitions may also be indicated to prevent unnecessary exposure of workers.

Ventilation

Exhaust ventilation may be used to remove excessive heat and/or humidity if a source of cooler air is available. If it is possible to enclose the heat source, such as in the case of ovens or certain furnaces, a gravity or forced air stack may be all that is necessary to prevent excessive heat from entering the workroom. If a partial enclosure or local hood is indicated, control velocities as shown in Section 5 may be used to determine the volume of air to be exhausted.

In the case of many operations which do not lend themselves to local exhaust, general ventilation may be indicated. In order to arrive at the air volumes required it is necessary to estimate the summation of all sources of both sensible and latent heat, as well as to determine in advance the temperature rise or humidity

Table 3-2

High Environmental Dry and Wet-Bulb Temperatures*
That Can Be Tolerated in Daily Work by Healthy,
Acclimatized Men Wearing Warm Weather Clothing

Activity	Relative Humidity %	Air Movement					
		15-25 fpm		100 fpm		300 fpm	
		Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb
Summer season	80	89	84	91	85	93	87
Light sedentary	60	94	82	96	84	98	85
activities	40	100	79	101	81	103	82
(85 ET)	20	109	75	110	75	110	75
	5	119	69	118	69	117	68
Summer season	80	83	78	86	81	89	83
Heavy work	60	88	76	90	78	93	80
(80 ET)	40	93	73	95	75	97	76
	20	100	69	101	70	102	70
	5	107	64	107	64	106	63
Winter season	80	78	73	81	77	85	79
Light or heavy	60	81	71	85	74	88	76
work	40	86	68	89	70	91	72
(75 ET)	20	91	63	93	65	94	66
	5	97	58	97	58	97	59

*(Including radiation effect)

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rise which will be acceptable. The volume of air required for sensible heat may be estimated from the following equation:

$$\text{cfm} = \frac{\text{Total Btu/hr sensible heat}}{1.08 \times \text{Temp. rise -- F}}$$

In order to use this equation it is necessary to first estimate the heat load. This will include sun load, people, lights and motors as well as other particular sources of heat. Of these, sun load, lights and motors are all completely sensible. The people heat load is part sensible and part latent. In the case of hot processes which give off both sensible and latent heat, it will be necessary to estimate the amounts or percentages of each. In using the above equation for sensible heat, the temperature rise which will be permitted must be decided upon. Thus in a locality where 90 F outside dry bulb may be expected, if it is desired that the inside temperature not exceed 100 F, or a 10 degree rise, a certain air volume will be necessary. If an inside temperature of 95 F is required, the air volume will be doubled.

For latent heat load, the procedure is similar although more difficult. If the total amount of steam evaporated is known, the heat load may be estimated by multiplying the pounds of steam per hour by 1000. Then

$$\text{cfm} = \frac{\text{btu/hr latent heat}}{0.67 \times \text{Grains/lb difference}}$$

When the amount of water released is known, the following formula is used:

$$\text{cfm} = 116.7 \frac{\text{Pounds/hr water released as vapor}}{\text{Grains/pound difference} \times d}$$

where d = density of air in pounds/cu ft

The term "grains per pound difference" is taken from the psychrometric chart or tables and represents the difference in moisture content of the outside air and the conditions acceptable to the engineer designing the exhaust system. The air quantities calculated from the above two equations should not be added to arrive at the required air quantity. Rather, the higher quantity should be used, since both sensible and latent heat are absorbed simultaneously. Furthermore, in the majority of cases the sensible heat load far exceeds the latent heat load so that the design can be calculated only on the basis of sensible heat.

Velocity Cooling

If the air dry bulb or wet bulb temperatures are lower than 95 - 100 F, the worker may be cooled by convection or evaporation as shown by the Effective Temperature Charts, Fig. 3-4 and 3-5. When the dry bulb temperature is higher than 95 - 100 F, increased air velocity may add heat to the worker by convection; if the wet bulb temperature is high also, evaporative heat loss may not increase proportionately and the net result will be an increase in the workers' heat burden. Many designers consider that supply air temperature should not exceed 80 F for practical heat relief.

Current practice indicates that air velocities considerably higher than those shown in Fig. 3-4 and 3-5 can be used successfully for direct cooling of workers and the following may be used as guides. For best results provide directional control of the air supply (see Fig. 7-2) to accommodate daily and seasonal variations in heat exposure and supply air temperatures.

TABLE 3-3 ACCEPTABLE AIR MOTION AT THE WORKER

Continuous Exposure	Air Velocity, fpm
Air conditioned space	50-75
Fixed work station, general ventilation or spot cooling: Sitting	75-125
Standing	100-200
Intermittent Exposure, Spot Cooling or Relief Stations	
Light heat loads and activity	1000-2000
Moderate heat loads and activity	2000-3000
High heat loads and activity	3000-4000

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Enclosures

In certain hot industries, such as in steel mills, it is unnecessary and impractical to attempt to control the heat from the process. If the operation is such that remote control is possible, an air conditioned booth or cab can be utilized to keep the operators reasonably comfortable in an otherwise intolerable atmosphere.

Insulation

If the source of heat is a surface giving rise to convection, heat insulation at the surface will reduce this form of heat transfer. Insulation by itself, however, will not usually be sufficient if the temperature is very high or if the heat content is high.

Radiation Control

Since radiation is a form of heat energy which needs no medium for its transfer, radiant heat cannot be controlled by any of the above means. Painting or coating the surface of hot bodies with materials having low radiation emission characteristics is one method of reducing radiation.

TABLE 3-4 RELATIVE EFFICIENCIES OF COMMON SHIELDING MATERIALS

Surface of Shielding	Reflection of Radiant Heat Incident Upon Surface	Emission of Radiant Heat from Surface
Aluminum, bright	95	5
Zinc, bright	90	10
Aluminum, oxidized	84	16
Zinc, oxidized	73	27
Aluminum paint, new clean	65	35
Aluminum paint, dull, dirty	40	60
Iron, sheet, smooth	45	55
Iron, sheet, oxidized	35	65
Brick	20	80
Lacquer, black	10	90
Lacquer, white	10	90
Asbestos board	6	94
Lacquer, flat black	3	97

For materials such as molten masses of metal or glass which cannot be controlled directly, radiation shields are effective. These shields can consist of metal plates, screens, or other material interposed between the source of radiant heat and the workers. Shielding reduces the radiant heat load by reflecting the major portion of the incident radiant heat away from the operator and by re-emitting to the operator only a portion of that radiant heat which has been absorbed. Additional ventilation will control the sensible heat load but will have only a minimal effect, if any, upon the radiant heat load.

Protective Suits for Short Exposures

For brief exposures to very high temperatures, insulated aluminized suits and other protective clothing may be worn. These suits reduce the rate of heat gain by the body but provide no means of removing body heat; therefore, only short exposures may be tolerated.

Respiratory Heat Exchangers

For brief exposures to air of good quality but high temperature, a heat exchanger on a half-mask respirator facepiece is available. This device will bring air into the respiratory passages at a tolerable temperature but will not remove contaminants nor furnish oxygen in poor atmospheres.

Refrigerated Suits

Where individuals must move about, cold air may be blown into a suit or hood worn as a portable enclosure. The usual refrigeration methods may be used with insulated tubing to the suit. It may be difficult, however, to deliver air at a sufficiently low temperature. If compressed air is available, cold air may be delivered from a vortex tube worn on the suit (75). Suits of this type are commercially available.

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Section 4

HOOD DESIGN DATA

Introduction

Proper design of exhaust hoods is necessary if a local exhaust system is to effectively control atmospheric contamination at its source with a minimum air flow and power consumption. The theory of capture velocity depends on the creation of air flow past the source of contaminant sufficient to remove the highly contaminated air around the source or issuing from that source and to draw the air into an exhaust hood.

It can be shown that dust particles in the small micron sizes, even if impelled at extremely high original velocities, travel a very short distance in air--a matter of a few inches at the most (References 7, 16). Thus the fine dust particles of health significance follow the air currents and are often referred to as "air-borne dust." The same considerations apply to mists and fumes. Vapors and gases, of course, mix intimately with air and follow the air currents.

Larger dust particles released at high velocities (example, the larger particles from grinding) do have an appreciable trajectory or "throw" in air. These larger particles cannot be captured unless directed into the hood. Scattering can also be prevented by properly placed barriers. It is desirable to collect this dust as well as the truly air-borne dust and thus utilize the exhaust ventilation to improve the housekeeping and maintenance situation in the plant.

Principles of Hood Design

Basically, hood design requires sufficient knowledge of a process or operation so the most effective hood or enclosure can be installed to provide minimum exhaust volumes for effective contaminant control. The more complete the enclosure, the more economical and effective the installation will be. Many designers develop their hoods by mentally enclosing the operation completely, from there providing access and working openings as indicated. From this complete enclosure concept, familiar hood shapes like booths, side or down-draft hoods with or without side shields are developed. All openings are kept to a minimum and located away from the natural path of the contaminant travel wherever possible. Inspection and maintenance openings are provided with doors whenever practicable.

Local hoods that do not enclose or confine the contaminant are recommended only as a last resort because exhaust volumes are large and control can be so easily upset by cross drafts in the area.

Canopy hoods are effective for the control of hot processes and for those operations which release sudden surges of hot gases and vapors. Canopies should not be used where men must work directly over the operation as in the case of plating tanks and cementing tables since the flow of air passes the worker's breathing zone and can increase his exposure to toxic materials.

Exhaust duct takeoffs will be located, when possible, to be in the line of normal contaminant travel and will be arranged so desired distribution of exhaust air flow is attained. In the case of large shallow hoods, the air movement tends to concentrate in front of the duct opening. Satisfactory air distribution can be attained by using multiple takeoffs or by installing interior baffles or filter banks.

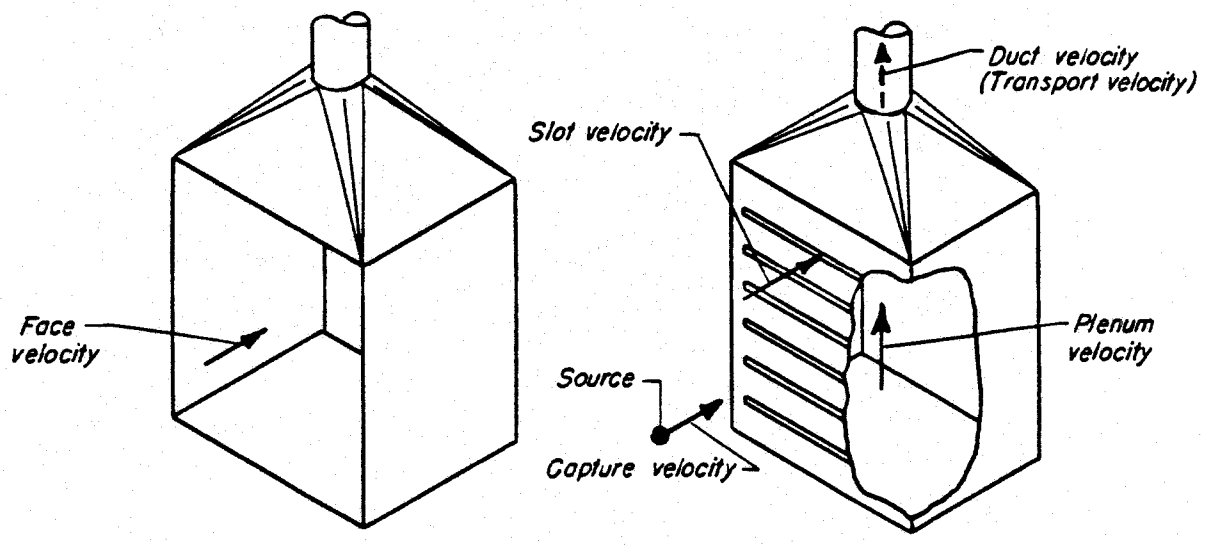
Effects of Flanging

Wherever possible, flanges should be provided to eliminate air flow from ineffective zones where no contaminant exists. Increasing the hood effectiveness in this manner will usually reduce air requirements by 25% (See Figures 4-2, 4-3 and 4-4.) For most applications the flange width can be equal to the hood diameter or side but need not exceed 6 in.

It is only after the hood design has been determined that exhaust volume requirements can be calculated. With enclosures, volumes are calculated from the known open area of the hood and the selection of the capture or indraft velocity sufficient to prevent outward escapement. Where enclosure of the process is impracticable, air flow pattern in front of the hood must be such that selected capture velocities will be maintained in the area of generation, conveying the contaminant to the hood opening.

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Capture Velocity – Air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood.

Face Velocity – Air velocity at the hood opening.

Slot Velocity – Air velocity through the openings in a slot-type hood, fpm. It is used primarily as a means of obtaining uniform air distribution across the face of the hood.

Plenum Velocity – Air velocity in the plenum, fpm. For good air distribution with slot-types of hoods, the maximum plenum velocity should be 1/2 of the Slot Velocity or less.

Duct Velocity – Air velocity through the duct cross section, fpm. When solid material is present in the air stream, the duct velocity must be equal to the minimum Tronsport Velocity.

Transport (Conveying) Velocity – Minimum air velocity required to move the particulates in the air stream, fpm.

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PRINCIPLES OF EXHAUST HOODS

DATE 1-66 | Fig. 4-1

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Plain Openings

Air will move in all directions toward openings under suction. By definition, flow contours are lines of equal velocity in front of a hood. Similarly, streamlines are lines perpendicular to velocity contours. (The tangent to a streamline at any point indicates the direction of air flow at that point.) Figure 4-2 illustrates air flow in front of a circular opening.

The equation of flow before free hanging hoods (Reference 9) for round hoods, and rectangular hoods which are essentially square, is:

$$V = \frac{Q}{10X^2 + A}$$

Where:

V = Centerline velocity at X distance from hood, fpm
X = Distance outward along axis in ft. (Note: equation is accurate only for limited distance of X, where X is within 1-1/2 D)
Q = Air flow, cfm.
A = Area of hood opening in square feet.
D = Diameter of round hoods or side of essentially square hoods.

As can be seen from this equation and from Figure 4-2, there is a rapid velocity decrease with increasing distances from the hood, varying almost inversely with the square of the distance.

Where distances of X are greater than 1-1/2D, the velocity decreases less rapidly with distance than the above equation indicates (See References 38 and 54).

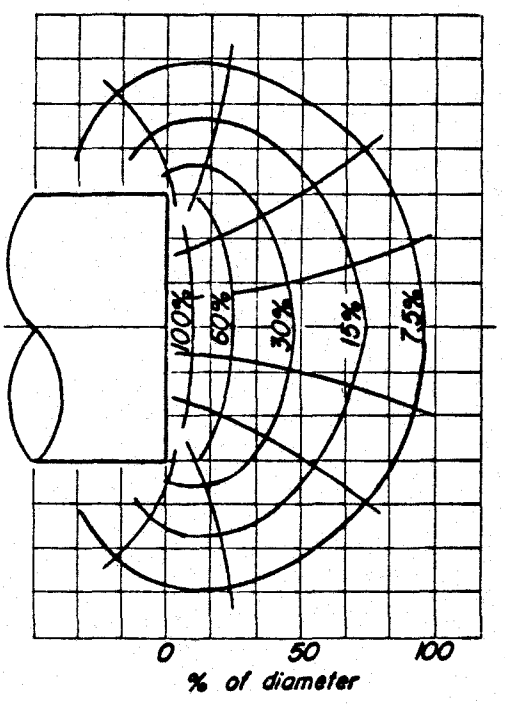


Fig. 4-2

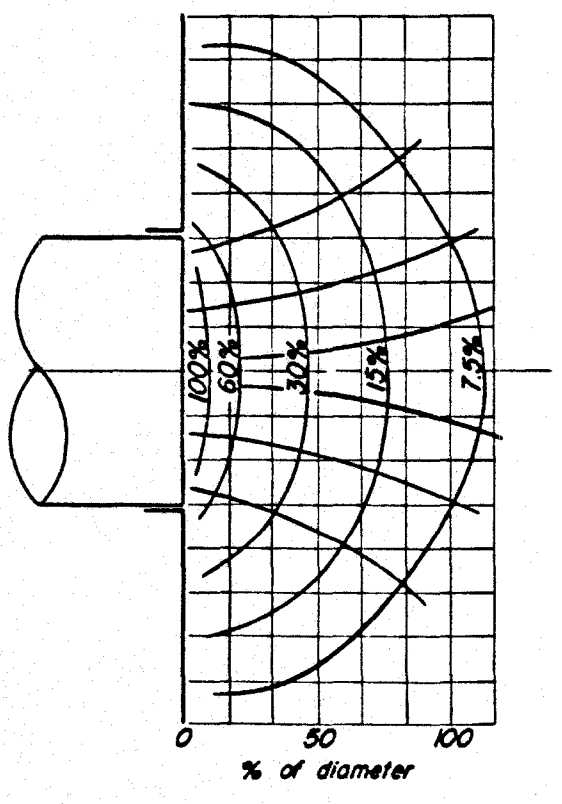


Fig. 4-3

Velocity contours (expressed in percentage of opening velocity) and streamlines for circular openings.

The preceeding formula applies to air flow conditions in front of freely suspended plain openings. Figure 4-4 illustrates other hood types and gives the air volume formulae which apply.

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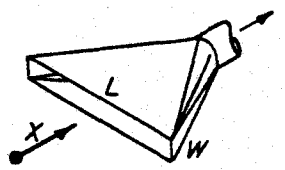
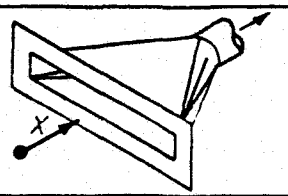
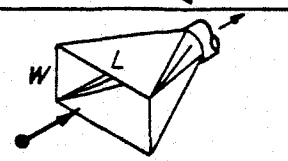
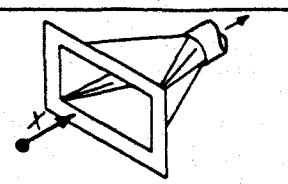
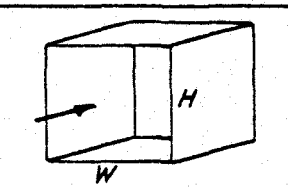
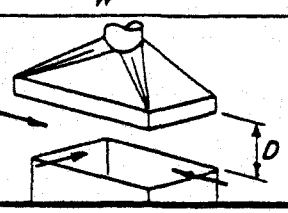
HOOD TYPE	DESCRIPTION	ASPECT RATIO, $\frac{W}{L}$	AIR VOLUME
	SLOT	0.2 or less	Q = 3.7 LVX (Reference 38)
	FLANGED SLOT	0.2 or less	Q = 2.8 LVX (Reference 38)
 A = WL (sq. ft.)	PLAIN OPENING	0.2 or greater and round	$Q = V(10X^2+A)$ (Reference 9)
	FLANGED OPENING	0.2 or greater and round	$Q = 0.75V(10X^2+A)$ (Reference 9)
	BOOTH	To suit work	Q = VA = VWH
	CANOPY	To suit work	Q = 1.4 PDV See VS-903 P = perimeter of work D = height above work

Fig. 4-4

Capture Velocities

Capture velocity is the velocity at any point in front of the hood necessary to overcome opposing air currents and to capture the contaminated air by causing it to flow into the exhaust hood.

Exceptionally high volume hoods (example, large side-draft shakeout) require less air volume than would be indicated by the capture velocity values recommended for small hoods. This phenomenon is ascribed to:

1. The presence of a large air mass moving into the hood.
2. The fact that the contaminant is under the influence of the hood for a much longer time than is the case with small hoods.
3. The fact that the large air volume affords considerable dilution as described above.

Table 4-1 offers capture velocity data. Additional information is found in Section 5, Table 5-9-2.

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TABLE 4-1

RANGE OF CAPTURE VELOCITIES (7,24)

Condition of Dispersion of Contaminant	Examples	Capture Velocity, fpm
Released with practically no velocity into quiet air.	Evaporation from tanks; degreasing, etc.	50-100
Released at low velocity into moderately still air.	Spray booths; intermittent container filling; low speed conveyor transfers; welding; plating; pickling	100-200
Active generation into zone of rapid air motion	Spray painting in shallow booths; barrel filling; conveyor loading; crushers	200-500
Released at high initial velocity into zone of very rapid air motion.	Grinding; abrasive blasting, tumbling	500-2000

In each category above, a range of capture velocity is shown. The proper choice of values depends on several factors:

Lower End of Range	Upper End of Range
1. Room air currents minimal or favorable to capture.	1. Disturbing room air currents.
2. Contaminants of low toxicity or of nuisance value only.	2. Contaminants of high toxicity.
3. Intermittent, low production.	3. High production, heavy use.
4. Large hood—large air mass in motion.	4. Small hood—local control only.

Hood Design Procedure

Effective control of a contaminant producing process is brought about by first eliminating or minimizing all air motion about the process and then capturing the contaminated air by causing it to flow into the exhaust hood. Flow toward the suction opening must be sufficiently high to maintain the necessary capture velocity and to overcome opposing air currents.

Elimination of sources of air motion as a first step in hood design is an important factor in cutting down the required air volume and the corresponding power consumption. Important sources of air motion are:

1. Thermal air currents, especially from hot processes or heat-generating operations.
2. Motion of machinery, as by a grinding wheel, belt conveyor, etc.
3. Material motion, as in dumping or container filling.
4. Movements of the operator.
5. Room air currents (which are usually taken at 50 fpm minimum and may be much higher).
6. Spot cooling and heating equipment.

The shape of the hood, its size, location and rate of air flow are important design considerations.

The hood should enclose the operation as much as possible. If enclosure is not practicable, the hood should be located as close as possible to the source and shaped to control the area of contamination.

Flanges should be used whenever possible to eliminate exhausting air from ineffective areas (see page 4-1) and also to decrease the hood entry loss.

Hood Entry Coefficient and Static Pressure

If by creating suction air enters an opening, a typical flow pattern results as shown in Figure 4-2. Maximum convergence of the air stream occurs at a short distance downstream at the plane of the vena contracta where the diameter of the jet is smaller than the diameter of the duct.

The formation of the vena contracta is accompanied by a conversion of static pressure to velocity pressure and from velocity pressure back to static pressure. A loss of about 2% in static pressure results from the conversion of static to velocity pressure and a much greater loss in static pressure results from the conversion of velocity pressure at the vena contracta to static pressure as the air fills the duct. The area of the air stream at the vena contracta will vary with the shape of the hood or duct opening and for most hood shapes will range from 70% to 100% of the duct area.

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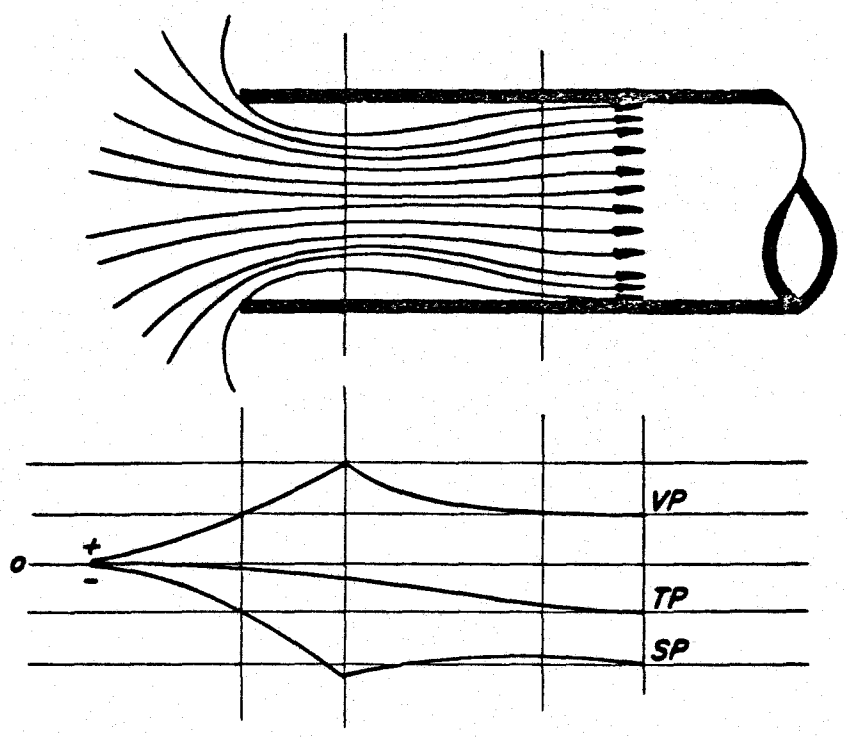


Fig. 4-5. Air flow at the vena contracta.

The losses due to pressure conversion result in a decreased rate of flow as indicated by the coefficient of entry, C_e. The coefficient of entry is defined as the actual rate of flow caused by a given static pressure compared to the theoretical flow which would result if the static pressure could be converted to velocity pressure with 100% efficiency. It is the ratio of actual to theoretical flow. Figure 4-8 provides C_e values for many hood types.

Coefficient of entry C_e represents the percentage of flow that will occur into a given hood based on the SP developed in the branch. CFM for any hood can be written either in the usual ($4005\ A\ \sqrt{VP}$) or as ($4005\ A\ C_e\ \sqrt{SP_h}$)

$$Q = 4005\ A\sqrt{VP} = 4005\ A\ C_e\ \sqrt{SP}_h$$

$$C_e = \sqrt{\frac{VP}{SP_h}}$$

Hood entry loss h_e is another convenient means of determining air flow through a hood and can be defined as representing the loss in pressure caused by air flowing into a duct.

SP_h at hood = VP in the duct + h_e. Relationship between C_e and h_e can be derived as follows:

$$C_e = \sqrt{\frac{VP}{SP_h}}$$

Substitute: $SP_h = VP + h_e$

$$C_e = \sqrt{\frac{VP}{VP + h_e}}$$

$$C_e^2 = \frac{VP}{VP + h_e}$$

$$h_e = \frac{VP}{C_e^2} - VP$$

$$= \frac{(1 - C_e^2)}{(C_e^2)}\ VP$$

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It is, therefore, desirable to minimize the air stream contraction which occurs at the vena contracts zone by suitable hood design. Figure 4-8 illustrates the effect of hood design on the entry coefficient and on the entry loss in terms of velocity head in the connecting duct, the latter being another way of expressing hood entry loss.

Considering the grinding wheel hood shown in Figure 4-8, some typical calculations are as follows:

Example Problem I

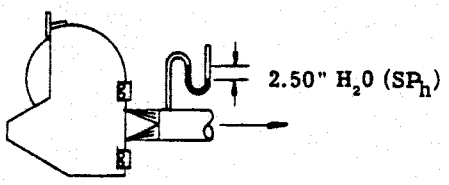
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C_e = 0.78

SP_h = 2.50 inches water

Duct Diameter = 5 inches

Duct Area = 0.136 square feet



where SP_h = static pressure, inches water

VP = velocity pressure, inches water

h_e = hood entry loss, inches water

F_h = hood entry loss factor

TO FIND

a. Air Volume

b. Duct Velocity

c. Per Cent Loss in Velocity Head

a. $Q = 4005\, C_e\, A \sqrt{SP_h} = 4005 \times 0.78 \times 0.136 \sqrt{2.50} = 672$ cfm

b. $V = \frac{Q}{A} = \frac{672}{0.136} = 4950$ fpm

c. $VP = \left(\frac{V}{4005}\right)^2 = \left(\frac{4950}{4005}\right)^2 = 1.52$

$SP_h = VP + h_e$

$h_e = SP_h - VP = 2.50 - 1.52 = 0.98$

$F_h = \frac{0.98}{1.52} = 0.645$

% Loss = F x 100 = 0.645 x 100 = 64.5%

As a ventilation standard, static pressure alone without reference to the duct diameter is meaningless. Decreasing the branch duct size results in higher velocity, greater resistance and a lowered rate of flow although the static pressure value is increased. The ventilation performance of hoods should be based primarily on air volumes handled.

Slots for Air Distribution

Slot hoods are most commonly used to provide uniform exhaust air flow at adequate capture velocity over a finite length of contaminant generation—such as an open tank—or over the face of a large hood such as a side draft design. The function of the slot is solely to obtain proper air distribution. Slot velocity does not contribute toward capture velocity; a high slot velocity simply generates high pressure losses. Note that the capture velocity equation (Figure 4-4) shows that the capture velocity is related to the exhaust volume and the slot length, not the slot velocity.

Slot hoods usually consist of a narrow exhaust opening and a plenum chamber. Uniform exhaust air distribution across the slot is obtained by careful design. Splitter vanes may be used in the plenum; however, in most industrial exhaust systems vanes are subject to corrosion and/or erosion and provide locations for material build-up. Adjustable slots can be provided but these are subject to tampering and maladjustment. The most practicable hood is the fixed slot and unobstructed plenum type. The design of the slot and plenum is such that the pressure loss through the slot is high compared with the pressure loss through the plenum. Thus all portions of the slot are subjected to essentially equal suction and the slot velocity will be essentially uniform.

There is no straight-forward method for calculating the pressure drop from one end to the other of a slot-plenum combination. A very useful approximation, applicable to most hoods, is to design for a maximum plenum velocity equal to 1/2 of the slot velocity. For most slot hoods a 2,000 fpm slot velocity and 1,000 fpm plenum velocity is a reasonable choice for uniformity of flow and moderate pressure drop. Following are some broad design guidelines:

Centered Exhaust Take Off design results in the smallest practical plenum size since the air approaches the duct from both directions. Where large, deep plenums are possible, as with shakeout hoods, the slot velocity may be as low as 1,000 fpm with a 500 fpm plenum velocity.

End Take Off configurations require large plenum sizes because all of the air must pass in one direction.

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Note that where slot-plenum hoods are used for dust control, plenum velocities must be 3,000 fpm or higher to transport particulate matter through the hood. Otherwise, settling and plugging will occur.

Calculation of Static Pressure Losses in Exhaust Hoods

Simple Hoods: Plain duct openings, flanged duct openings, canopies and similar hoods have only one significant energy loss, at the point where the air enters the duct. At this location a pronounced vena contracta is formed and an energy loss occurs first in the conversion of static pressure to velocity pressure. As the air passes through the vena contracta, the flow area enlarges to fill the duct and velocity pressure converts to static pressure, again with some energy loss. The more pronounced the vena contracta, the greater will be the energy loss and hood static pressure. The hood entry loss (h_e) can be expressed therefore in terms of a single factor (F) which, when multiplied by the duct velocity pressure (VP), will give the entry loss (h_e) in inches of water.

Example Problem II

In a simple hood (Figure 4-6) the hood static pressure is equal to the velocity pressure in the duct plus the hood entry loss. (See page 1-3, "Acceleration of Air and Hood Entrance Losses".) The velocity pressure represents the pressure necessary to accelerate the air from rest to the duct velocity; the hood entry loss represents the energy necessary to overcome the loss as the air enters the duct. This may be expressed as:

$$SP_h = h_{ed} + VP_d$$

when face velocity is less than 1000 fpm (when face velocity is higher than 1000 fpm, the hood should be treated as a compound hood. See following.).

Where: h_{ed} = entry loss of transition (See Figure 6-10)

VP_d = Duct Velocity Pressure

A typical calculation is as follows:

$$\text{Given: Face Velocity} = \frac{Q}{A_{face}} = 250 \text{ fpm}$$

$$\text{Duct Velocity} = \frac{Q}{A_{duct}} = 2000 \text{ fpm}$$

$$VP_d = 0.25''$$

$$F = 0.25\ VP_d$$

$$SP_h = h_{ed} + VP_d$$

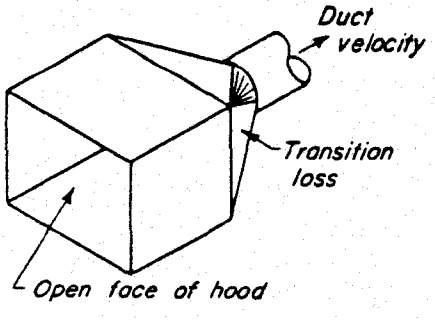


Fig. 4-6

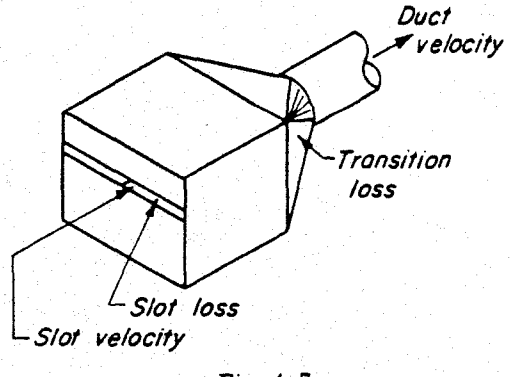


Fig. 4-7

Compound Hoods: Other types of hoods have two or more points of significant energy loss and must be considered in greater detail. Common examples are hoods having double entry losses: slot type hoods and multiple opening, lateral draft hoods commonly used on plating, paint dipping and degreasing tanks and foundry side draft shakeout ventilation.

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Figure 4-7 illustrates a double entry loss hood; this is a single slot hood with a plenum and a transition from the plenum to the duct. The purpose of the plenum is to give uniform velocity across the slot opening. Air enters the slot, in this case a sharp-edged orifice, and loses energy due to the vena contracta at this point. The air then continues through the plenum where the greater portion of the slot velocity is retained because the air stream projects itself across the plenum in a manner similar to the "blowing" supply stream shown in Figure 1-6. (The retention of velocity in the plenum is characteristic of most local exhaust hoods because of the short plenum length. In the case of very large hoods or exhausted sealed rooms, however, the velocity loss must be taken into account.) The air then converges into the duct through the transition where the second significant energy loss occurs.

Example Problem III

In Figure 4-7 the air enters the slot, a slot entry loss occurs and the air is accelerated to the slot velocity. It then crosses the plenum and enters the duct through the hood transition where another entry loss occurs and the air is accelerated further from its initial velocity in the slot to the higher duct velocity. In most cases, the slot velocity is equal to or lower than the duct velocity; in all cases, however, the air must be accelerated to the higher velocity.

The hood static pressure for a double entry hood can be expressed as the equation:

$$SP_h = h_{es} + VP_s + h_{ed} + VP_d - VP_s$$

thus: (1) $SP_h = h_{es} + h_{ed} + VP_d$ when duct velocity is greater than slot velocity

(2) $SP_h = h_{es} + h_{ed} + VP_s$ when slot velocity is greater than duct velocity

where: h_{es} = entry loss through slot (See Figure 6-10)

VP_s = slot velocity pressure

h_{ed} = entry loss of transition (See Figure 6-10)

VP_d = duct velocity pressure

Some typical calculations, using "Equation 1", are as follows:

Plating Hood	Foundry Shakeout Hood
Slot velocity = $\frac{Q}{A_{slot}}$ = 2000 fpm	Slot velocity = 1000 fpm
VP = 0.25"	VP_s = 0.07"
h_{es} slot = 1.78 VP_s	h_{es} slot = 1.78 VP_s
Duct velocity = $\frac{Q}{A_{slot}}$ = 2000 fpm	Duct velocity = 3500 fpm
VP_d = 0.25"	VP_d = 0.76"
h_{ed} transition = 0.25 VP_d	h_{ed} transition = 0.25 VP_d

$$SP_h = h_{es} + h_{ed} + VP_d$$

Substituting given values:

$$SP_h = 1.78\ VP_s + 0.25\ VP_d + VP_d$$

$SP_h = (1.78 \times 0.25) + (0.25 \times 0.25) + 0.25$	$SP_h = (1.78 \times 0.07) + (0.25 \times 0.76) + 0.76$
$SP_h = 0.7575" = 0.76"$	$SP_h = 1.0746" = 1.07"$

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The use of "Equation 2" is illustrated in the case of a hood where:

Slot velocity = 4000 fpm
Duct velocity = 2000 fpm
VP_s = 1.00"
VP_d = 0.25"

$$SP_h = h_{es} + h_{ed} + VP_s{}^*$$
$$= (1.78 \times 1.00") + (0.25 \times 0.25") + 1.00"$$
$$SP_h = 2.8425" = 2.84"$$

* In an actual installation there may be some regain of the higher VP as the air passes through the hood. It is not possible to predict this, however, and it is better to assume that the energy requirement is as shown.

Certain hoods may be constructed with internal baffles and/or slots and can have more than two significant energy losses. In such cases, a simple step-by-step calculation of all losses will result in an accurate determination of SP_h.

Ventilation of Radioactive and High Toxicity Operations

Ventilation of radioactive and high toxicity processes requires a knowledge of the hazards, the use of proven control methods and adequate maintenance, including monitoring. While the degree of air or gas cleanliness required will vary with the operation, in most cases the order of cleaning before discharge to atmosphere will be considerably beyond the more usual industrial clean air standards.

The chemical laboratory exhaust hood (VS-203) illustrates typical design criterion. The influence of eddy currents from air supply systems, the care in sizing and locating exhaust connections, the study of air flow patterns within the hood and the cleaning of exhaust gases are much more involved than the rule of thumb design efforts for usual laboratory hoods where dilution ventilation greatly contributes to satisfactory control. The same care is mandatory for air supply and exhaust systems and the selection of air cleaning equipment. Air cleaning of supply air is normally of a high order of efficiency and the exhaust air cleaning is often a combination of high-efficiency collectors or filters backed up by absolute or ultra high-efficiency designs.

Exposure of service personnel and contamination hazards from servicing or replacing collector or filter elements justify the expensive equipment so often encountered. Wet dust collector designs in place of inexpensive air filters may store material more safely and may make contamination of an area less likely. Reverse jet fabric arresters will often be used in place of less expensive conventional fabric because there are fewer feet of air seals to leak and fewer elements to be replaced. Scalping or prefilters installed in series with absolute filters will reduce replacement cycle, reduce handling, waste disposal and possible contamination problems.

The following general rules should be followed in the design of hoods for radioactive and high toxicity materials:

1. Operations in which radioactive materials are handled should be enclosed as much as possible to prevent contaminating large air volumes. (The use of glove boxes minimizes air volumes and simplifies air-treatment problems.)
2. High velocities and cross-drafts should be avoided because they may increase contamination and dust loading many fold.
3. The volume of air withdrawn from the hood must be greater than the volume of contaminated gases, fumes or dusts created in the hood.
4. If possible, the operations requiring large amounts of wet digestion and volatilized acid or solvent treatment should be confined to one group of hoods and the handling of dry material in others.
5. Whenever possible, radioactive aerosols should be removed by filtration as close to the hood as practical to prevent unnecessary contamination of equipment and ductwork.
6. The value or accountability of the material may require a design so that even the smallest chips and turnings can be reclaimed.
7. An adequate supply of coolant inside the hood may be necessary, depending on the pyroforic nature of the contaminant.
8. Accessibility for decontamination of the hood and duct system must be made as easy as possible and quite frequently stainless steel is used for the metal parts of the hood for this reason.
9. The fan should be located so ductwork within the building is under a negative pressure.

Normally, for laboratory type hoods, an average face velocity of 125-200 fpm and a minimum face velocity of 100 fpm would be necessary to insure that no contaminant would escape into the room. In addition, face

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velocities of laboratory hoods with adjustable fronts should be controlled within reasonable limits in order to reduce the disturbances of air-borne materials within the hood. This velocity control can be accomplished by either proportional bypass (constant volume) or controlled face velocity (variable volume). Hoods with high heat loads should have a major portion of the air exhausted through the slot at the top.

In the laboratory handling of high alpha or beta emitters, enclosed glove boxes should be used. With the necessary tight construction, an exhaust volume of from 35 to 50 cfm is usually sufficient for these enclosures. The air locks needed with these hoods should be exhausted if they open directly to the room.

Adequate quantities of makeup air must be furnished by mechanical supply systems and intelligently distributed with relation to exhaust points. Supply air distribution must be arranged to provide general air flow from clean areas toward more contaminated areas. Filtration of supply air is necessary to reduce air-borne dust concentrations, thus prolonging the life of ultrahigh efficiency exhaust filters.

The use of prefilters in laboratory type hoods for radioactive materials prevents contamination of the exhaust piping. A gauge should be installed indicating pressure drop across the filter, so that the filter will be replaced when pressure drop exceeds design value. Filtration of room supply air will prolong the life of ultra high efficiency hood exhaust filters.

Where there is a possibility of spontaneous or continuous release of toxic materials, or where several hoods are connected to a single exhaust system the exhaust fan should be operated continuously. Standby fan capacity should be available for breakdowns.

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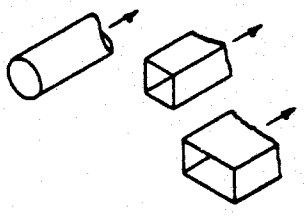
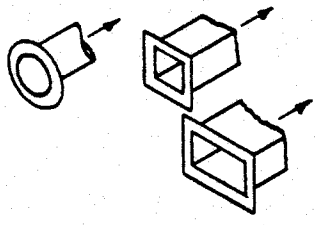
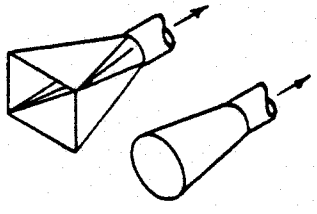
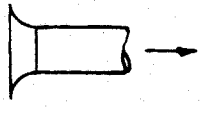
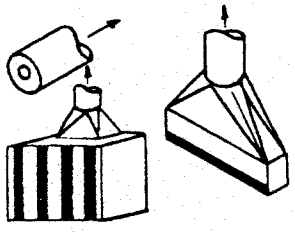
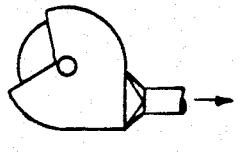
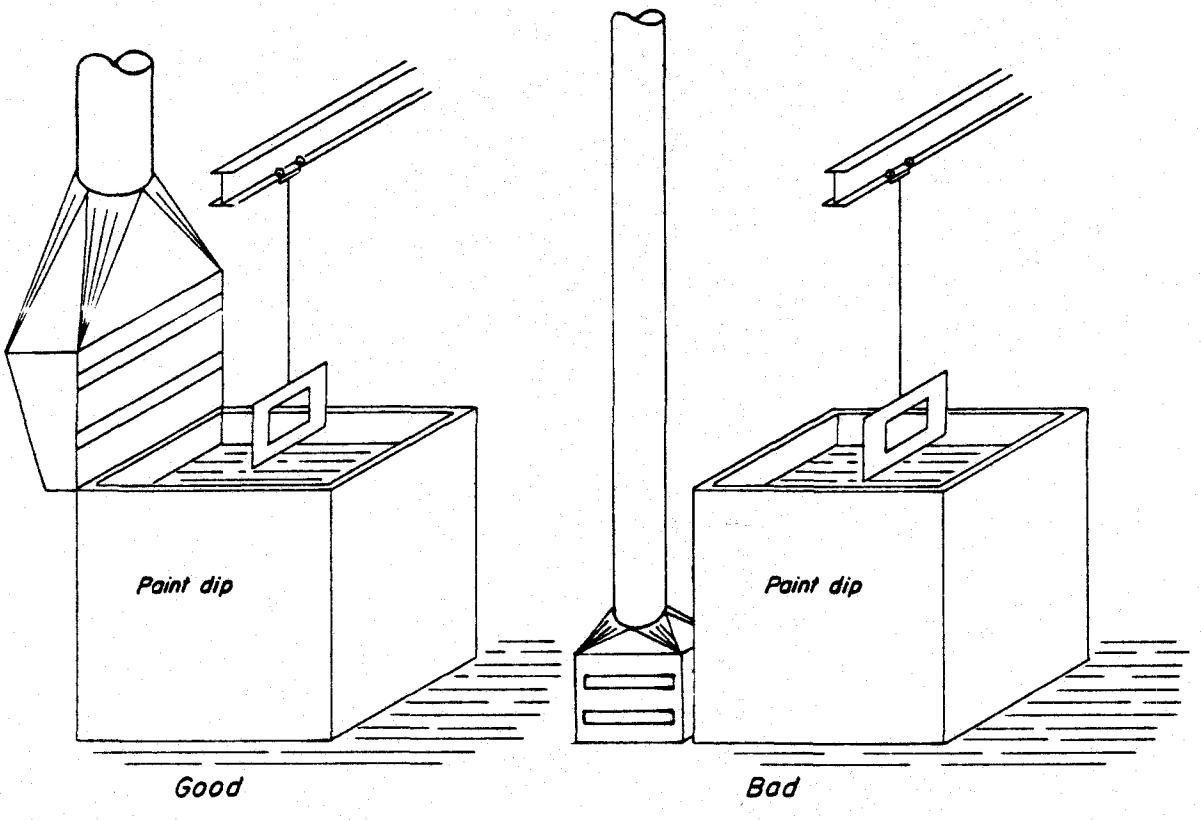
HOOD TYPE	DESCRIPTION	COEFFICIENT OF ENTRY, Ce	ENTRY LOSS
	PLAIN OPENING	0.72	0.93 VP
	FLANGED OPENING	0.82	0.49 VP
	TAPER or CONE HOOD	Varies with angle of taper or cone. See Fig. 6-10	
	BELL MOUTH INLET	0.98	0.04 VP
	ORIFICE	See Fig. 6-10	
	TYPICAL GRINDING HOOD	STRAIGHT TAKE-OFF 0.78	0.65 VP
		TAPERED TAKE-OFF 0.85	0.40 VP

Fig. 4-8

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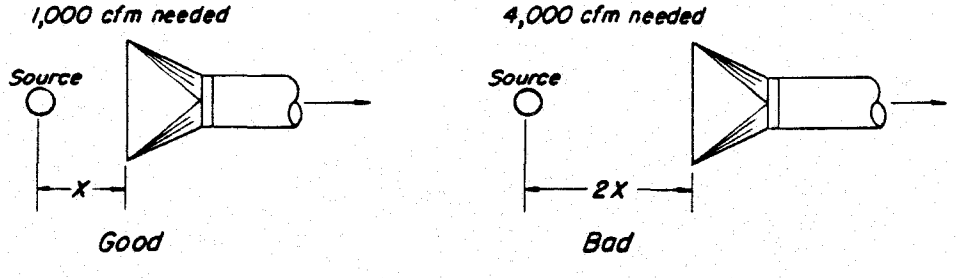
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LOCATION

Solvent vapors in health hazard concentrations are not appreciably heavier than air Exhaust from the floor usually gives fire protection only.

Example:	*Density of air*	*1.0*
	Density of 100% amyl acetate vapor	*4.49*
	Density lowest explosive mixture	*1.038*
	Density T.L.V. mixture	*1.0003*



LOCATION

Place hood as close to the source of contaminant as possible. The required volume varies with the square of the distance from the source.

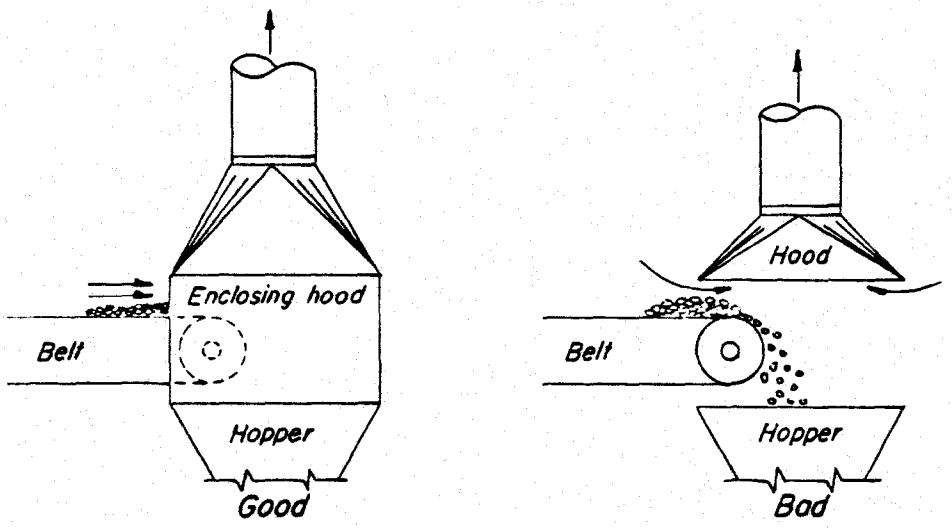
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PRINCIPLES OF EXHAUST HOODS

DATE 1-64 | Fig. 4-9

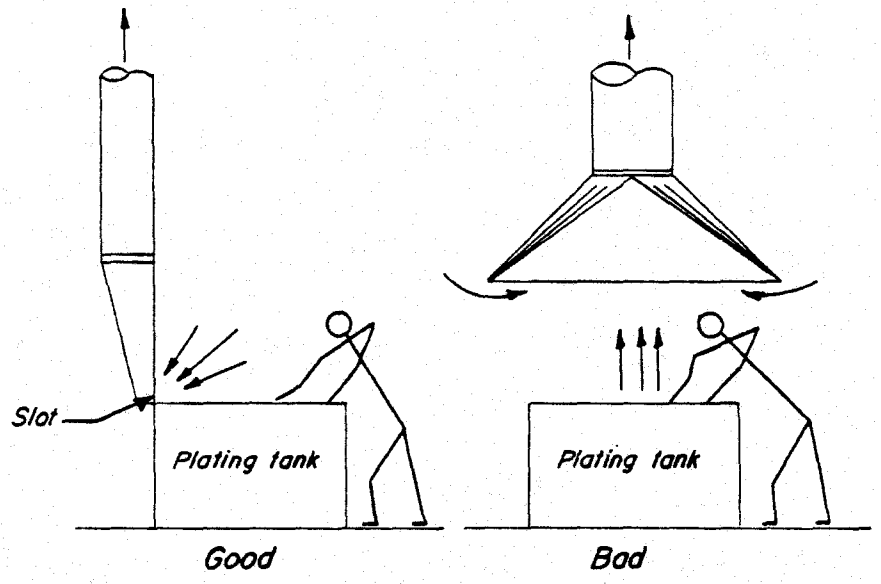
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ENCLOSE

Enclose the operation as much as possible. The more completely enclosed the source, the less air required for control.

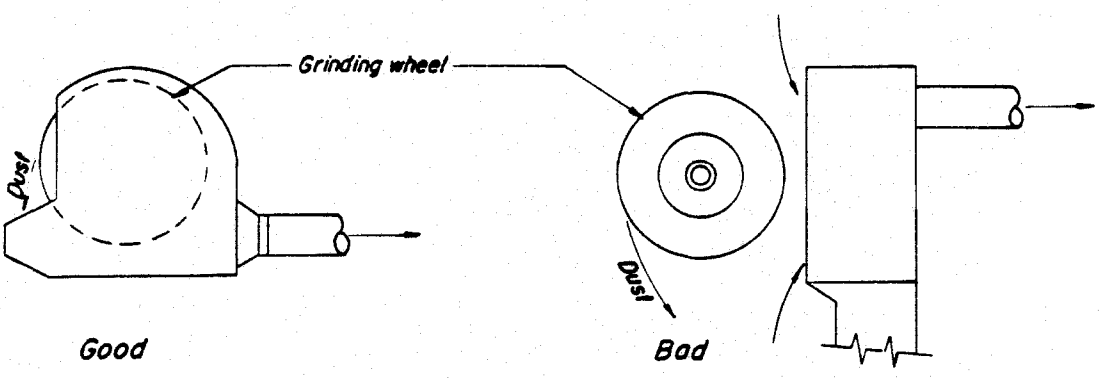


DIRECTION OF AIR FLOW

Locate the hood so the contaminant is removed away from the breathing zone of the worker.

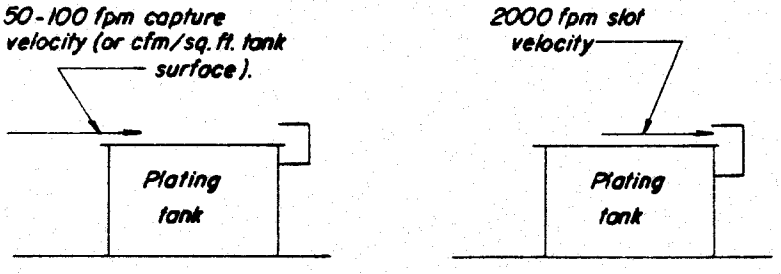
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PRINCIPLES OF EXHAUST HOODS	
DATE 1-64	Fig. 4-10

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LOCATION

Locate and shape the hood so the original velocity of the contaminant will throw it into the hood opening.

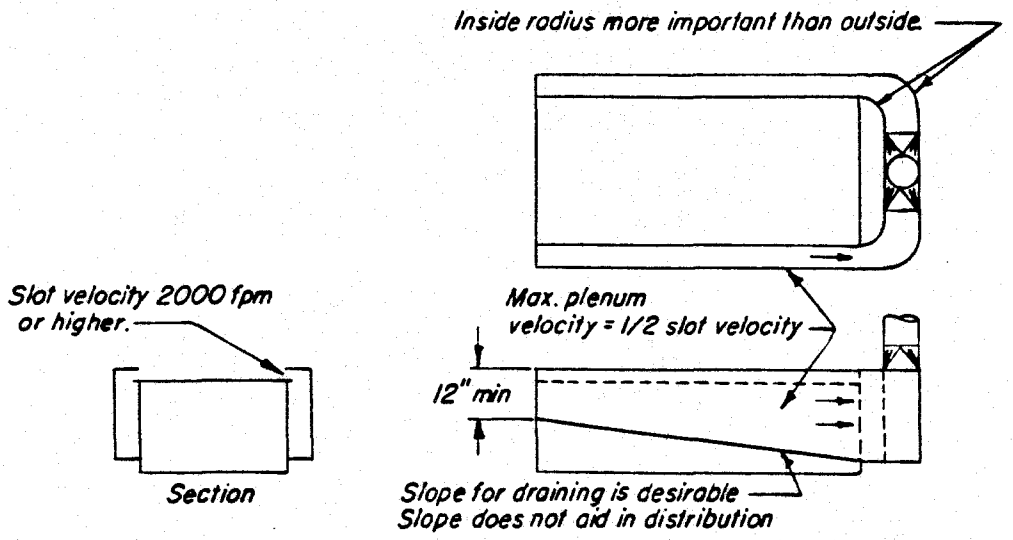


CAPTURE VELOCITY OR PROPER VOLUME

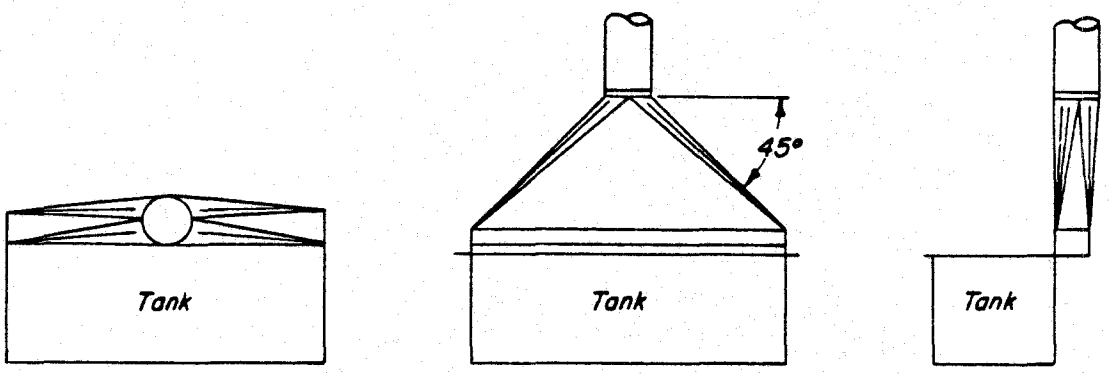
Create air flow past the source sufficient to capture the contaminant (see tables). Many arbitrary standards include this; others do not. Proper standards are usually on:
fpm capture basis at source.
cfm per sq. ft. of source basis.

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PRINCIPLES OF EXHAUST HOODS	
DATE 1-64	Fig. 4-11

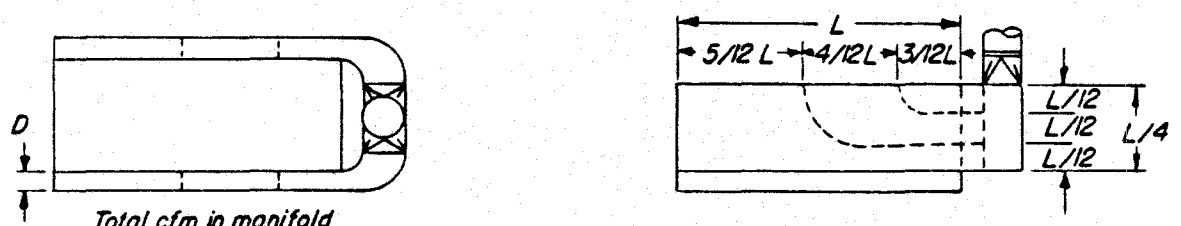
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DISTRIBUTION BY SLOT RESISTANCE



DISTRIBUTION BY FISH TAIL



$D = \frac{\text{Total cfm in manifold}}{500 \times L}$

DISTRIBUTION BY SPLITTER VANES

With low plenum velocities and high slot velocities, good distribution is obtained. If this design is not possible, splitter vanes should be used. Slots over 10 feet to 12 feet in length usually need multiple take-offs.

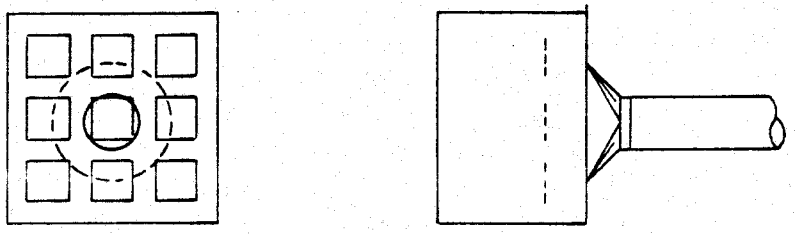
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PRINCIPLES OF MANIFOLD DESIGN

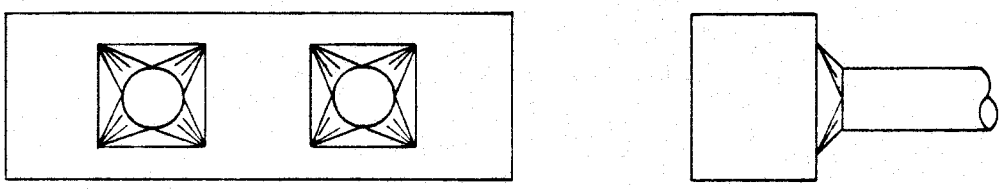
DATE 1-70 | Fig. 4-12

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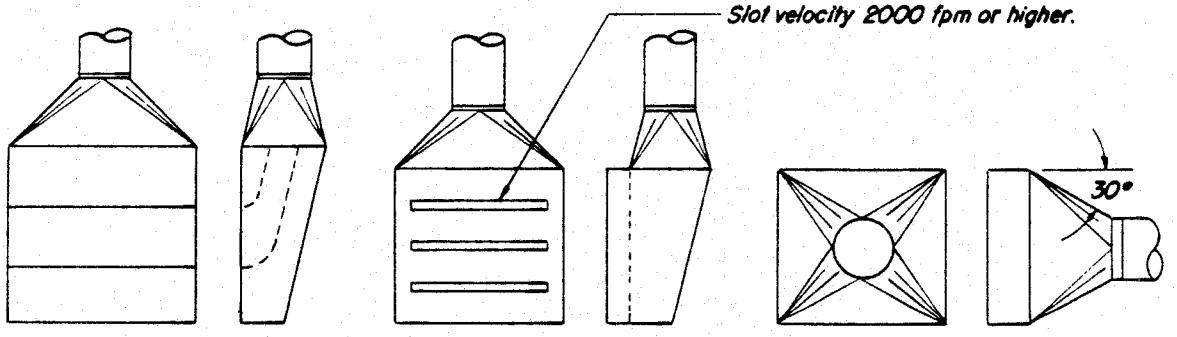


DISTRIBUTION BY BAFFLES
See Fig. 4-16



LONG BOOTHS - DISTRIBUTION BY MULTIPLE TAKE-OFFS and TAPERS

BOOTH-TYPE HOODS
(Same principle apply to canopy type)



DISTRIBUTION BY SPLITTER VANES

DISTRIBUTION BY SLOT (or baffles)

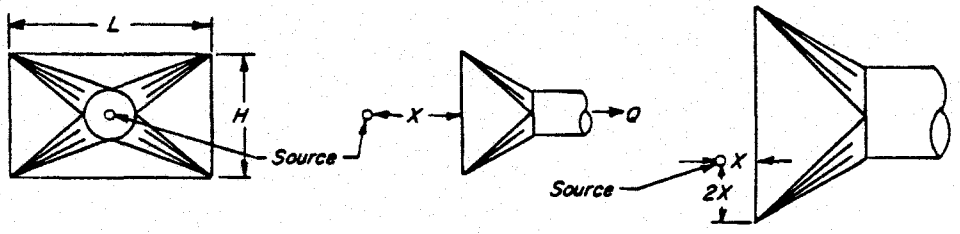
DISTRIBUTION BY TAPER

SIDE-DRAFT & SUSPENDED HOODS

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PRINCIPLES OF MANIFOLD DESIGN	
DATE 1-64	Fig. 4-13

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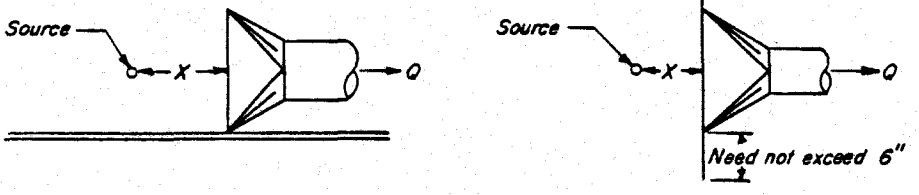
FREELY SUSPENDED HOOD

$Q = (10X^2 + A)V$

Refer to Section 4

LARGE HOOD

Large hood, X small-- measure X perpendicular to hood face, not less than 2X from hood edge.



HOOD ON BENCH OR FLOOR

$Q = 0.75(10X^2 + A)V$

HOOD WITH WIDE FLANGE

$Q = 0.75(10X^2 + A)V$

SUSPENDED HOODS

(Small side-draft hoods)

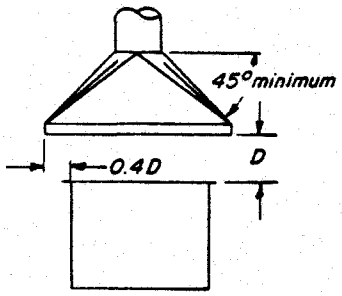
Q = Required exhaust volume, cfm

X = Distance from hood face to farthest point of contaminant release, feet.

A = Hood face area, sq ft

V = Capture velocity, fpm, at distance X.

Note: Air volume must increase as the square of distance of the source from the hood. Baffling by flanging or by placing on bench, floor, ect. has a beneficial effect.



CANOPY HOOD

Q = 1.4 PDV (P = perimeter of tank, feet)

Not recommeded if material is toxic and workers must bend over source. V ranges from 50 to 500 fpm depending on crossdrafts. Side curtains on two or three sides to create a semi-booth or booth are desirable. Suitable for steam vapor or other innocuous material.

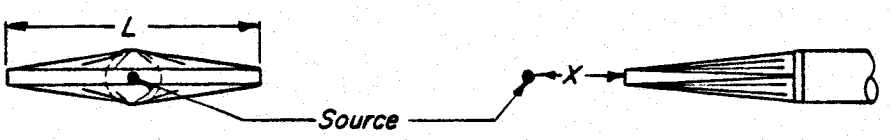
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HOOD DESIGN DATA

DATE 1-66 | Fig. 4-14

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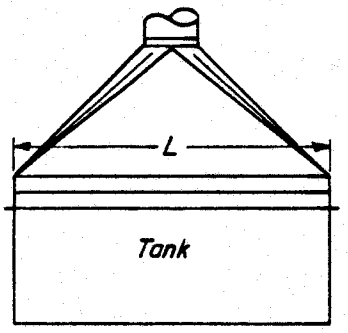


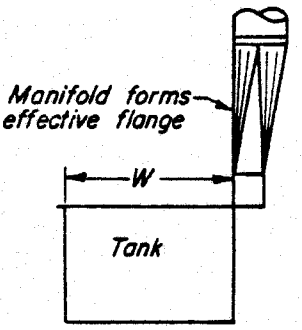
FREELY SUSPENDED SLOT
Q=3.7LVX



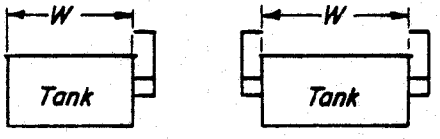
SLOT ON TABLE OR BENCH
Q = 2.8 LVX

Q= Required exhaust volume, cfm
X=Distance, feet, hood face to farthest point of source (usually on centerline of hood)
V=Capture velocity, fpm, at distance X
L=Length, feet, of hood, slot, table, tank, etc
W=Width, feet, of table, tank, etc

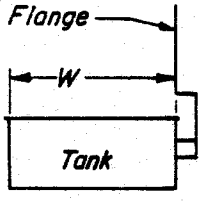




FLANGED SLOT
Q=CLW



SLOT ON TANK
Q=CLW
One-half Q in each slot if slots on both sides



FLANGED SLOT
Q=CLW

L=Length of slot, feet
W=Width of table or tank, feet
C=Constant, varies from 50 to 500, usual choice is 150 to 250. Flanged slots require lowest exhaust. See Section 5

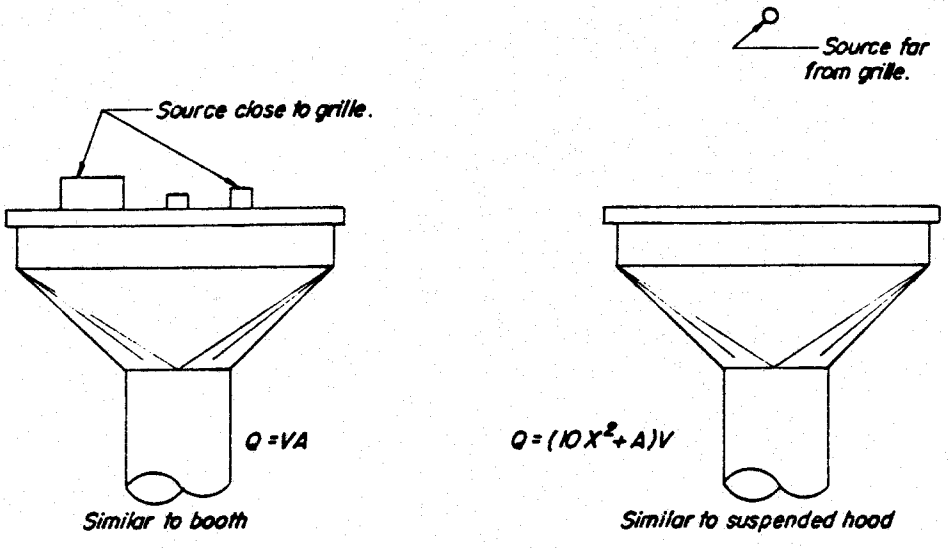
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HOOD DESIGN DATA

DATE 1-66 | Fig. 4-15

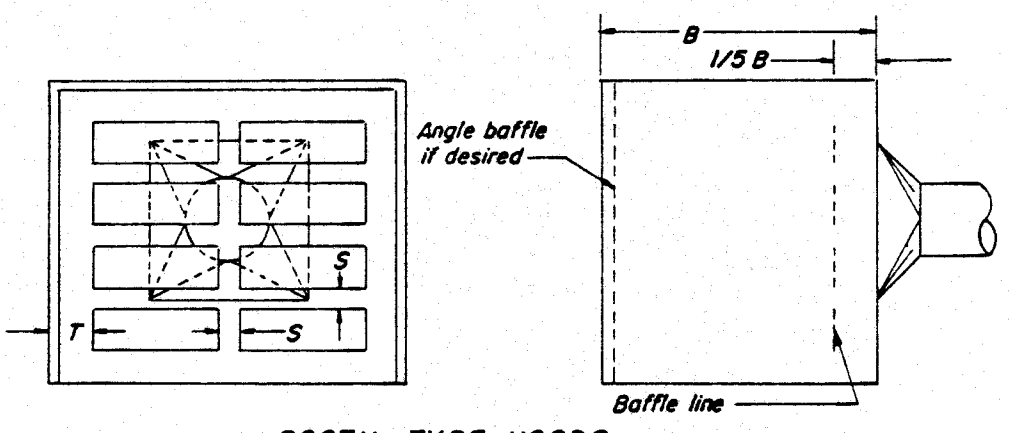
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DOWNDRAFT HOODS

Not recommended for hot or heat-producing operations if downdraft area is large, see "Capture Velocity" in this Section.



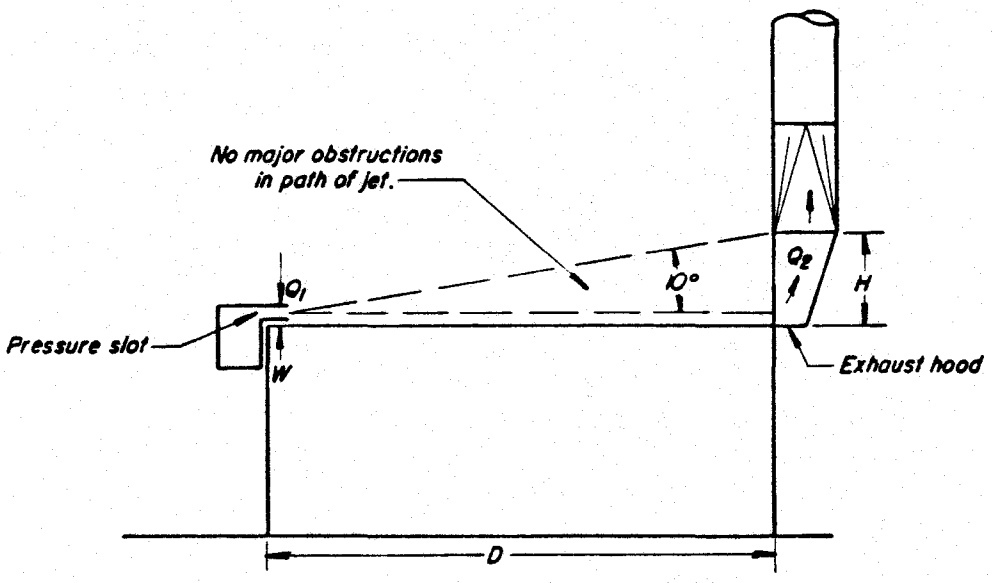
BOOTH - TYPE HOODS

Q = AV (A = face area, sq. ft.; V = face velocity, fpm).
Baffles are optional for air distribution; not required if a water wall booth or if other means for distribution is provided.
S varies from 4 inches to 8 inches, depending on size of booth.
T varies from 6 inches to 12 inches, depending on size of booth.
Increase the number of panels with size of booth.
For booths 3 feet by 3 feet and smaller, provide one panel 6 inches larger than fan diameter.

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HOOD DESIGN DATA	
DATE 1-64	Fig. 4-16

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PUSH PULL HOODS

Exhaust Hood

Quantity of air exhausted,
Q_2 = 100 to 150 cfm /sq. ft. of tank area, depending on temperature of liquid, cross drafts, agitation, etc.

Hood height should be,
$H = D \times \tan 10°$.
$= 0.18D$

Pressure Slot

Quantity of air supplied,

$$Q_1 = \frac{1}{D \times E} \times Q_2$$

where; D = length of throw, feet
E = entrainment factor.

Throw length, D, feet	Entrainment factor, E
0 - 8	2.0
8 - 16	1.4
16 - 24	1.0
over 24	0.7

Slot width W should be designed for a velocity of 1000 to 2000 fpm.

Design such systems so they can be easily modified or adjusted to obtain desired results.

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HOOD DESIGN DATA

DATE 1-64 | Fig. 4-17

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Section 5

SPECIFIC OPERATIONS

The following illustrations of hoods for specific operations are intended as guides for design purposes and apply to usual or typical operations. In most cases they are taken from designs used in actual installations of successful local exhaust ventilation systems. All conditions of operation cannot be categorized and because of special conditions, i.e., cross drafts, motion, differences in temperature or use of other means of contaminant suppression, modifications may be in order.

Unless it is specifically stated, the design data are not to be applied indiscriminately to materials of high toxicity, i.e., beryllium and radioactive materials. Thus the designer may require higher or lower air volumes or velocities or other modifications because of the peculiarities of the process in order to adequately control the air contaminant.

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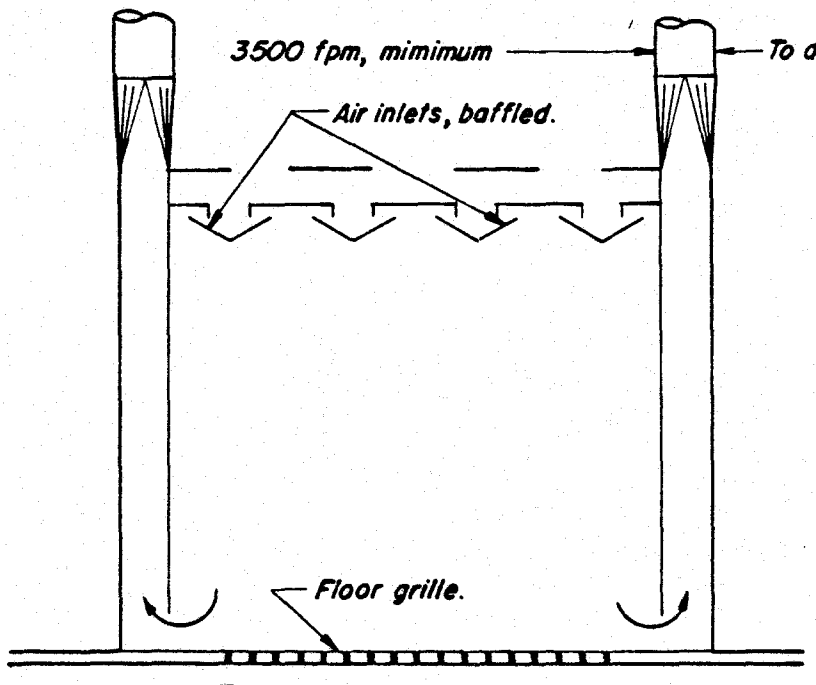
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SECTION THRU TYPICAL ROOM

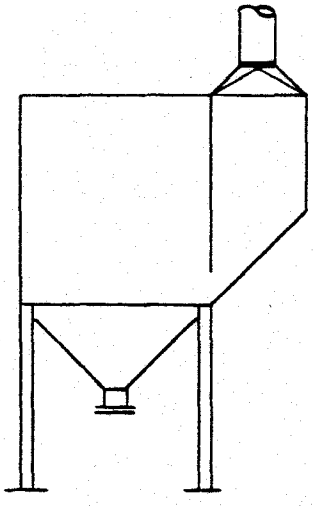
Rooms: 60-100 fpm downdraft; usual choice 80 fpm; or 100 fpm cross-draft. Operator in room requires Bureau of Mines approved abrasive blasting helmets.

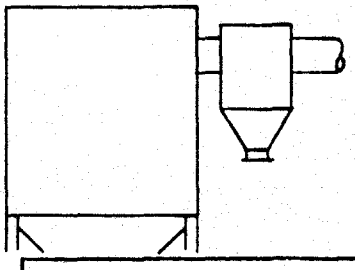
Rotary tables: 200 cfm /sq ft of total openings (taken without curtains).

Cabinets: 20 air changes per minute.

At least 500 fpm inward velocity at all operating openings. Openings to be baffled.

Entry loss: 1 VP; or calculate from individual losses.





For small cabinets: Use rear plenum or trap to settle.

Trap loss: 1.5 VP

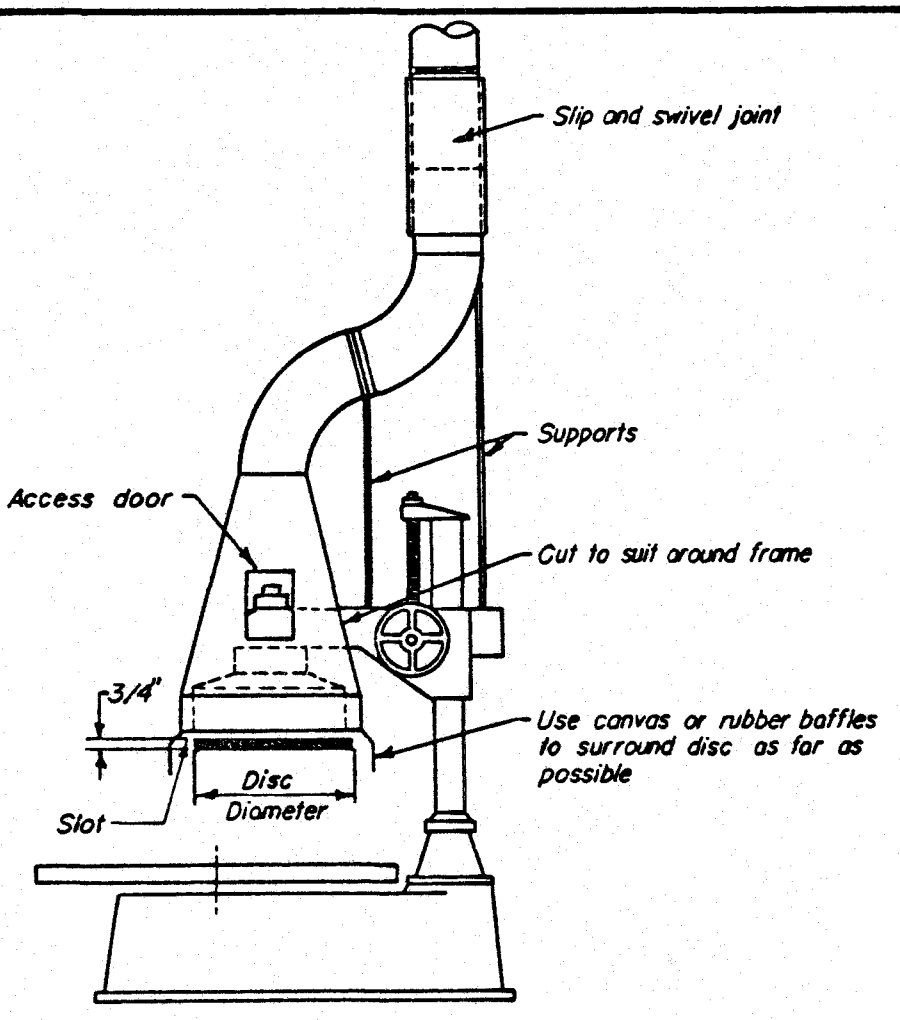
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ABRASIVE BLASTING VENTILATION

DATE	1-64	VS-101

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Disc diameter	Duct diameter	cfm
up to 20"	6"	900
over 20" to 30"	8"	1600
over 30" to 53"	12"	3500
over 53" to 72"	16"	6300

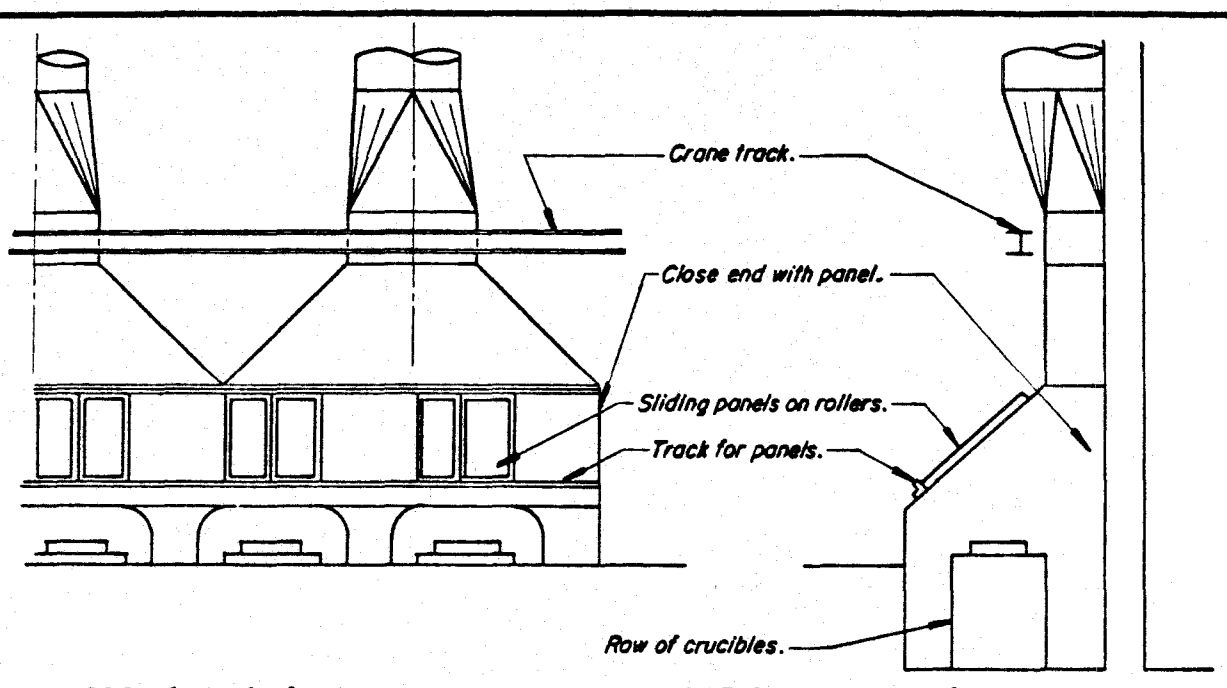
Minimum duct velocity = 4500 fpm branch
3500 fpm main
Minimum slot velocity = 2000 fpm
Entry loss = 1.0 slot velocity pressure plus 0.40 duct VP

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CORE GRINDER

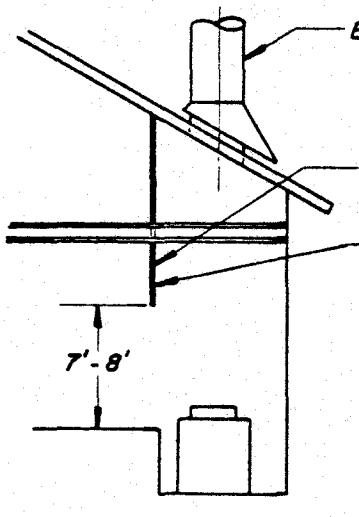
DATE 1-64 | VS-102

1002
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MT-PWHD-004538



Q = 200 scfm/sq ft of opening including doors, plus products of combustion.*
Entry loss = 0.5VP.
Duct velocity = 1000 - 3500 fpm **
* Correct for temperature.
** For horizontal runs, transport velocity is necessary.

NOTE: Same principle of sliding or swinging doors is applied to individual furnace enclosures.



Q = 200 cfm /sq ft of total opening, minimum.

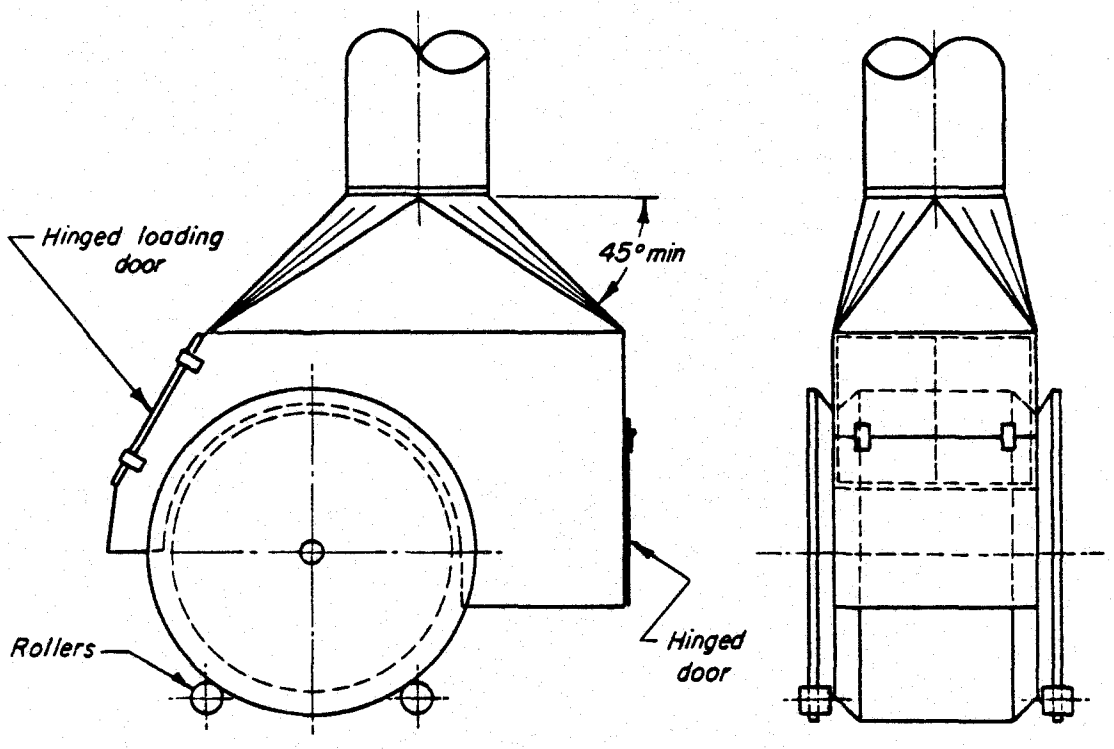
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MELTING FURNACE
CRUCIBLE NON-TILT

DATE 1-64 | VS-103

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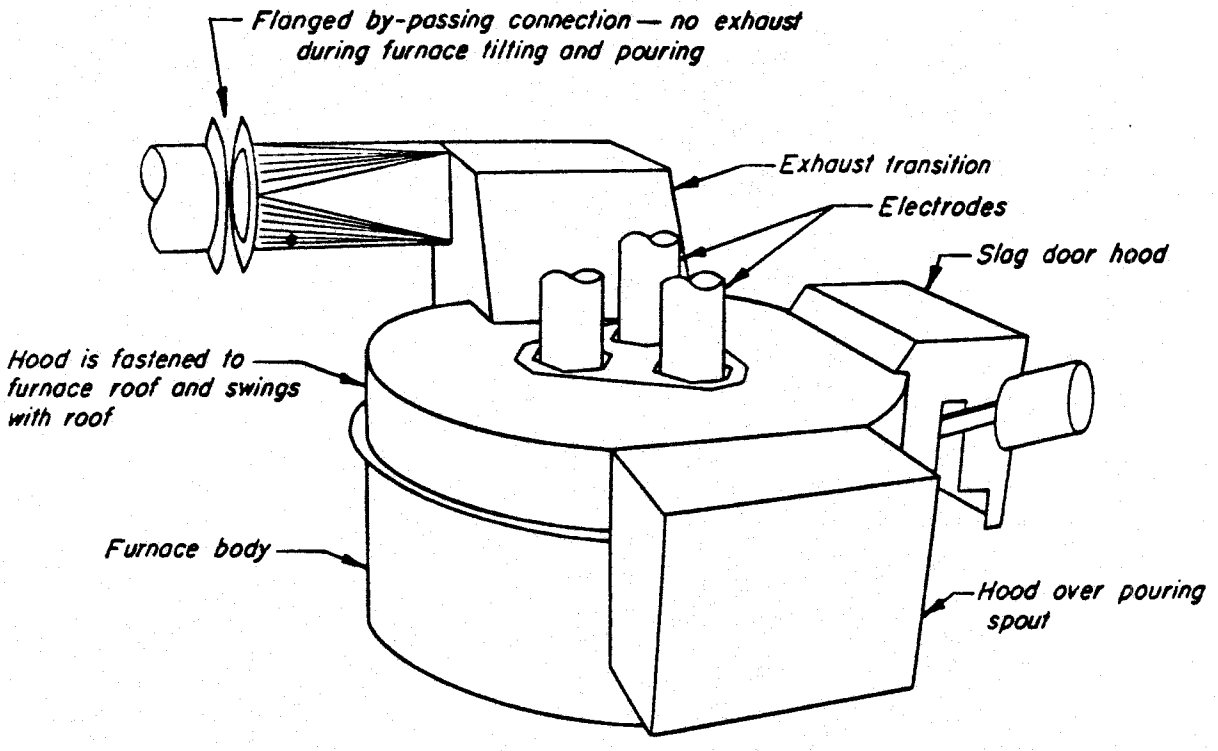


Q = 400 cfm/ft of opening
*Duct velocity = 1000 - 3500 fpm**
Entry loss = 1.78 VP slot + 0.25 VP duct
** For horizontal runs, transport velocity is necessary*

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ELECTRIC ROCKING FURNACE	
DATE 1-64	VS-104

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MT-PWHD-004540



For Q, SP and operating temperature, consult manufacturers
Approximate exhaust volume = 2500 cfm/ton of charge [1][22][23]

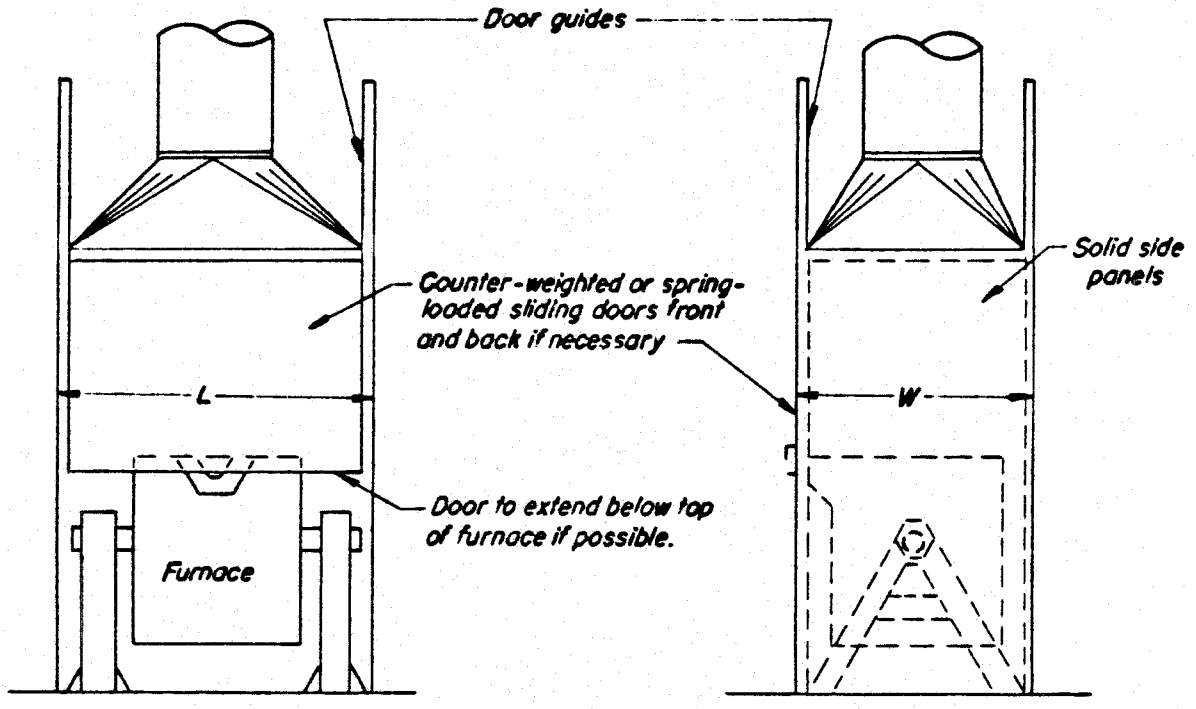
Alternate designs:

1. Other exhaust designs utilize direct furnace roof tap. For details consult manufacturers.
2. Canopy hood exhaust can be utilized but requires large exhaust air volumes; Q = 200 cfm/sq ft of open area between furnace and lower edge of canopy.

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HOOD FOR TOP ELECTRODE MELTING FURNACE	
DATE 1-72	VS-105

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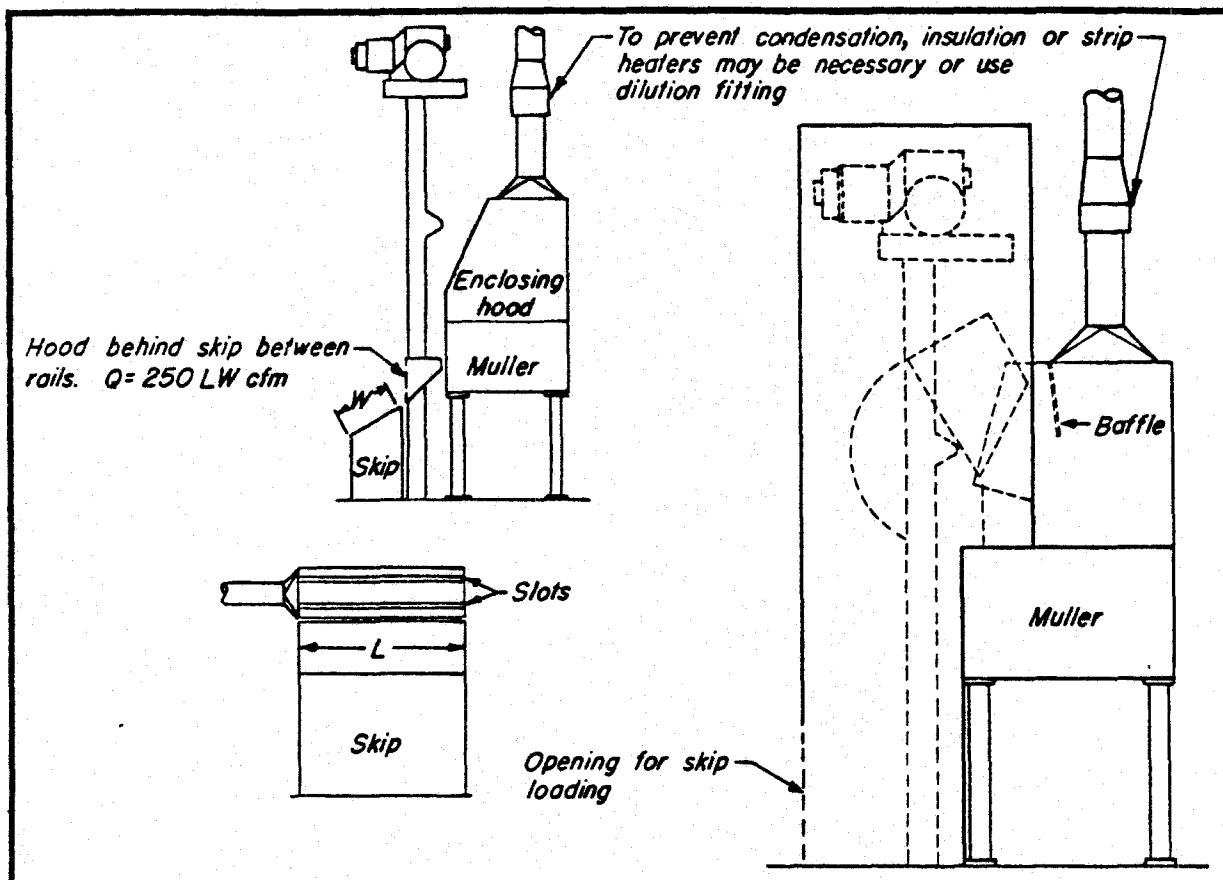


Q = 200 LW; but not less than 200 scfm/sq ft of all openings with doors open.*
Entry loss = 0.25 VP
Duct velocity = 1000 - 3500 fpm**
*Correct for temperature and combustion products.
**For horizontal runs, transport velocity is necessary.

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MELTING FURNACE - TILTING	
DATE 1-64	VS-106

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MT-PWHD-004542



Q= 150 cfm/sq ft through all openings but not less than:

Mixer diam, feet	Exhaust, cfm
4	750
6	900
7	1050
8	1200
10	1575

For Cooling Mullers, See VS-108

Other types of mixers: enclose as much as possible and provide 150 cfm/sq ft of remaining openings

When flammable solvents are used in mixer, calculate minimum exhaust volume for dilution to 25% of the L E L See Section 2

Duct velocity = 3500 fpm, min

Entry loss = 0.25 VP

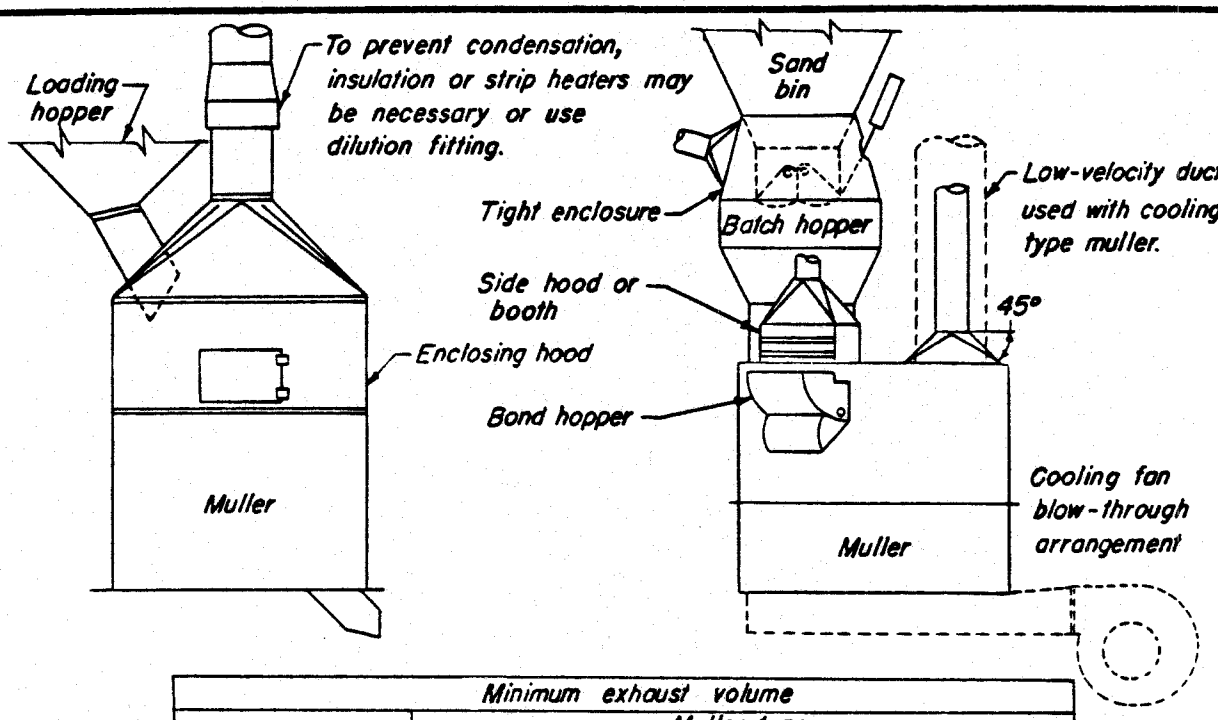
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MIXER AND MULLER HOOD

DATE 1-72 | VS-107

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MT-PWHD-004543



Location	Minimum exhaust volume		
	Muller type		
	No cooling	Blow-thru cooling	Draw-thru cooling
Batch hopper	Note 1	600	Note 1
Bond hopper	600	600	600
Muller:	Note 2	Note 3	Note 3
4' diameter	750	"	"
6' diameter	900	"	"
7' diameter	1050	"	"
8' diameter	1200	"	"
10' diameter	1575	"	"

Duct velocity = 4500 fpm minimum
Entry loss = 0.25 VP

Notes:

1. Batch hopper requires separate exhaust with blow-thru cooling. With other fan arrangement, (muller under suction) separate exhaust may not be required. (If skip hoist is used, see VS-107)
2. Maintain 150 fpm velocity through all openings in muller hood. Exhaust volume shown are the minimum to be used.
3. Cooling mullers do not require exhaust if maintained in dust tight condition. Blow-thru fan must be off during loading. If muller is not dust tight, exhaust as in note 2 plus cooling air volume.
4. When flammable solvents are used in mixer, calculate minimum exhaust volume for dilution to 25% of the L E L See Section 2

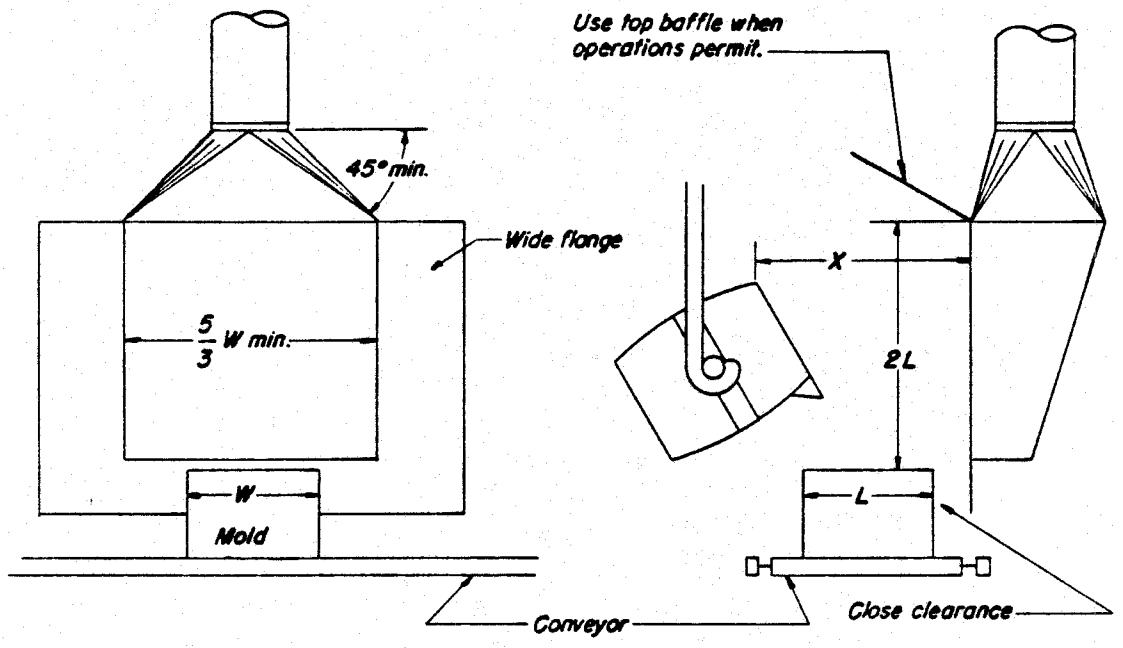
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MIXER AND MULLER VENTILATION

DATE 1-66 | VS-108

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JM - 83

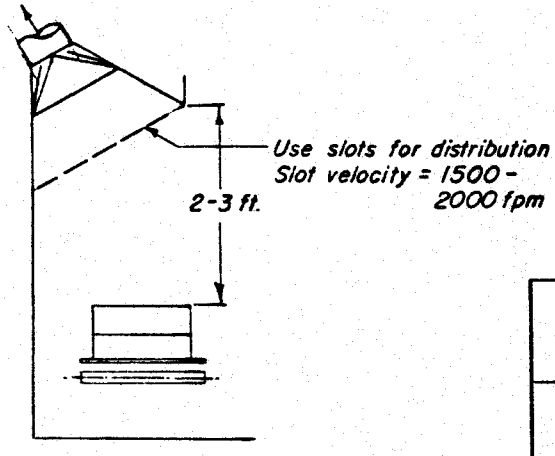
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SMALL MOLDS

Unflanged hood: $Q = 200 (10X^2 + \text{hood area})$.
Flanged hood, reduce Q 25%
Duct velocity = 2000 fpm
Entry loss = 0.25 VP (For slots, 1.78 slot VP + 0.25 duct VP).

PARTIAL SIDE ENCLOSURE



Q = 200 - 300 cfm/lin ft of hood.

NOTE:
For large molds and ladles provide large side-draft hood similar to shakeout.
Q = 400 cfm/sq ft working area.

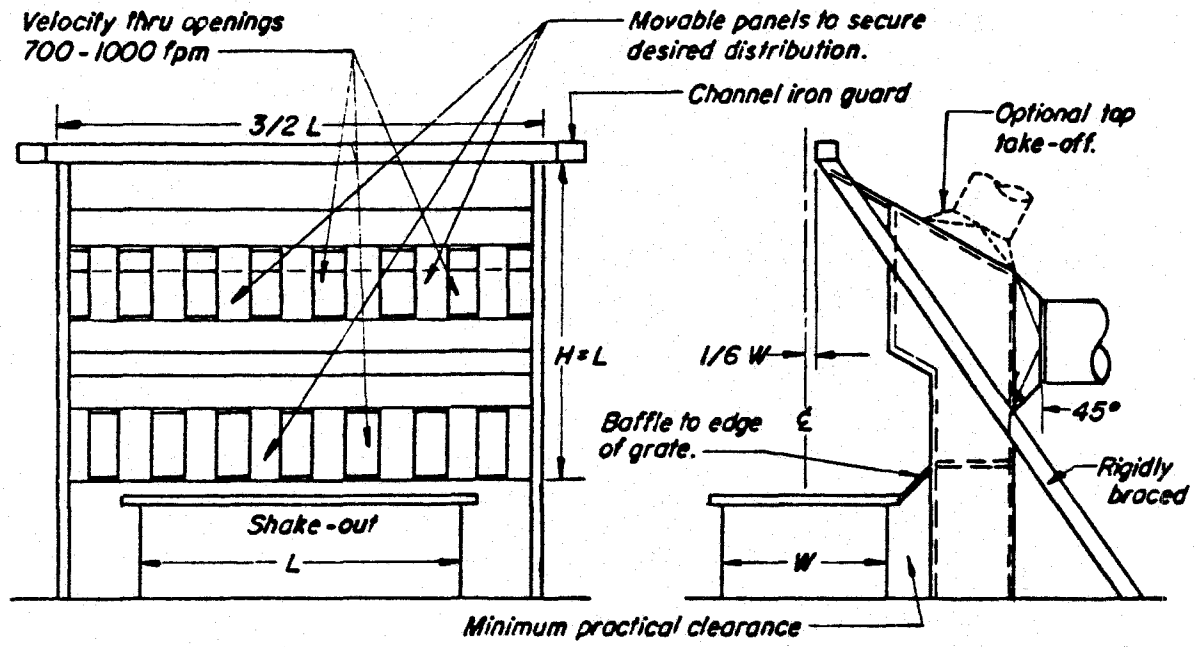
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POURING STATION

DATE 1-64 | VS-109

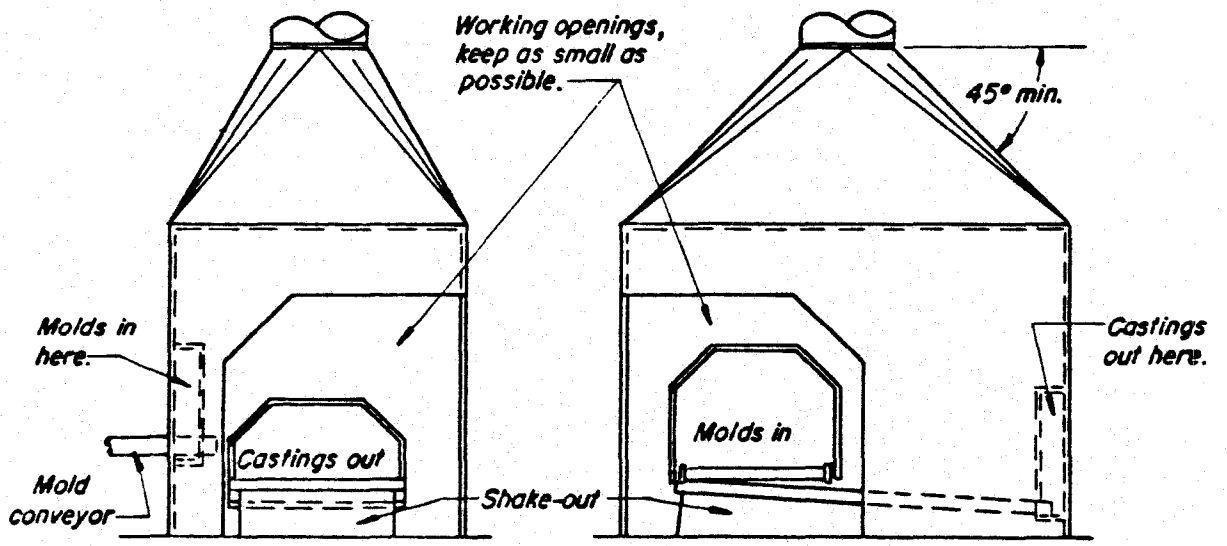
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MT-PWHD-004545



SIDE-DRAFT HOOD

Duct velocity = 3500 fpm minimum.
Entry loss = 1.78 slot VP + 0.25 duct VP



ENCLOSING HOOD

Provides best control with least volume.
Duct velocity = 3500 fpm minimum.
Entry loss = 0.25 VP

See VS-112

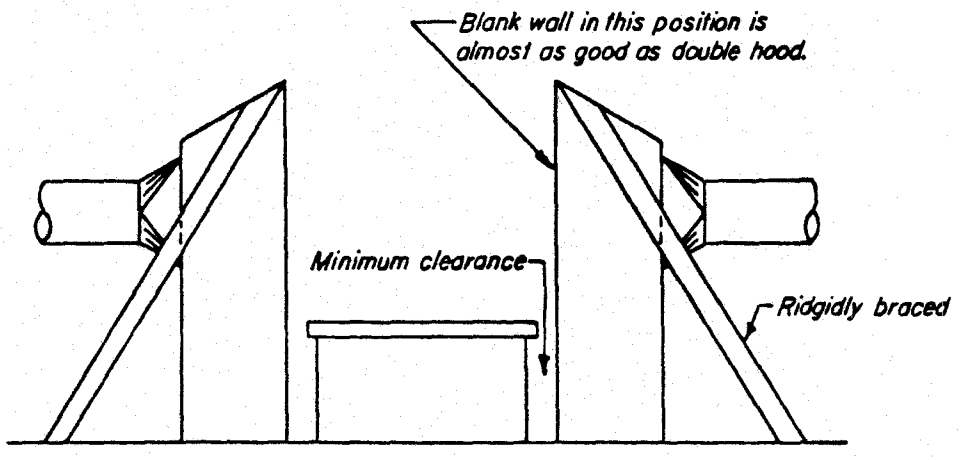
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FOUNDRY SHAKEOUT

DATE	1-64	VS-110

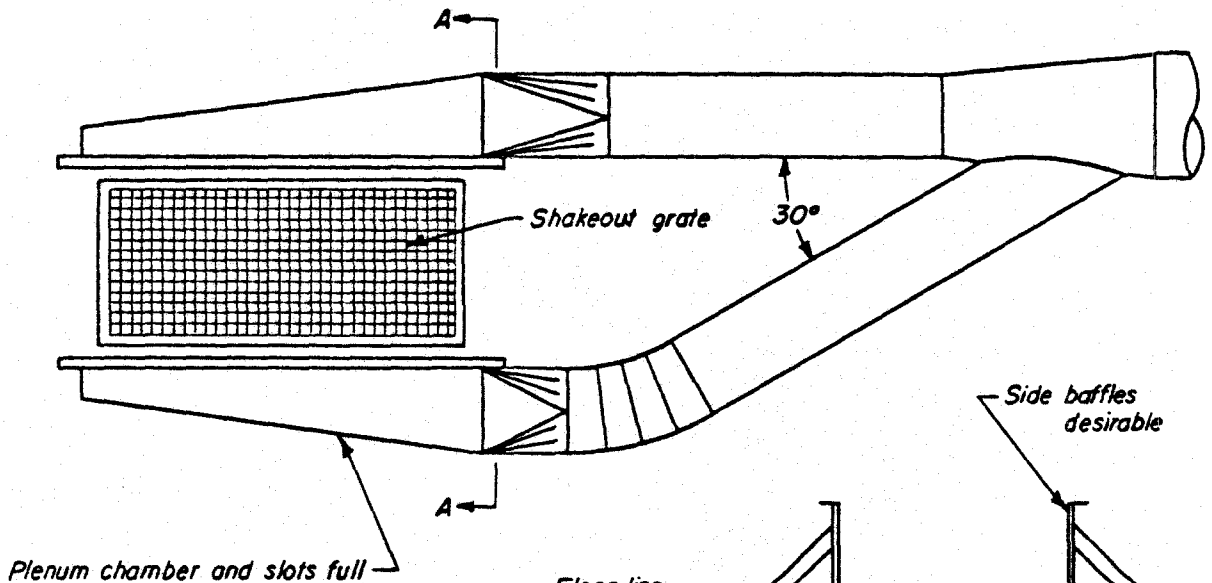
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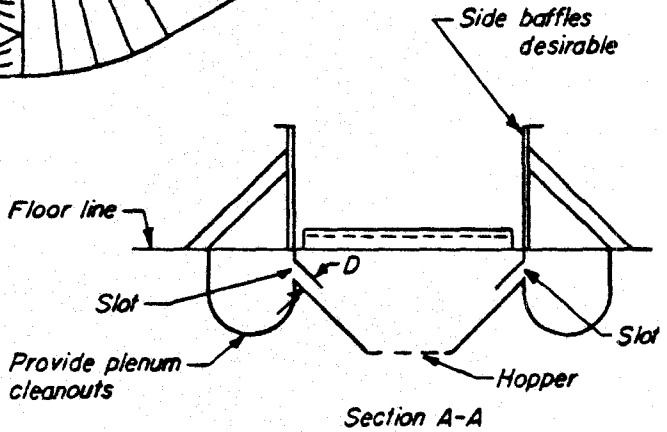
MT-PWHD-004546



DOUBLE SIDE-DRAFT

Proportions same as single side-draft hood except for overhang.





Section A-A

DOWNDRAFT HOOD

Slots sized for 1500 - 2000 fpm
Duct velocity = 4000 fpm minimum
Size D for 1000 fpm or less.
Entry loss = 1.78 slot VP plus fittings
For cool castings only
Difficult to prevent plugging or excess fines removal

See VS-112

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FOUNDRY SHAKEOUT

DATE 1-64 | VS-111

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Property L. H. Manning

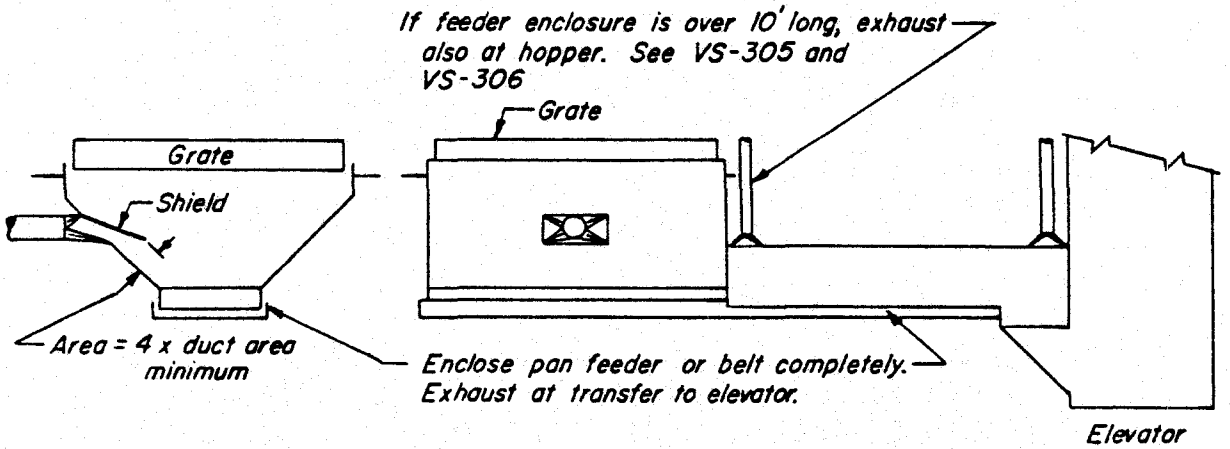
Shakeout exhaust, minimum*

Type of hood	Hot castings	Cool castings
Enclosing**	200 cfm/sq ft opening At least 200 cfm/sq ft grate area	200 cfm/sq ft opening At least 150 cfm/sq ft grate area
Enclosed two sides and 1/3 top area**	300 cfm/sq ft grate area	275 cfm/sq ft grate area
Side hood (as shown or equivalent)**	400-500 cfm/sq ft grate area	350-400 cfm/sq ft grate area
Double side hood**	400 cfm/sq ft grate area	300 cfm/sq ft grate area
Downdraft***	Not recommended 600 cfm/sq ft grate area	200-250 cfm/sq ft grate area

*Choose higher values when
(1) Castings are quite hot
(2) Sand to metal ratio is low
(3) Cross-drafts are high

**Shakeout hoppers require exhaust with 10% of the total exhaust volume.

***Grate area must be greater than flask area. If castings and sand completely cover grate, ventilation will not function.



Hopper exhaust detail

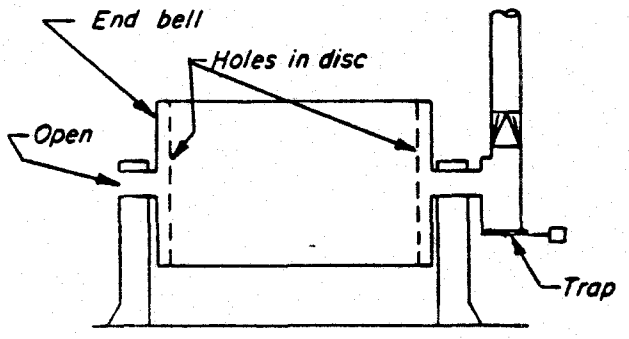
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FOUNDRY SHAKEOUT

DATE 1-64 | VS-112

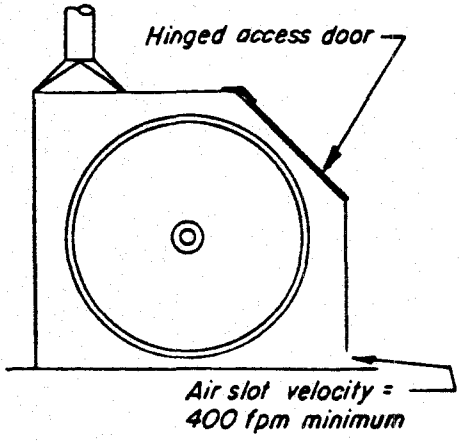
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SECTION THRU HOLLOW TRUNNION TUMBLER

Duct velocity = 5000 fpm
Entry loss = 3.25" - 8.25" H_2O (depends on design*)



STAVE MILL (END SECTION)

Duct velocity = 3500 fpm minimum
Entry loss varies with take-off 0.25 - 0.50 VP

EXHAUST VOLUMES

Square mill side diam in.	Round mill I.D. in inches	cfm**	
		Trunnion	Stave
	Up to 24 incl.	430	800
Up to 24 incl.	24 - 30	680	900
25 - 30	31 - 36	980	980
31 - 36	37 - 42	1330	1330
37 - 42	43 - 48	1750	1750
43 - 48	49 - 54	2200	2200
49 - 54	55 - 60	2730	2730
55 - 60	61 - 66	3300	3300
61 - 66	67 - 72	3920	3920
67 - 72		4600	4600

* Low-loss designs have large air inlet openings in end bell. Holes in end discs are sized for velocities of 1250-1800 fpm
** For lengths over 70", increase cfm proportionately

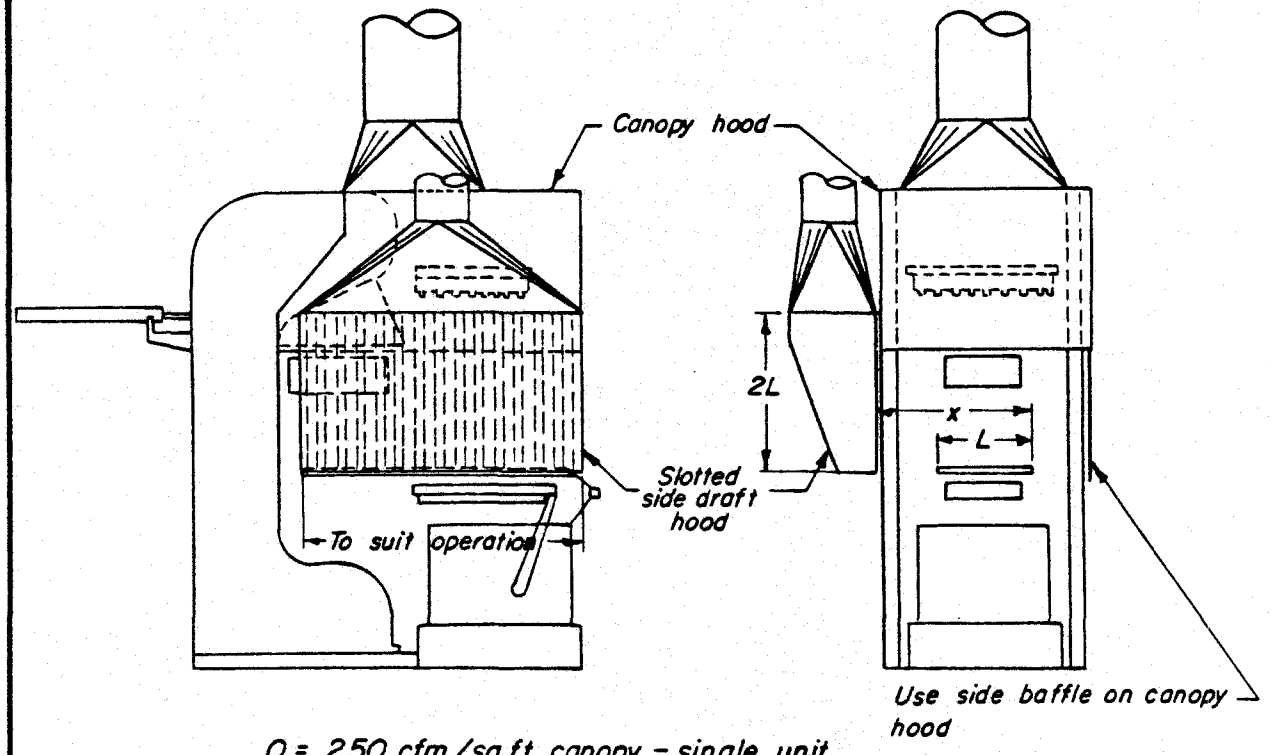
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TUMBLING MILLS

DATE 1-64 | VS-113

1013 PRODUCED JM - 83

MT-PWHD-004549



Q = 250 cfm/sq ft canopy - single unit
150 cfm/sq ft canopy - double unit
Entry loss = 0.25 VP for tapered take-off

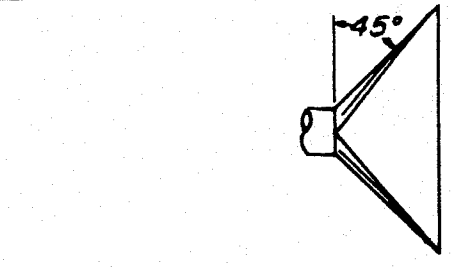
Slotted side draft hoods required to remove smoke as hot cores emerge from machine.
Capture velocity = 75 fpm minimum
Q = 75(10x² + hood area)
Entry loss = 1.78 slot VP + 0.25 duct VP

Conveyor or cooling area require ventilation for large cores. Scrop conveyor or tote boxes may require ventilation also.

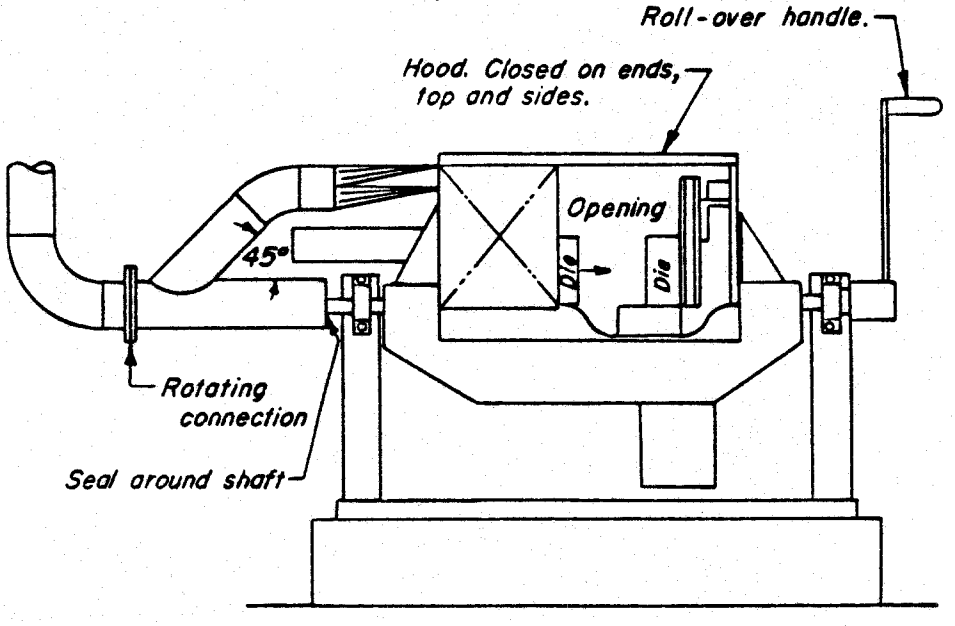
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
SHELL CORE MOLDING	
DATE 1-72	VS-114

1014
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MT-PWHD-004550



Top view of take-off connection.



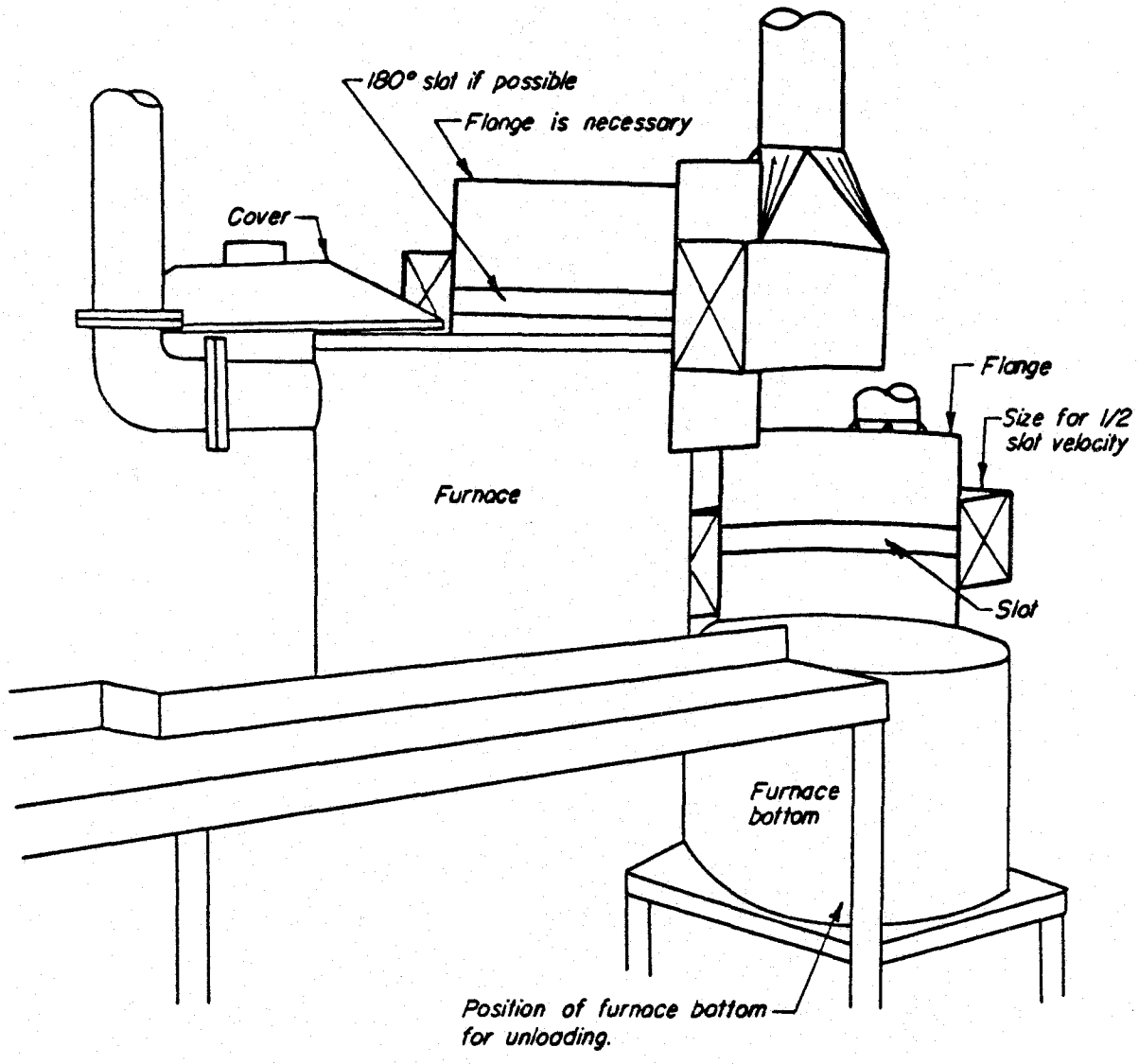
Side view

Q=200 cfm/sq ft of open face area
Duct velocity = 3500 fpm minimum
Entry loss = 0.25 duct VP

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CORE MAKING MACHINE SMALL ROLL OVER TYPE	
DATE 1-70	VS-115

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MT-PWHD-004551

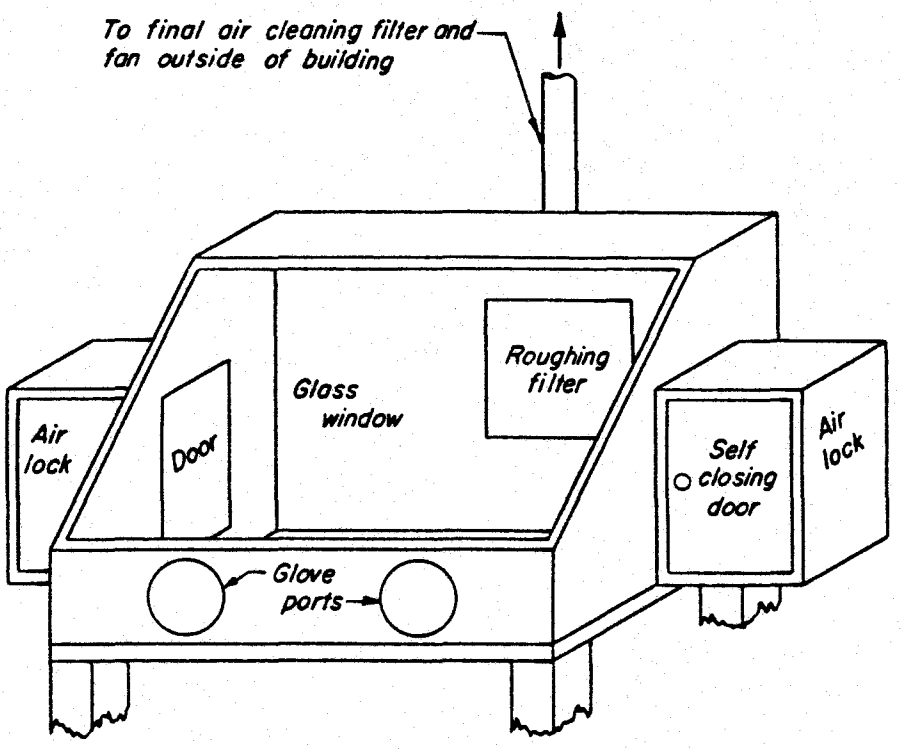


Q = 175 cfm/sq ft of furnace top with curved slot and flanges.
Slot velocity = 2000 fpm
Duct velocity = 3500 fpm
Entry loss = 1.78 slot VP + 0.25 duct VP

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CRUCIBLE MELTING FURNACE HIGH TOXICITY MATERIAL	
DATE 1-64	VS-201

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Q = 50 cfm/sq ft of open door area and 0.25" SP on a closed system.
Entry loss = 0.50 VP
Duct velocity = 2000 - 4000 fpm
Filters: 1. Inlet air filters in doors.
2. Roughing filter at exhaust connection to hood.
3. Final air cleaning filter.
All facilities totally enclosed in hood. Exterior controls may be advisable.
Arm length rubber gloves are sealed to glove port rings.
Strippable plastic on interior and air cleaner on exhaust outlet may be used to facilitate decontamination of the system.
Filter units may be installed in the doors to allow the air flow necessary for burners etc.
For filters, see Section II

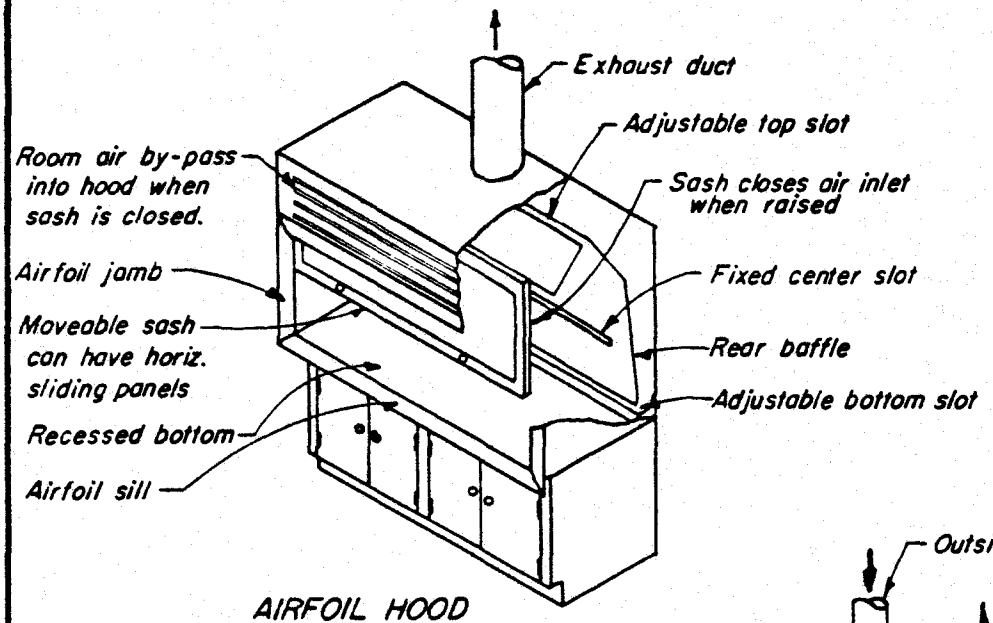
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DRY BOX OR GLOVE HOOD FOR HIGH TOXICITY & RADIOACTIVE MATERIALS

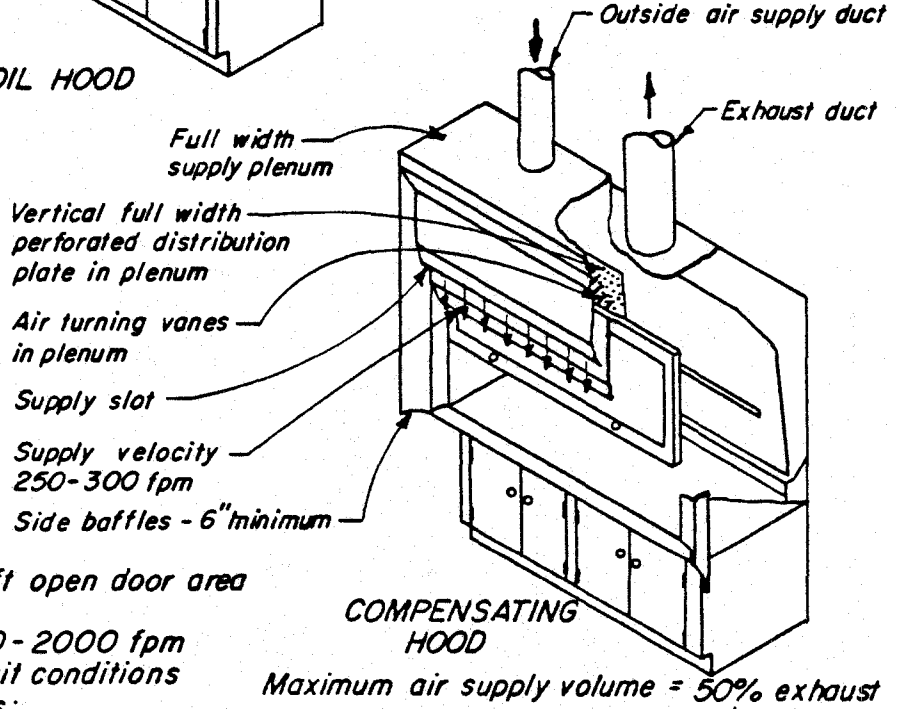
DATE *1-66* | *VS-202*

1017 PRODUCED JM - 83

MT-PWHD-004553



AIRFOIL HOOD



COMPENSATING HOOD

Q = 100-150 cfm/sq ft open door area
Entry loss = 0.5 VP
Duct velocity = 1000-2000 fpm to suit conditions
Design specifications:
Toxic, corrosive substances – See VS-204
Perchloric acid - See VS-205

Maximum air supply volume = 50% exhaust volume

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LABORATORY HOOD	
DATE 1-72	VS-203

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MT-PWHD-004554

A. Exhaust volume

1. 100 cfm/sq ft of door area	Nuisance, corrosive materials. Moderate toxicity materials. Tracer quantities of radioisotopes.
2. 150 sfm/sq ft of door area	High toxicity materials (TLV ≤ 10ppm; 0.1 mg/m^3). Low MPC radioactive materials
3. Glove Box (Dry Box) preferred (Use bench hood with caution and only under ideal conditions)	Very high toxicity materials. (Pathogenic microorganisms)

B. Provide uniform exhaust air distribution in hood. Adjustable baffles and slots are acceptable, but subject to tampering.

C. Locate hood away from heavy traffic aisles, doorways and supply grilles.

D. Use corrosion resisting materials suitable for expected use.

E. Locate exhaust fans outside of buildings.

F. Avoid sharp corners at jambs and sill. Flanges and rounded hood inlets are desirable.

G. Provide filters for radioactive materials in greater than 'exempt' quantities.

H. By-pass opening in hood is desirable to avoid excessive indraft under partially-closed sash and to simplify laboratory air flow balance.

I. Installation and maintenance.
Adjust air flow for ± 20% variation in face velocity. Use suitable velocity measuring instrument. (See Section 9)
Inspect hood periodically; monthly for new or critical installations. Quarterly or semi-annually for others.

J. Provide tempered make-up air to laboratory. Make-up air volume to be selected for slight indraft of air from corridor or adjacent rooms.

K. In order to reduce exhaust volumes, local exhaust hoods should be considered instead of laboratory bench hoods for fixed set-ups.

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LABORATORY HOOD DATA	
DATE *1-72*	*VS-204*

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MT-PWHD-004555

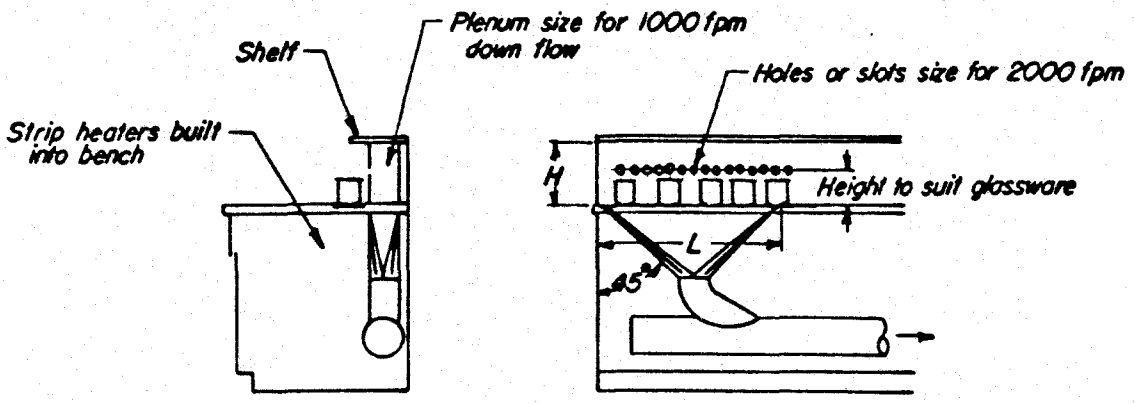
Perchloric Acid is extremely dangerous because it is a very strong oxidizer. When the acid reacts with organic material an explosive reaction product may be formed.

1. Do not use any other material in a hood designed specifically for perchloric acid. Do not use perchloric acid in a hood designed for other purposes. Identify Perchloric Acid hoods with large warning signs.
2. Provide exhaust ventilation equivalent to 150 cfm/sq ft of door opening. Q = 150 × front open area.
3. Utilize local exhaust ventilation within the hood to minimize condensation of vapors inside the hood.
4. Locate all utility controls outside the hood.
5. Materials of construction for this type of hood and ductwork must be non-reactive, acid resistant and relatively impervious. Stainless steel, type 316 with welded joints, is preferred. Unplasticized polyvinyl chloride or an inorganic ceramic coating such as porcelain are acceptable.
6. Ease of cleanliness is paramount using all welded construction for stainless steel with accessible rounded corners.
7. The work surface should be water tight with a minimum of 1/2" dished front and sides and an integral trough at the rear to collect the washdown water.
8. Design washdown facilities into the hood and ductwork. Use daily or more often to thoroughly clean perchloric acid from the exhaust system surfaces.
9. Each perchloric acid hood should have an individual exhaust system. Avoid horizontal runs, and sharp turns.
10. Construct the hood and ductwork to allow easy visual inspection of hidden surfaces.
11. Use a high efficiency (greater than 80%) wet collector constructed for perchloric acid service. Locate as close to the hood as possible to minimize the accumulation of perchloric acid in the exhaust duct.
12. Use only an acid resistant metallic fan, a mettalic fan protected by an inorganic coating or an air ejector.
13. Lubricate the fan with a fluorocarbon type grease.
14. Locate the fan outside of the building.
15. The exhaust discharge must terminate out-of-doors preferably using a vertical discharge cap which extends well above the roof eddy zone. See figures 6-23 and 8-3.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
PERCHLORIC ACID HOOD DATA	
DATE *1-72*	*VS-205*

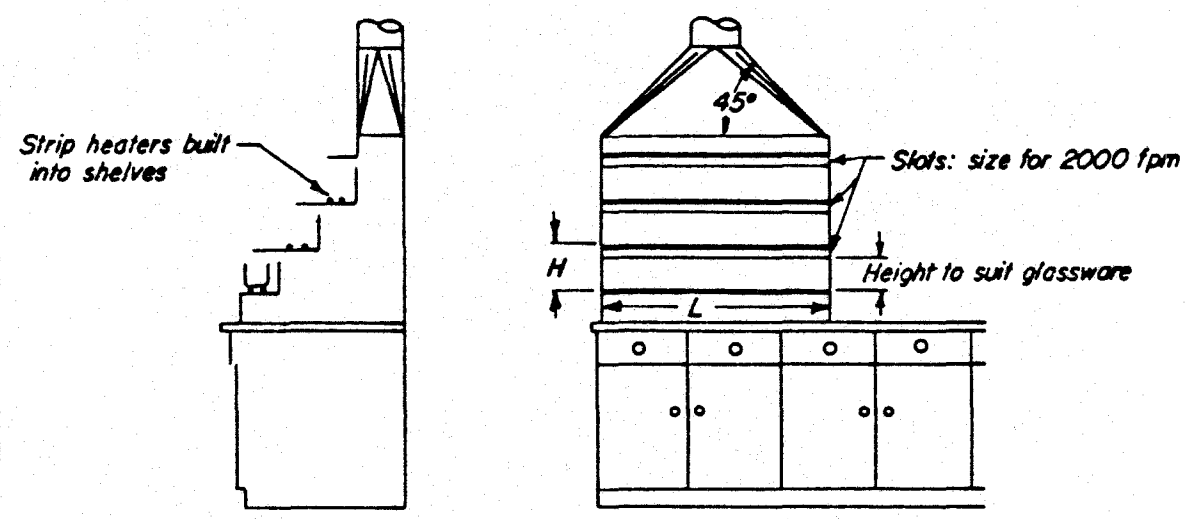
PROJ 1020 JM - 83

MT-PWHD-004556



EVAPORATION BENCH

Q= 20 cfm/lineal foot of hood or 50 HL
Duct velocity = 2000 fpm
Entry loss = 1.78 slot VP + 0.25 duct VP



EVAPORATION HOOD

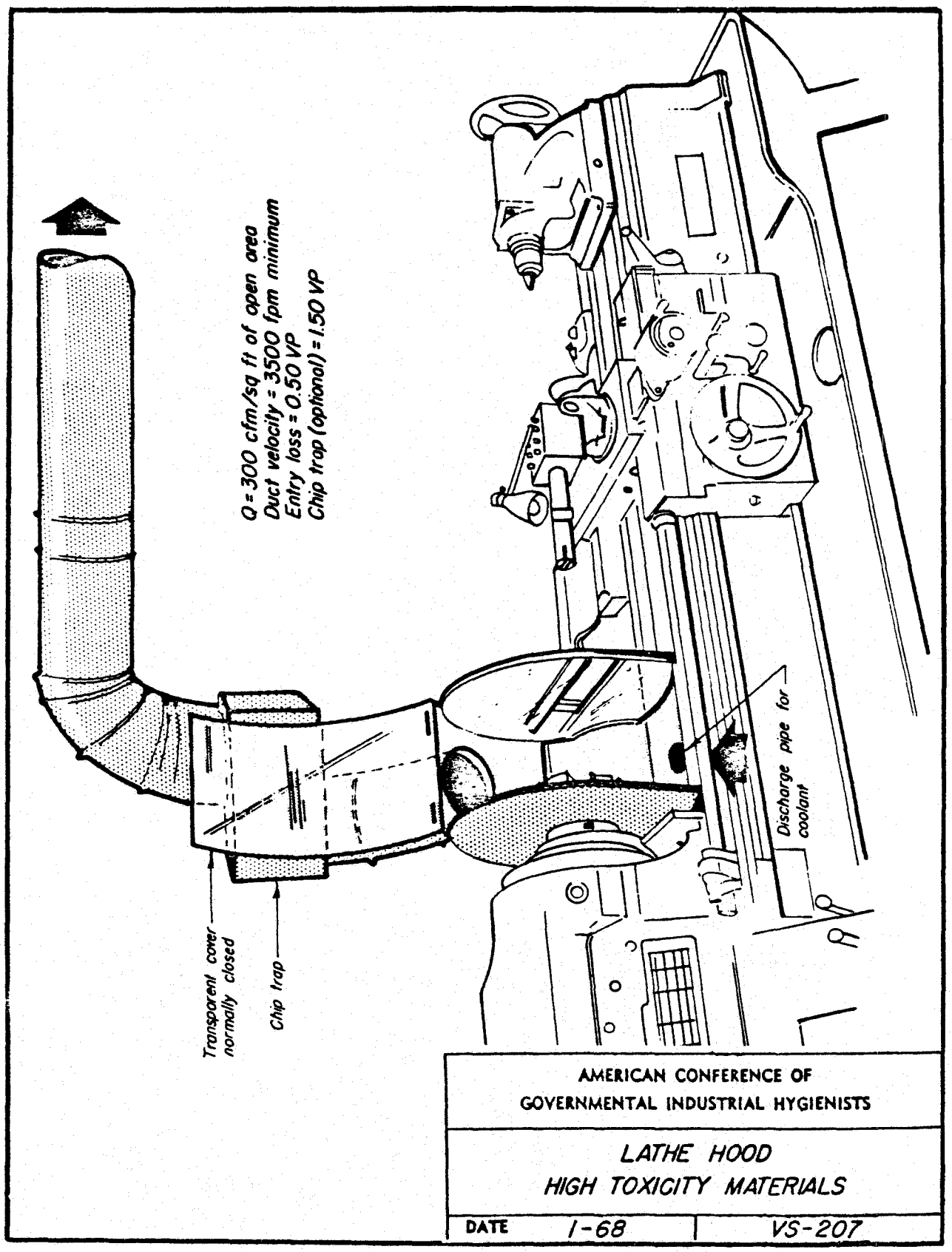
Q= 20 cfm/lineal foot of shelf or 50 HL for each shelf
Duct velocity = 2000 fpm
Entry loss = 1.78 slot VP + 0.25 duct VP

Reference 95

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
SPECIALIZED LABORATORY HOOD DESIGNS	
DATE 1-68	VS-206

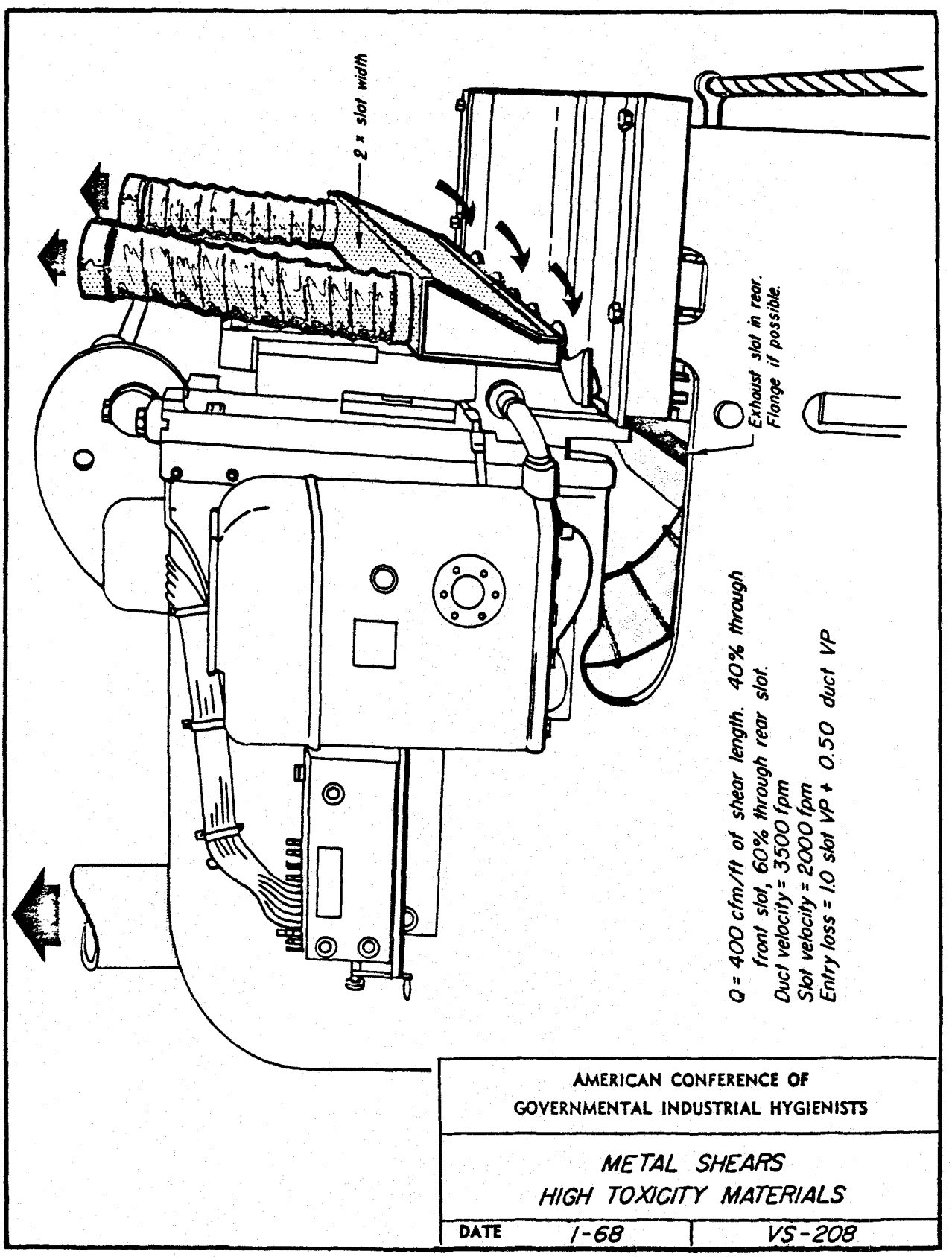
1021
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JM - 83

MT-PWHD-004557



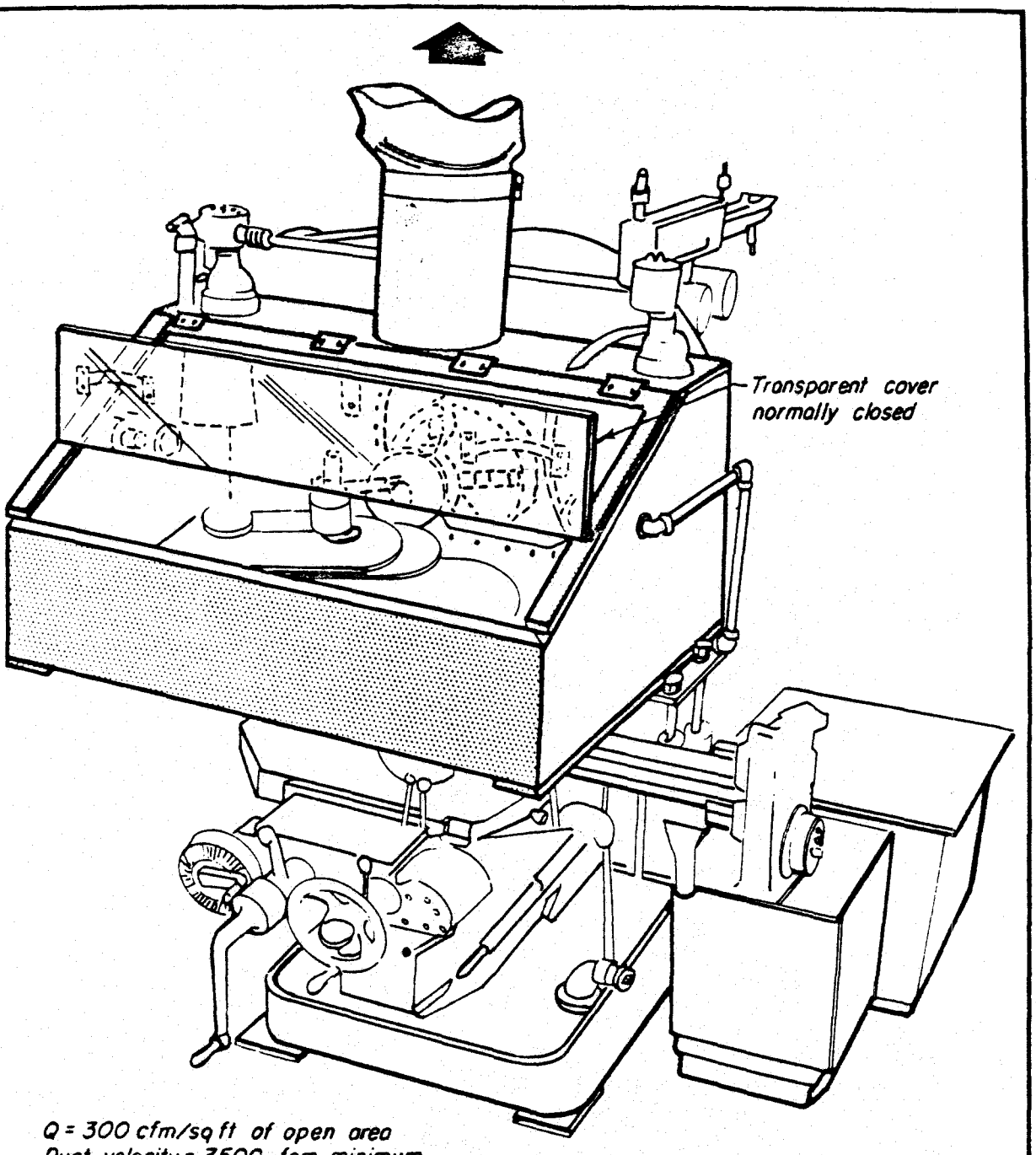
PRODUCED 1022
JM - 83

MT-PWHD-004558



PRODUCED23
JM - 83

MT-PWHD-004559



Q = 300 cfm/sq ft of open area
Duct velocity = 3500 fpm minimum
Entry loss = 0.35 VP

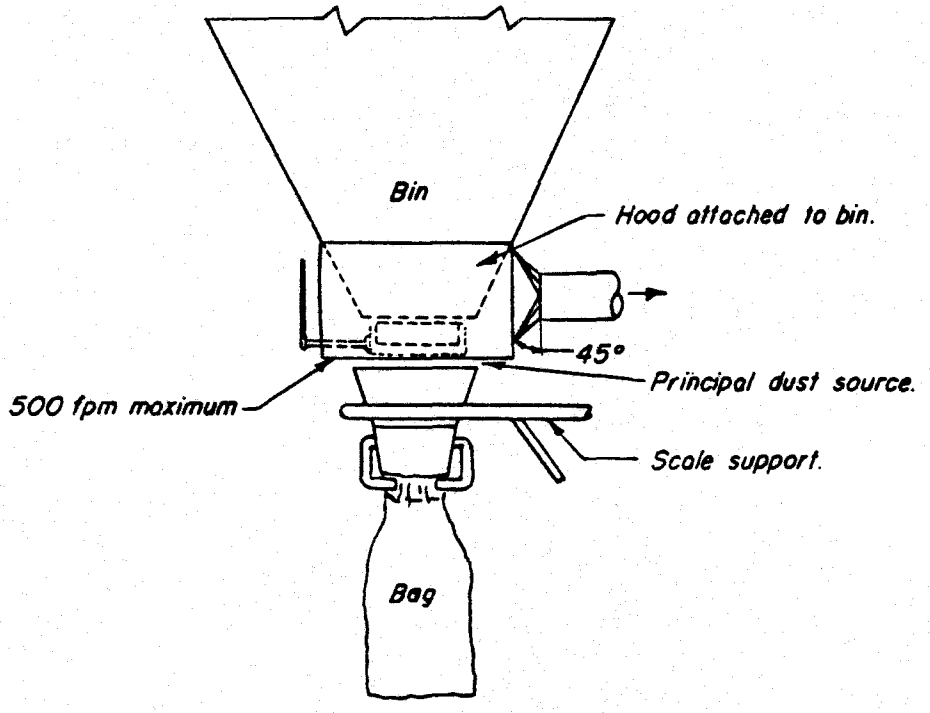
AMERICAN CONFERENCE OF
GOVERNMENTAL INDUSTRIAL HYGIENISTS

MILLING MACHINE HOOD
HIGH TOXICITY MATERIALS

DATE 1-68 | VS-209

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JM - 83

MT-PWHD-004560

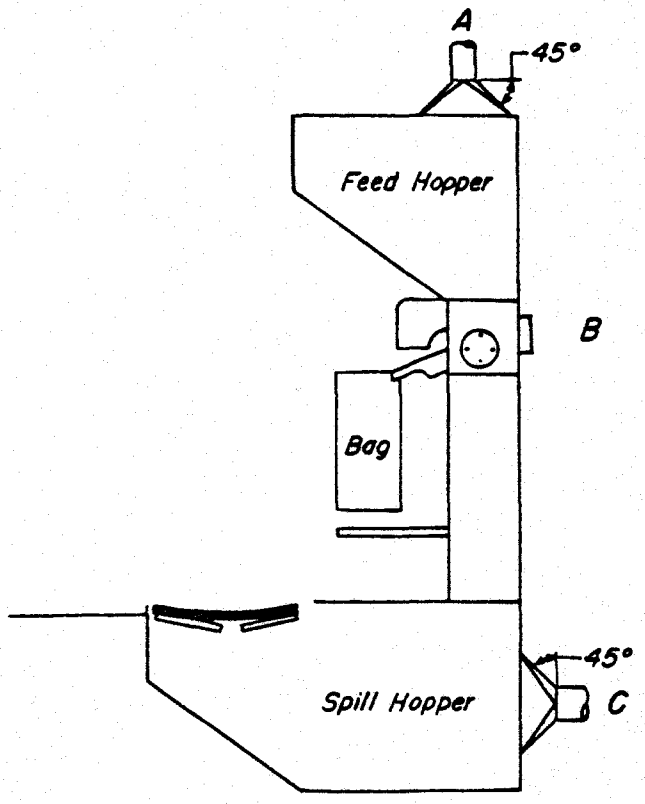


Q = 400 - 500 cfm - non-toxic dust
1000 - 1500 cfm - toxic dust
Duct velocity = 3500 fpm minimum
Entry loss = 0.25 VP

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BAG FILLING	
DATE 1-64	VS-301

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1025 JM - 83

MT-PWHD-004561

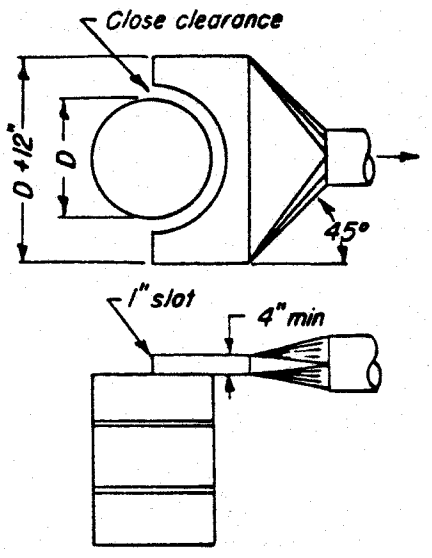


Q = 500 cfm/filling tube
= 500 cfm at Feed Hopper
= 950 cfm at Spill Hopper
Duct velocity = 3500 fpm minimum
Branch entry loss = 0.25 VP (A & C)
= 1.00 VP at open end (B)

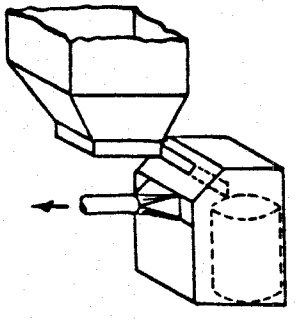
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
BAG TUBE PACKER	
DATE 1-64	VS-302

PRODUCED
JM0283

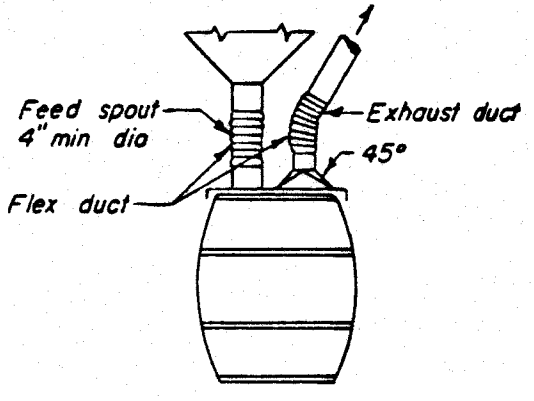
MT-PWHD-004562



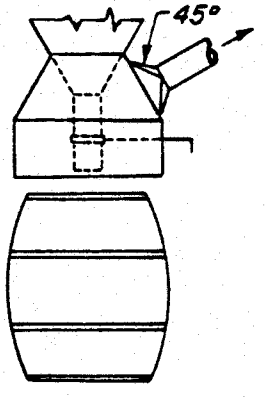
Q = 100 cfm/sq ft barrel top min
Duct velocity = 3500 minimum
Entry loss = 0.25 VP + 1.78 slot VP
Manual loading.



Q = 150 cfm/sq ft open face area
Duct velocity = 3500 fpm minimum
Entry loss = 0.25 VP for 45° taper



Q = 50 cfm x drum dia (ft) for weighted lid
150 cfm x drum dia (ft) for loose lid
Duct velocity = 3500 fpm minimum
Entry loss = 0.25 VP

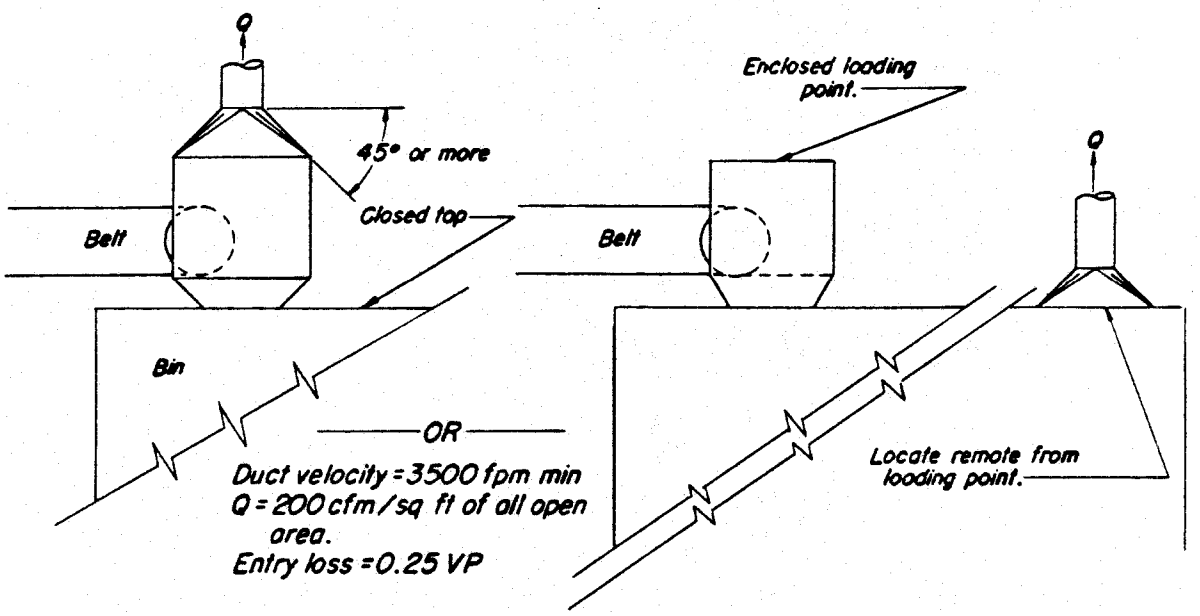


Q = 300-400 cfm
Duct velocity = 3500 fpm min
Entry loss = 0.25 VP

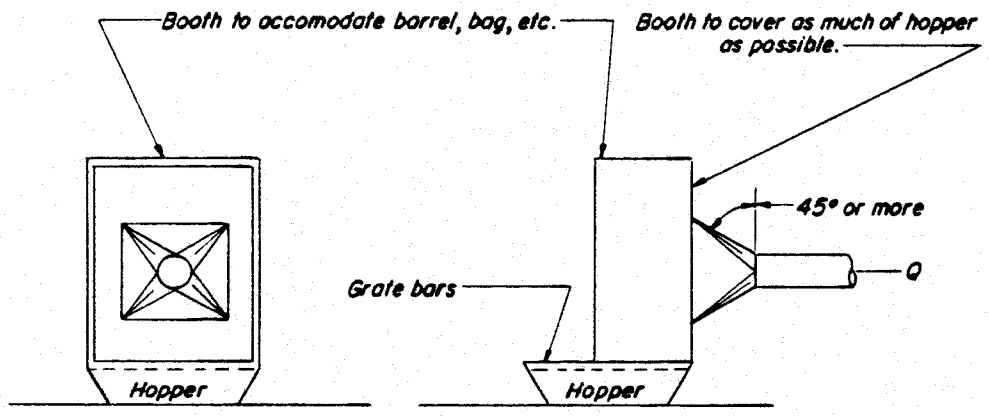
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS		
BARREL FILLING		
DATE	1-64	VS-303

PRODUCED 1987
JM - 83

MT-PWHD-004563



MECHANICAL LOADING*



Duct velocity = 3500 fpm minimum
Q = 150 cfm/sq ft face
Entry loss = 0.25 VP

MANUAL LOADING

*BELT SPEED — VOLUME

Less than 200 fpm - 350 cfm/ft of belt width. Not less than 150 cfm/ft of opening.

Over 200 fpm - 500 cfm/ft of belt width. Not less than 200 cfm/ft of opening.

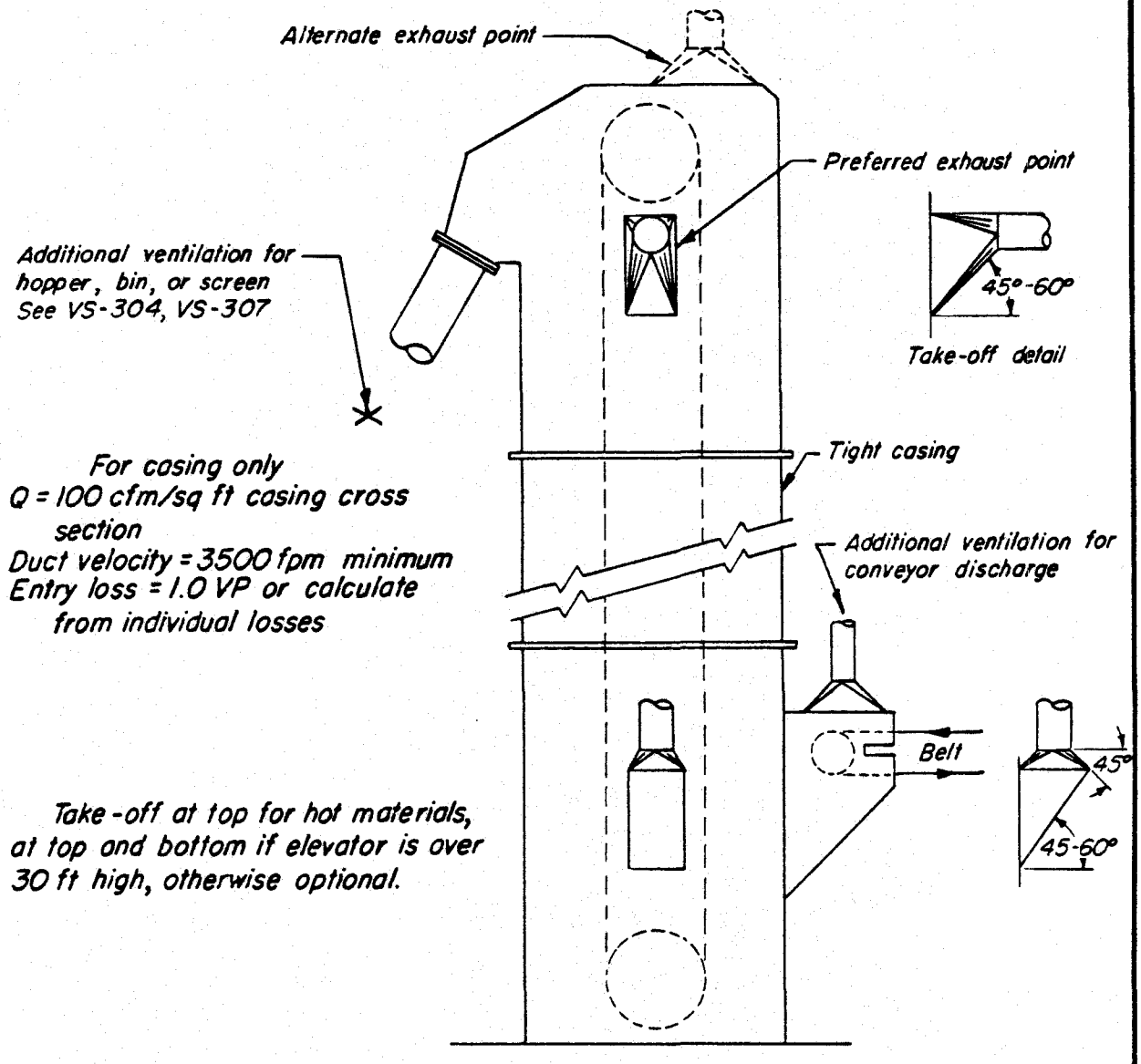
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BIN & HOPPER VENTILATION

DATE 1-72 | VS-304

PRODUCED 1028
JM - 83

MT-PWHD-004564



For casing only
Q = 100 cfm/sq ft casing cross section
Duct velocity = 3500 fpm minimum
Entry loss = 1.0 VP or calculate from individual losses

Take-off at top for hot materials, at top and bottom if elevator is over 30 ft high, otherwise optional.

Belt speed	Volume
Less than 200 fpm	— 350 cfm/ft of belt width. Not less than 150 cfm/ft of opening
Over 200 fpm	— 500 cfm/ft of belt width. Not less than 200 cfm/ft of opening

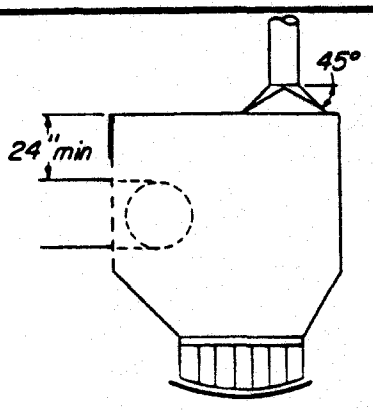
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BUCKET ELEVATOR VENTILATION

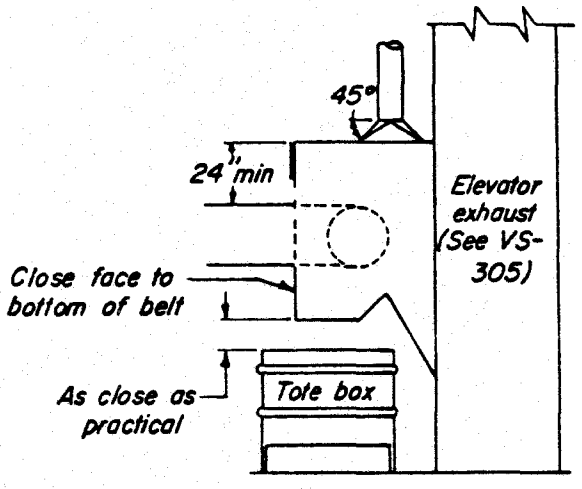
DATE 1-66 | VS-305

PRODUCED
IMI 83

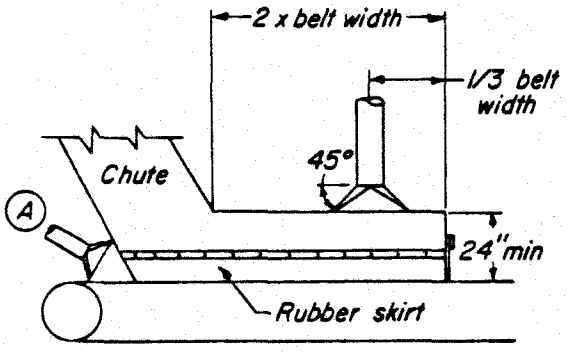
MT-PWHD-004565



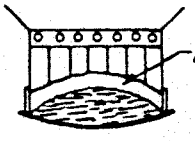
1. Conveyor transfer less than 3' fall. For greater fall provide additional exhaust at lower belt. See 3 below.



2. Conveyor to elevator with magnetic separator.



3. Chute to belt transfer and conveyor transfer, greater than 3' fall.
Use additional exhaust at (A) for dusty material as follows:
Belt width 12"-36", Q=700 cfm
above 36", Q=1000 cfm



Detail of belt opening

DESIGN DATA

Transfer points:
- Enclose to provide 150-200 fpm indraft at all openings.
- Minimum Q=350 cfm/ft belt width for belt speeds under 200 fpm
  = 500 cfm/ft belt width for belt speeds over 200 fpm and for magnetic separators
- Duct velocity = 3500 fpm minimum
- Entry loss = 0.25VP

Conveyor belts:
- Cover belt between transfer points
- Exhaust at transfer points
- Exhaust additional 350 cfm/ft of belt width at 30' intervals. Use 45° tapered connections.
- Entry loss = 0.25 VP

Note:
Dry, very dusty materials may require exhaust volumes 1.5 to 2.0 times stated values.

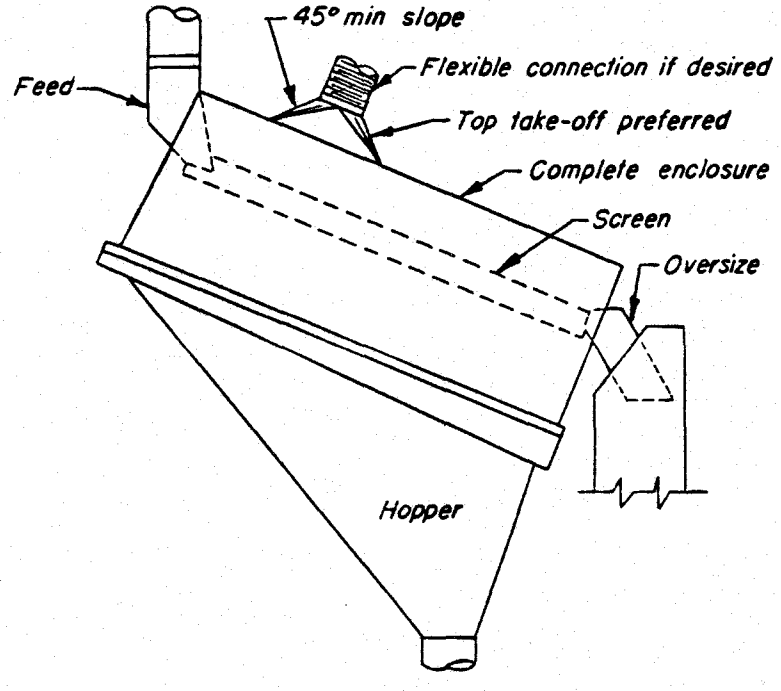
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CONVEYOR BELT VENTILATION

DATE 1-72 | VS-306

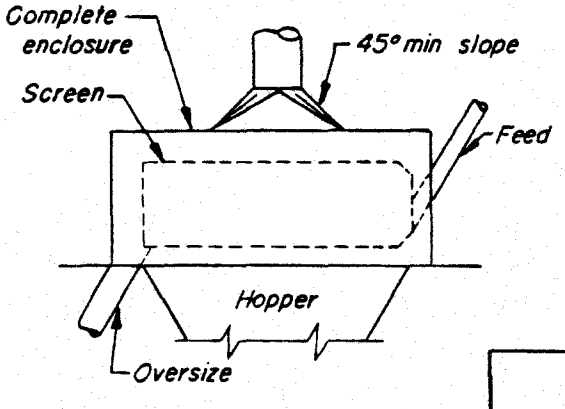
PRODUCED 1030 JM - 83

MT-PWHD-004566



FLAT DECK SCREEN

Q = 200 cfm/sq ft through hood openings, but not less than 50 cfm/sq ft screen area. No increase for multiple decks
Duct velocity = 3500 fpm minimum
Entry loss = 0.50 VP



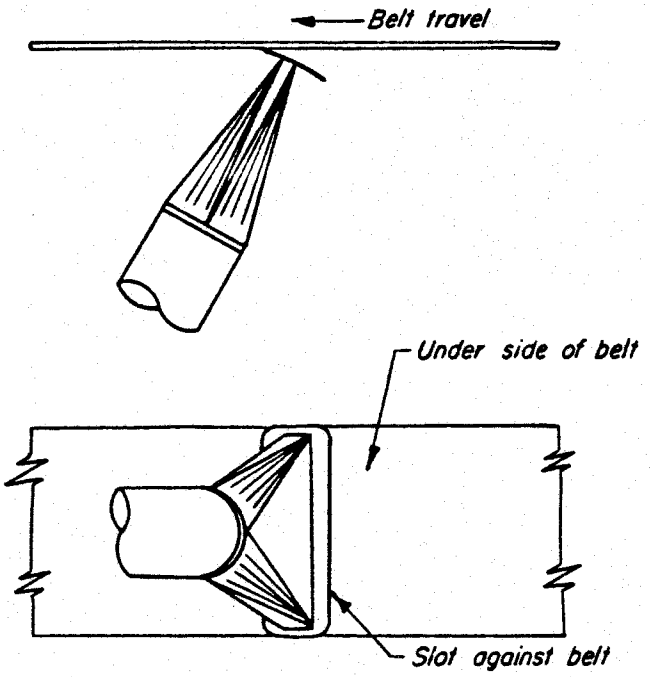
CYLINDRICAL SCREEN

Q = 100 cfm/sq ft circular cross section of screen; at least 400 cfm/sq ft of enclosure opening
Duct velocity = 3500 fpm minimum
Entry loss = 0.50 VP

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
SCREENS	
DATE 1-64	VS-307

PRODUCED 1031 JM - 83

MT-PWHD-004567



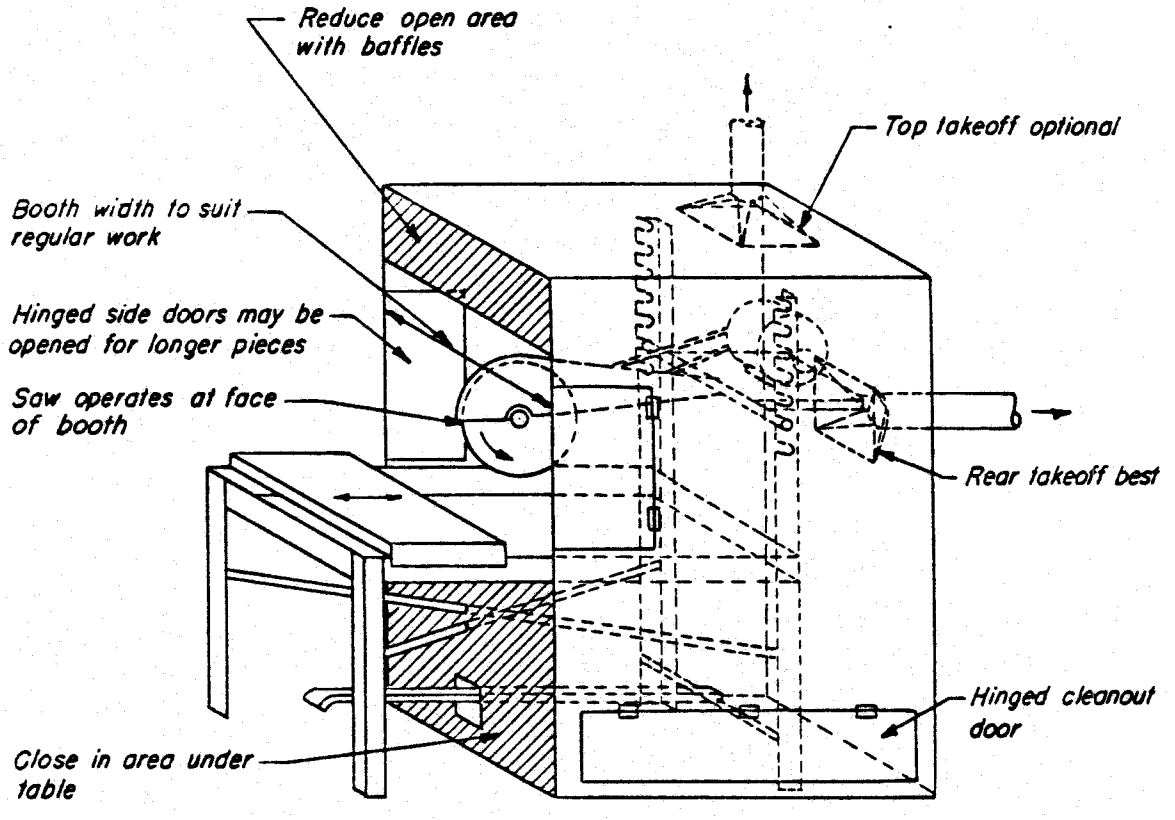
Q = 200 cfm/ft of belt width
Slot velocity = 2000 fpm
Duct velocity = 4000 fpm minimum

Not recommended for wet belts as in ore conveying.

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BELT WIPER	
DATE *1-66*	*VS-308*

PRODUCED 1032
JM - 83

MT-PWHD-004568



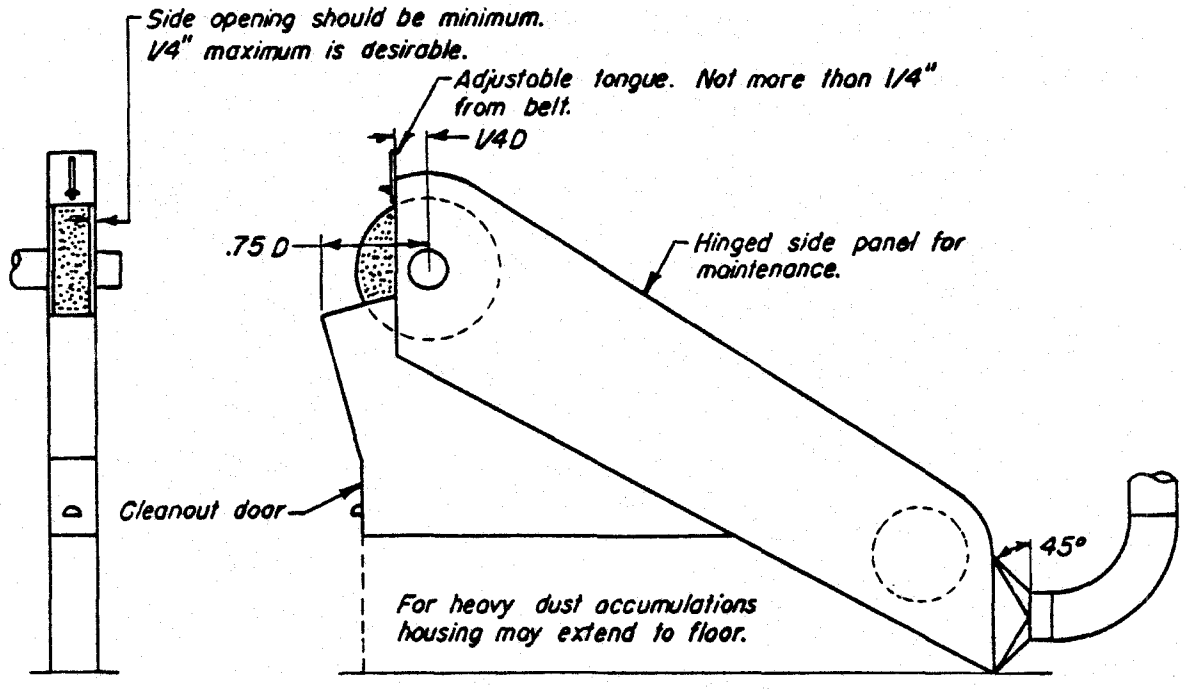
Q = 250 cfm/sq ft of open face area
Duct velocity = 3500 fpm minimum
Entry loss = 0.50 VP no taper
0.25 VP with taper

Stationary installation –
Indoor and outdoor: Connect to exhaust system and dust collector
Discharge outdoors

Portable use –
Indoor and outdoor: Use adequate unit collector and fan
Outdoor only: Use adequate fan, discharge at least 10' above ground

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ABRASIVE CUT-OFF SAW VENTILATION	
DATE 1-64	VS-401

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Belt width inches	Exhaust volume cfm	Exhaust volume cfm
	Good enclosure *	Poor enclosure
1 1/2	220	330
2	390	600
3	500	750
4	610	920
5	880	1300
6	1200	1600

* Hood as shown. No more than 25% of wheel exposed.
Entry loss = 0.40 VP
Duct velocity = 3500 fpm mimimum

Note:
For titanium and magnesium eliminate hopper and use 5000 fpm through hood cross section.

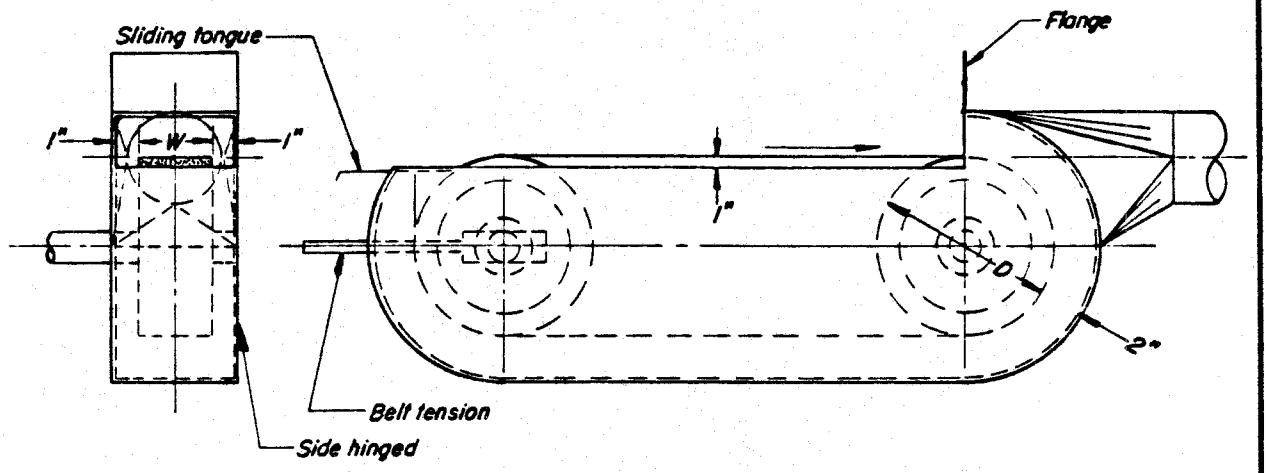
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BACKSTAND IDLER POLISHING MACHINE

DATE 1-64 | VS-402

PRODUCED 1034
JM - 83

MT-PWHD-004570



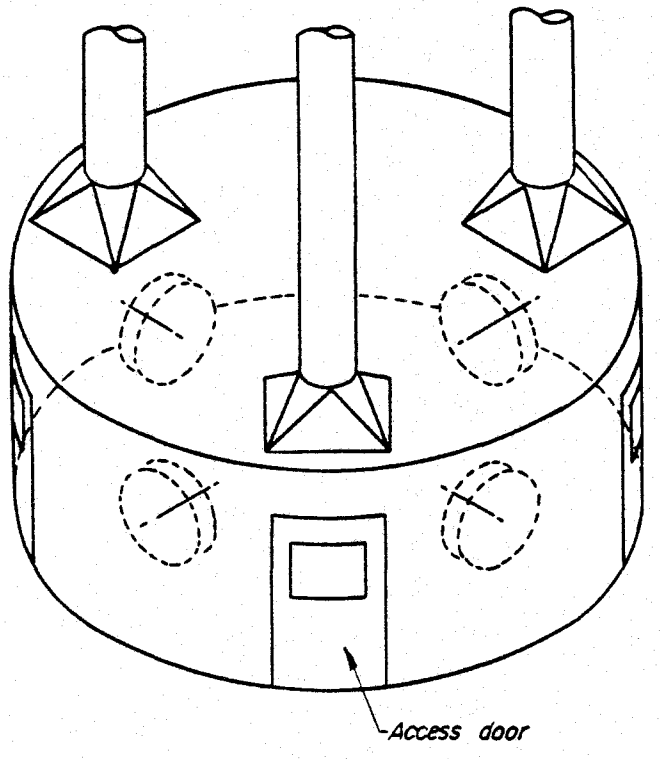
Belt width, inches	Exhaust volume, cfm
up to 3	220
3 to 5	300
5 to 7	390
7 to 9	500
9 to 11	610
11 to 13	740

Minimum duct velocity = 4500 fpm branch, 3500 fpm main.
Entry loss = 0.65 velocity pressure for straight take-off.
0.45 velocity pressure for tapered take-off.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
METAL POLISHING BELT	
DATE 1-64	VS-403

PRODUCED JM 83 1055

MT-PWHD-004571



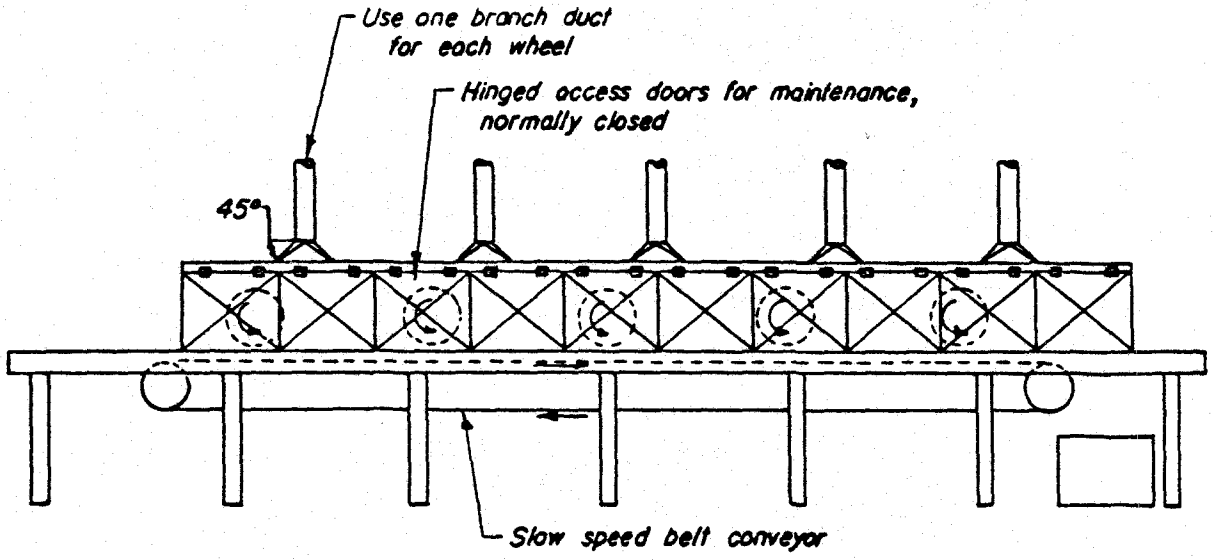
Q = 500 cfm/wheel, minimum
Not less than 250 cfm/sq ft total open area
Duct velocity = 3500 fpm minimum
Entry loss = 1.78 slot VP plus 0.25 duct VP
Use ammeters to goge wheel pressures

On small, 2 or 3 spindle machines, one take-off may be used
Multiple take-offs desirable
Provide automatic sprinklers or other fire protection. Consult Fire and Insurance Codes

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
CIRCULAR AUTOMATIC BUFFING	
DATE *1-64*	*VS-404*

PRODUCED 1036
JM - 83

MT-PWHD-004572

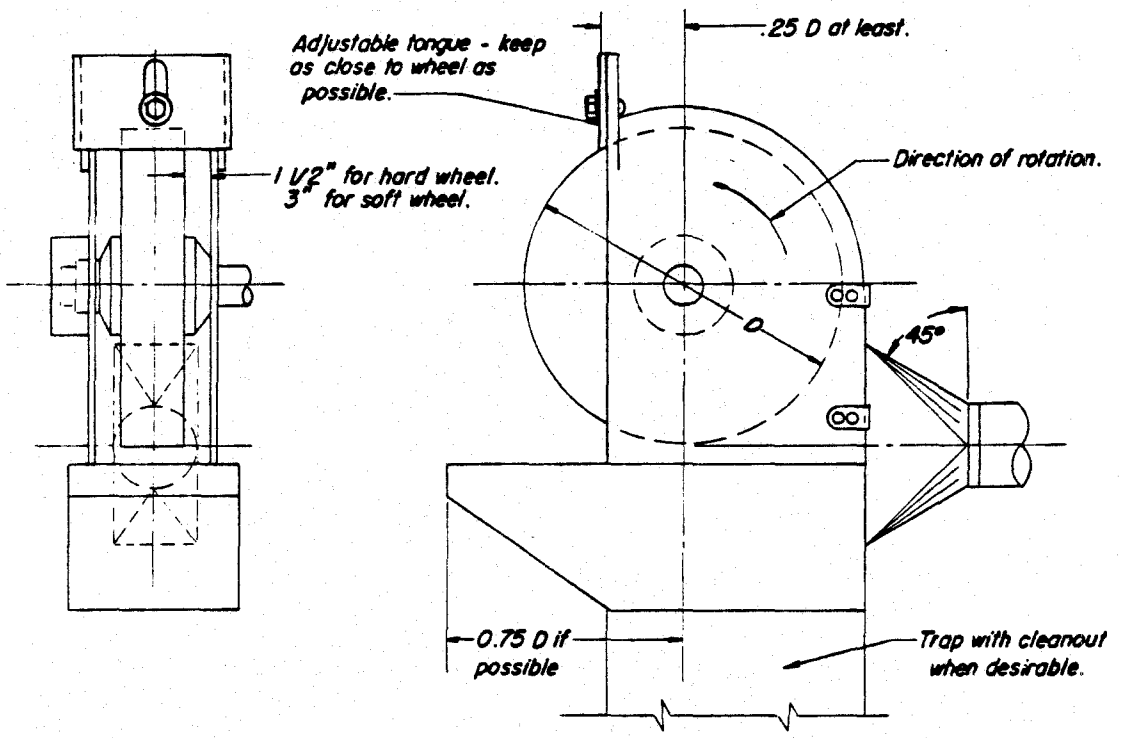


Q = 500 cfm/wheel, minimum
Not less than 250 cfm/sq ft total open area
Duct velocity = 4500 fpm minimum
Entry loss = 1.78 slot VP plus 0.25 duct VP
Use ammeters to gage wheel pressures
Wheel adjustments on outside of enclosure at the rear

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
STRAIGHT LINE AUTOMATIC BUFFING	
DATE 1-68	VS-405

PRODUCED
JM - 83

MT-PWHD-004573



Minimum duct velocity : 4500 fpm branch.
3500 fpm main.

Entry loss : 0.65 VP for straight take-off.
0.40 VP for tapered take-off.

Wheel diam. inches	Wheel width * inches	Exhaust volume cfm	Exhaust volume cfm
		Good enclosure	Poor enclosure
to 9	2	300	400
over 9 to 16	3	500	670
over 16 to 19	4	610	800
over 19 to 24	5	740	1100
over 24 to 30	6	1040	1400
over 30 to 36	6	1175	1800

* In cases of extra wide wheels, use wheel width to determine exhaust volume.

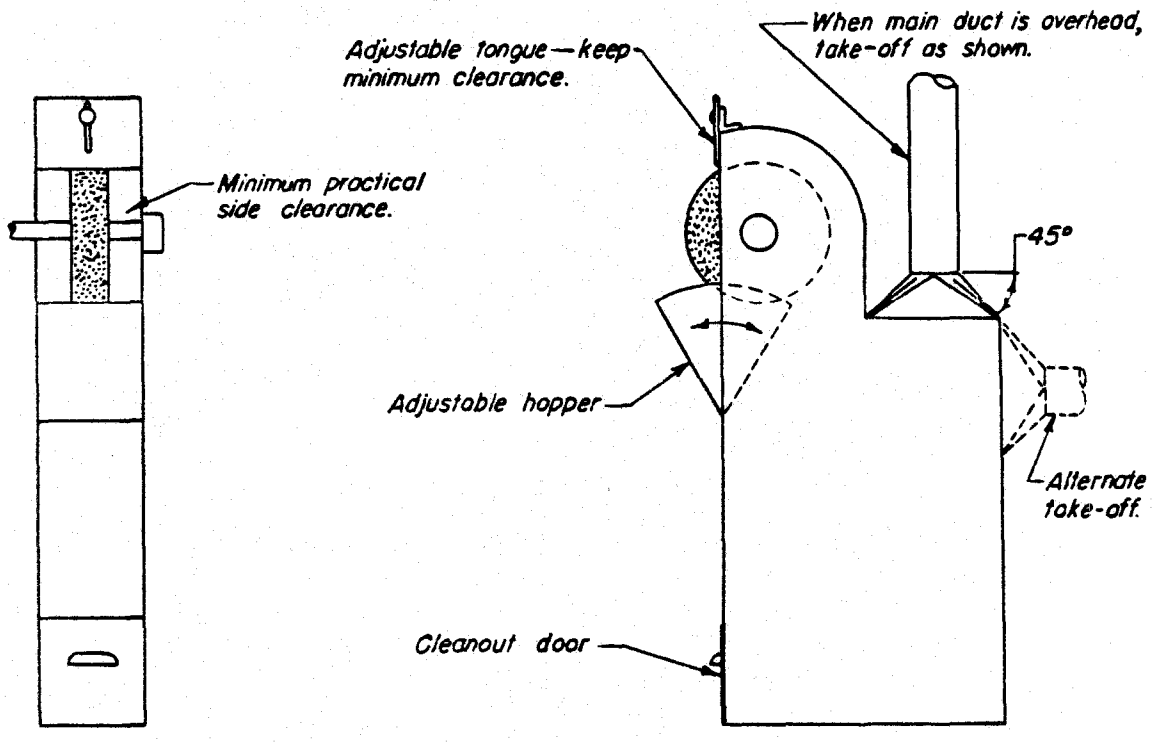
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

BUFFING AND POLISHING

DATE 1-64 | VS-406

PRODUCED
JM - 83

MT-PWHD-004574



Wheel diam inches	Wheel width inches	Exhaust volume cfm
to 9	2	400
over 9 to 16	3	670
over 16 to 19	4	800
over 19 to 24	5	1100
over 24 to 30	6	1400
over 30 to 36	6	1800

Note: For wider wheels than listed, increase cfm with width
Duct velocity = 4500 fpm minimum
Entry loss = 0.40 VP

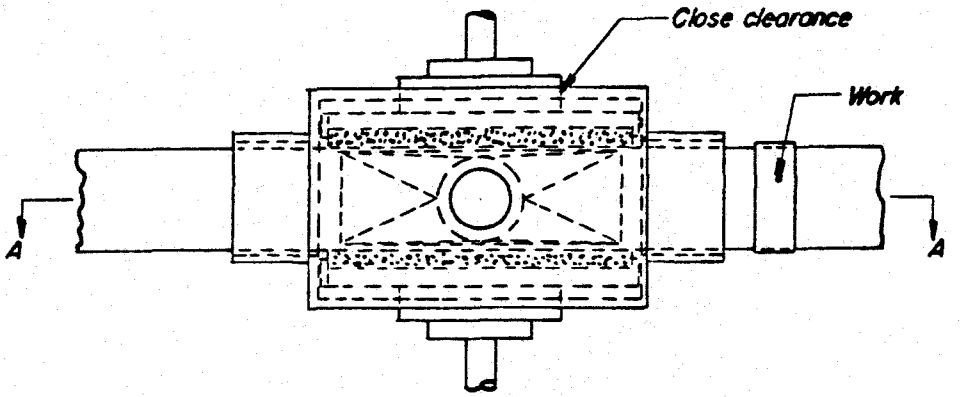
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

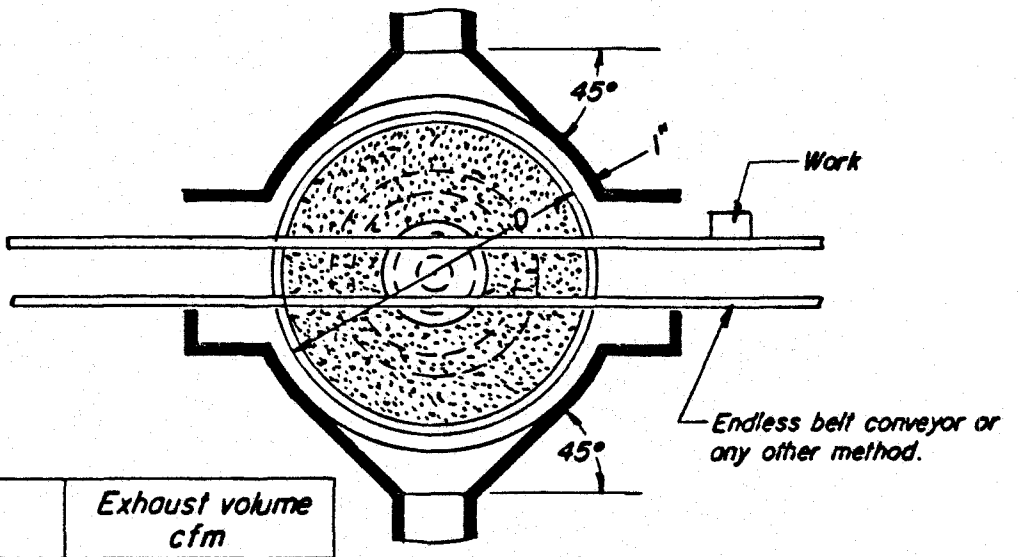
SOFT WHEEL BUFFING LATHE

DATE 1-64 | VS-407

PRODUCED
JM - 83

MT-PWHD-004575





Section A-A

Disc diam. inches	Exhaust volume cfm
up to 19	610
over 19 to 25	880
over 25 to 30	1200
over 30 to 53	1770
over 53 to 72	6280

Note : Practically complete enclosure of discs with machine housing and exhaust from the housing is acceptable.

Minimum duct velocity =
4500 fpm branch,
3500 fpm main.
Entry loss = 0.65 velocity pressure for straight take-off.
= 0.45 velocity pressure for tapered take-off.

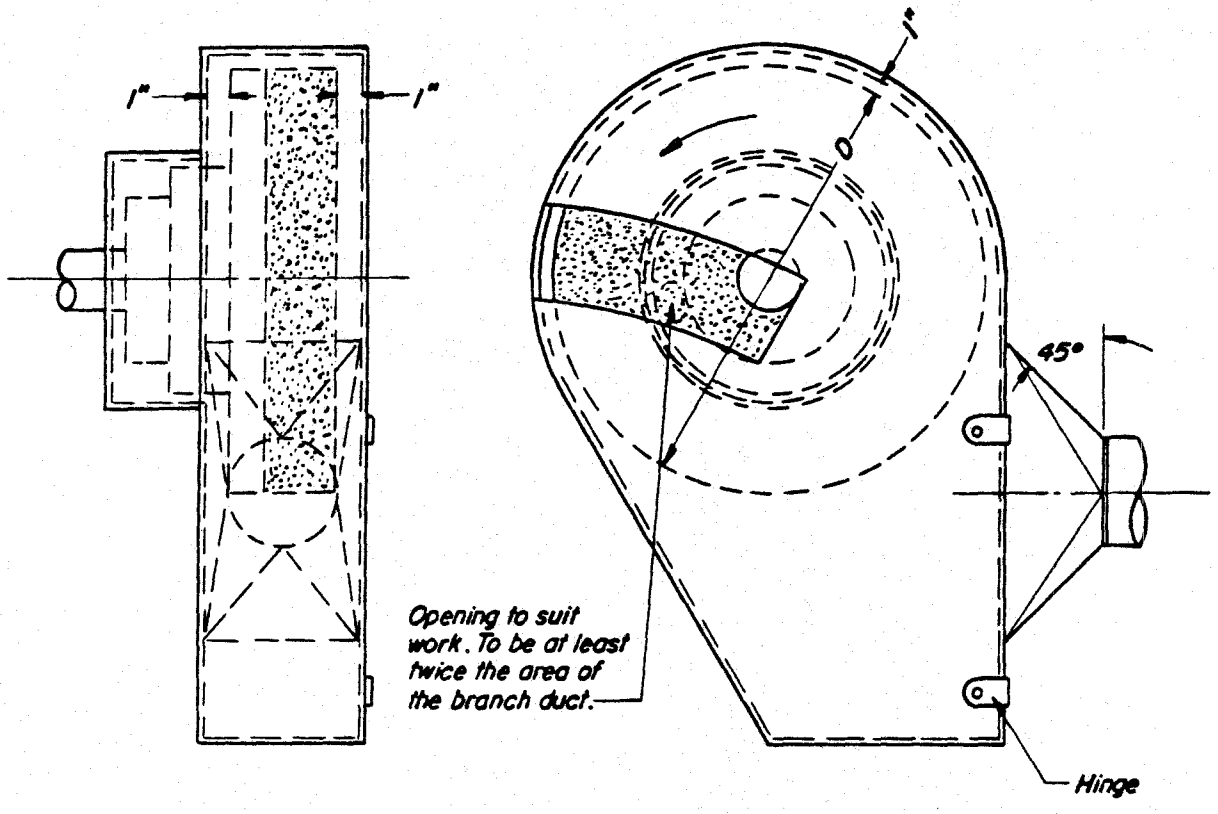
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

HORIZONTAL DOUBLE-SPINDLE DISC GRINDER

DATE 1-64 | VS-408

1040 PRODUCED JM - 83

MT-PWHD-004576



Disc diam., inches	Exhaust volume, cfm
Up to 12	220
over 12 to 19	390
over 19 to 30	610
over 30 to 36	880

Minimum duct velocity = 4500 fpm branch, 3500 fpm main.
Entry loss = 0.65 VP for straight take-off.
= 0.45 VP for tapered take-off.

Note: If best practical hood is a poor enclosure, increase exhaust volume accordingly.

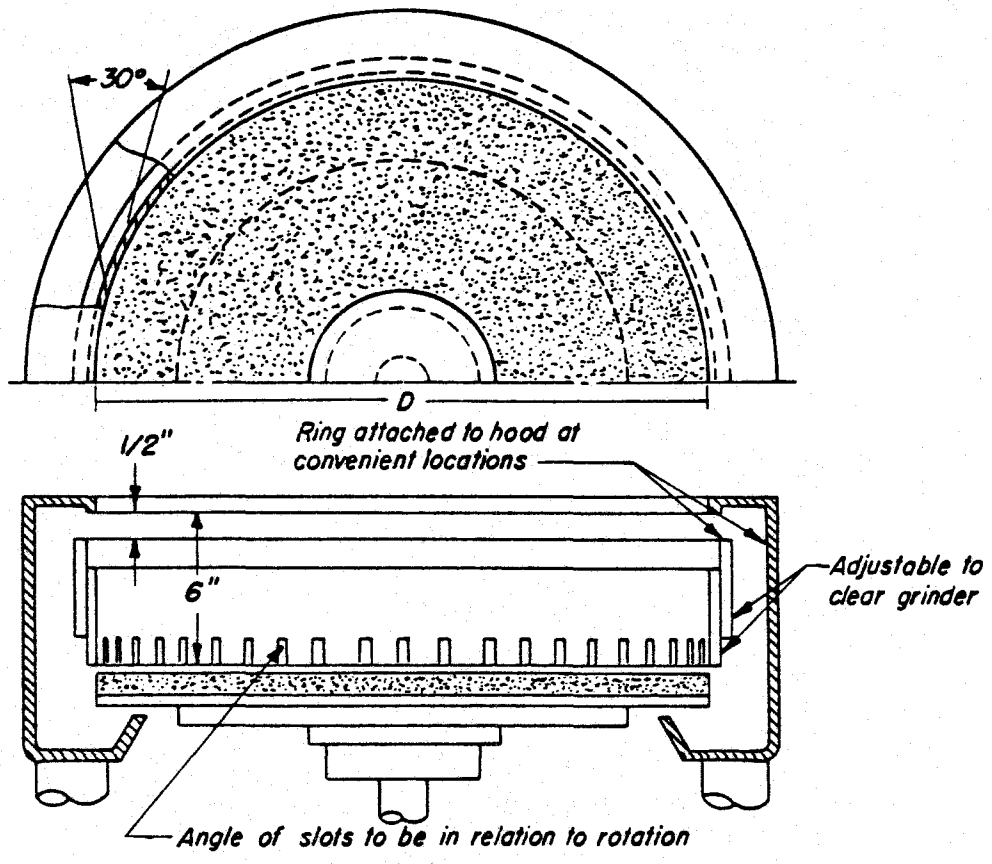
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

HORIZONTAL SINGLE-SPINDLE DISC GRINDER

DATE 1-64 | VS-409

1041 PRODUCED JM - 83

MT-PWHD-004577



Disc diam, inches	1/2 or more of disc covered		Disc not covered	
	No.*	Exhaust, cfm	No.*	Exhaust, cfm
up to 20	1	500	2	780
over 20 to 30	2	780	2	1480
over 30 to 53	2	1770	4	3530
over 53 to 72	2	3140	5	6010

* Number of exhaust outlets around periphery of hood; or equal distribution provided by other means.

Slot velocity = 2000 fpm
Duct velocity = 4500 fpm minimum in branch
3500 fpm minimum in main
Entry loss = 1.0 slot VP + 0.5 bronch duct VP

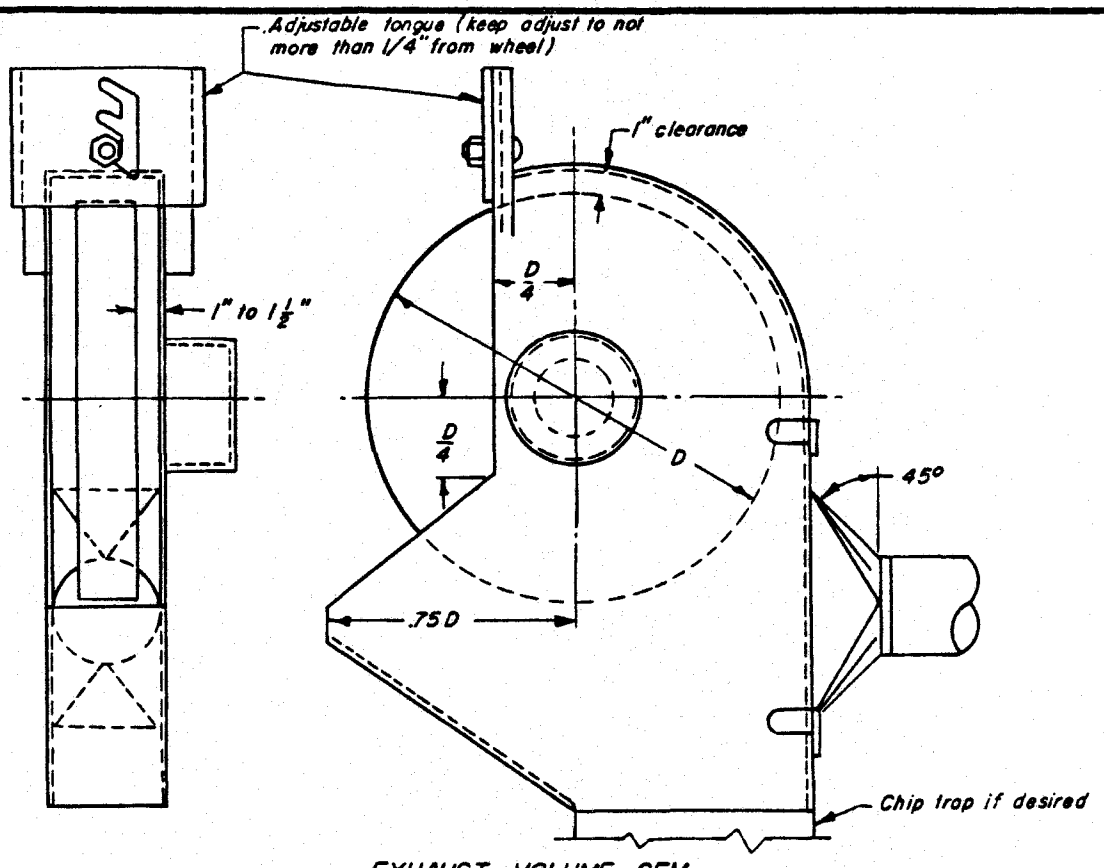
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

VERTICAL SPINDLE DISC GRINDER

DATE 1-64 | VS-410

REPRODUCED JM - 83

MT-PWHD-004578



EXHAUST VOLUME, CFM

Wheel diam inches	Wheel width inches	Good enclosure*	Poor enclosure
to 5	1	220	220
over 5 to 10	1 1/2	220	300
over 10 to 14	2	300	500
over 14 to 16	2	390	610
over 16 to 20	3	500	740
over 20 to 24	4	610	880
over 24 to 30	5	880	1200
over 30 to 36	6	1200	1570

* No more than 25% of wheel exposed.

Minimum duct velocity = 4500 fpm in branch
3500 fpm in main

Entry loss = 0.65 VP for straight takeoff
0.40 VP for tapered takeoff

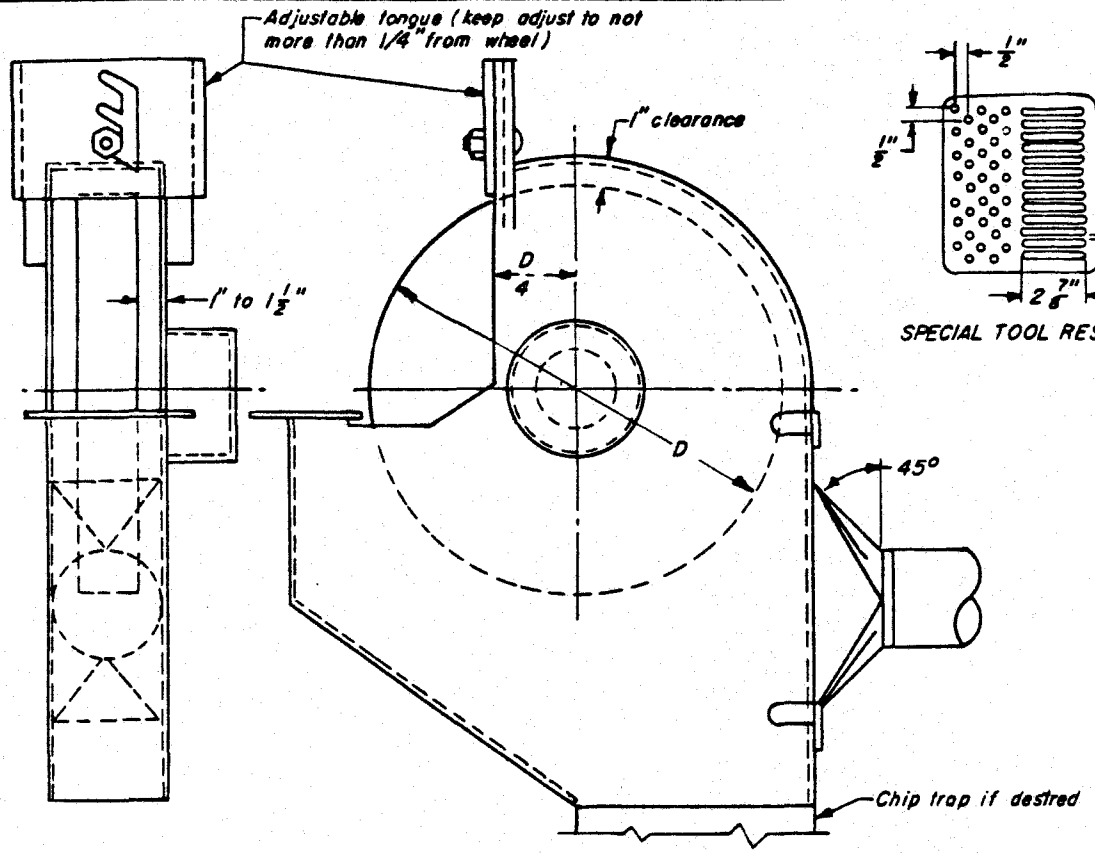
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

GRINDER WHEEL HOOD
SPEEDS BELOW 6500 sfm

DATE 1-72 | VS-411

1043 PRODUCED JM - 83

MT-PWHD-004579



EXHAUST VOLUME, CFM

Wheel diam inches	Wheel width inches	Good enclosure *	Poor enclosure
to 5	1	220	390
over 5 to 10	1 1/2	390	610
over 10 to 14	2	500	740
over 14 to 16	2	610	880
over 16 to 20	3	740	1040
over 20 to 24	4	880	1200
over 24 to 30	5	1200	1570
over 30 to 36	6	1570	1990

* Special hood and tool rest as shown.
Minimum duct velocity = 4500 fpm in branch
3500 fpm in main
Entry loss = 0.65 VP for straight takeoff
0.40 VP for tapered takeoff

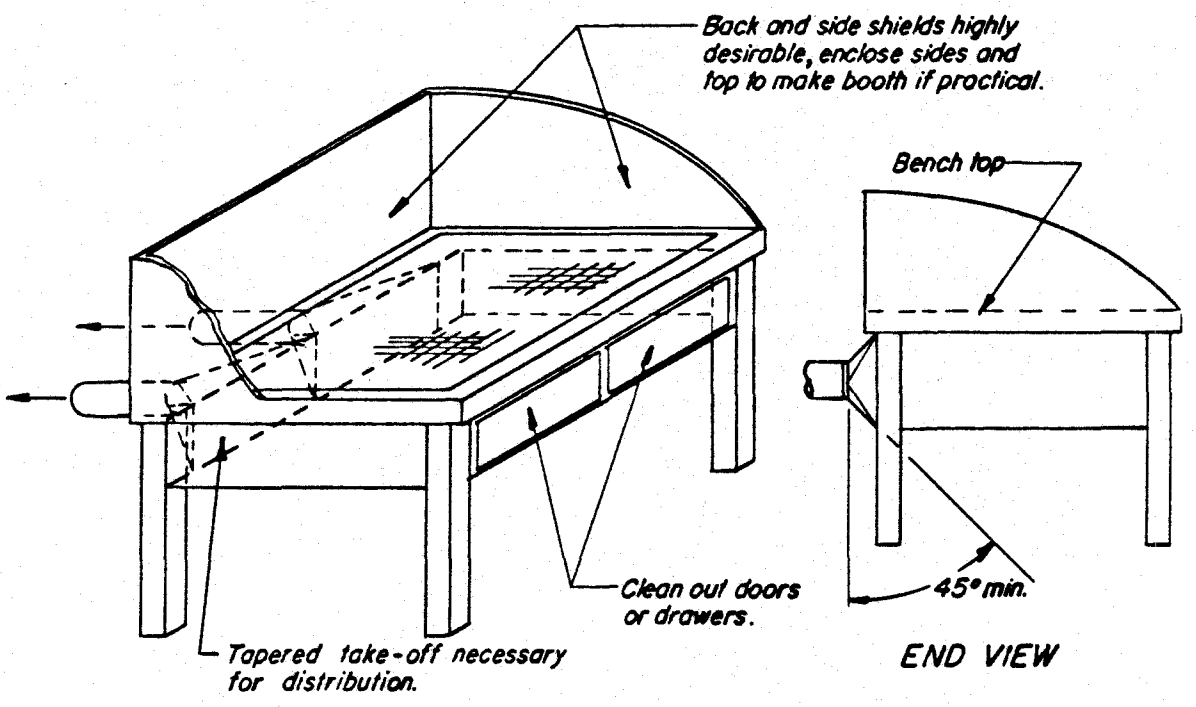
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

GRINDER WHEEL HOOD
SPEEDS ABOVE 6500 sfm

DATE 1-72 | VS-411.1

PRODUCED 1044
JM - 83

MT-PWHD-004580



Q = 150 - 250 cfm / sq ft of bench area.
Minimum duct velocity = 3500 fpm
Entry loss = 0.25 VP for tapered take-off.

Grinding in booth, 100 fpm face velocity also suitable.

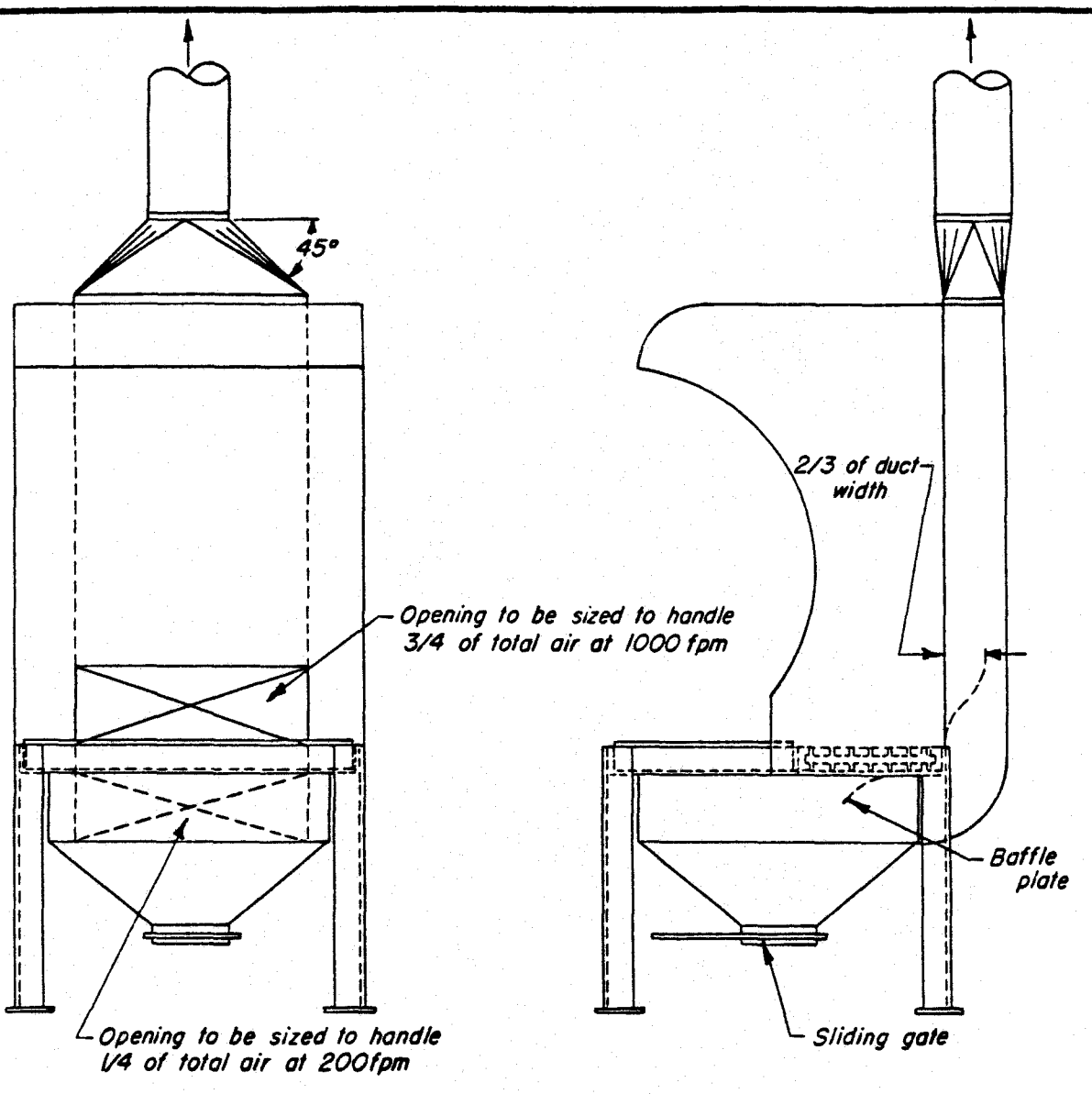
For downdraft grilles in floor: Q = 100 cfm / sq ft of working area.

Provide equal distribution. Provide for cleanout.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
PORTABLE HAND GRINDING	
DATE 1-64	VS-412

1045 PRODUCED JM - 83

MT-PWHD-004581

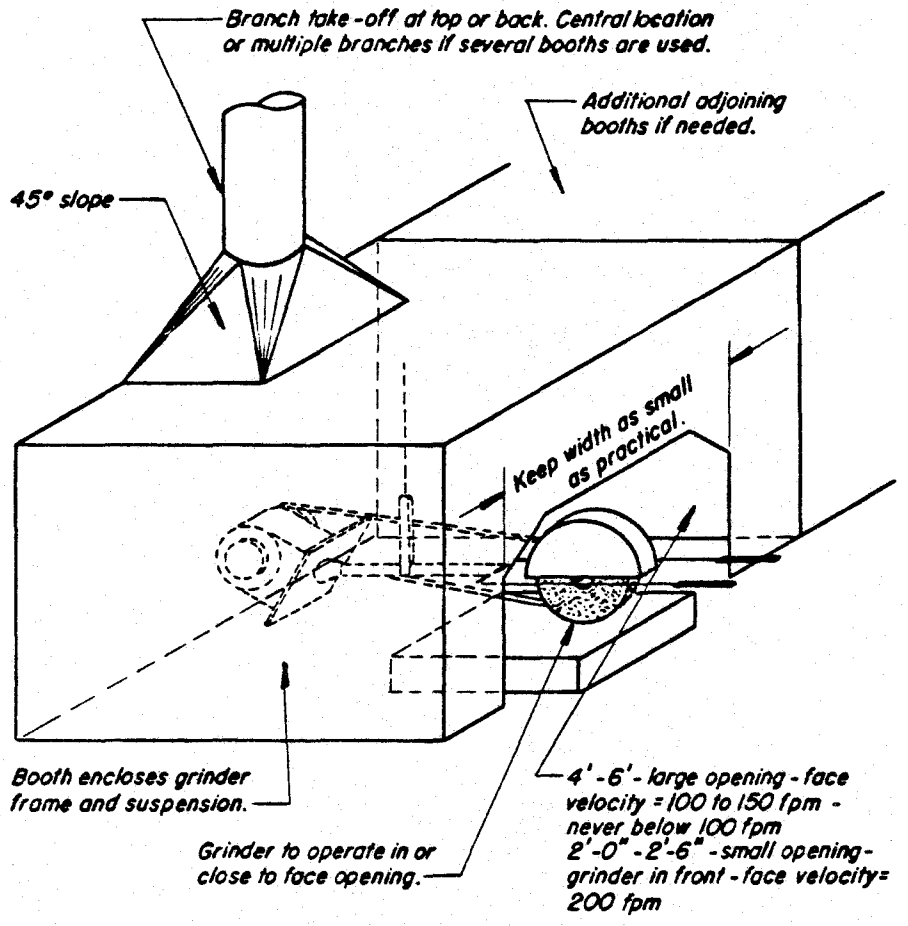


Q = 150 cfm/sq ft of hood face
Duct velocity = 3500 fpm
Entry loss = 0.25 VP

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
PORTABLE CHIPPING AND GRINDING TABLE	
DATE 1-66	VS-413

10 REPRODUCED JM - 83

MT-PWHD-004582



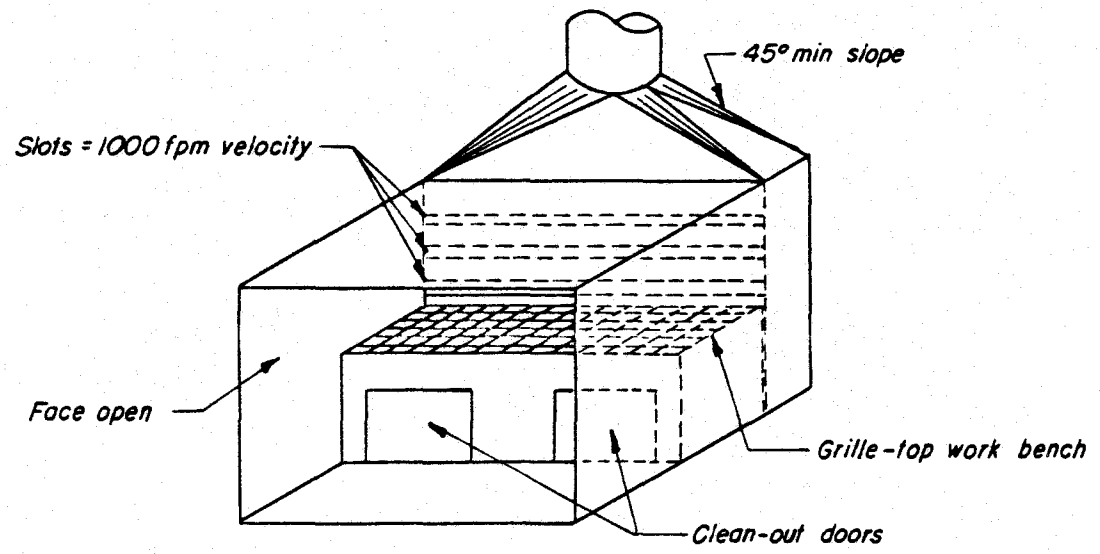
Minimum duct velocity = 3000 fpm
Entry loss = 0.5 VP

NOTE: Small local exhaust hoods mounted behind grinder wheel may trap the stream of sparks, but are usually not effective in control of air-borne dust.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
SWING GRINDER	
DATE 1-64	VS-414

PRODUCED
1047 JM - 83

MT-PWHD-004583

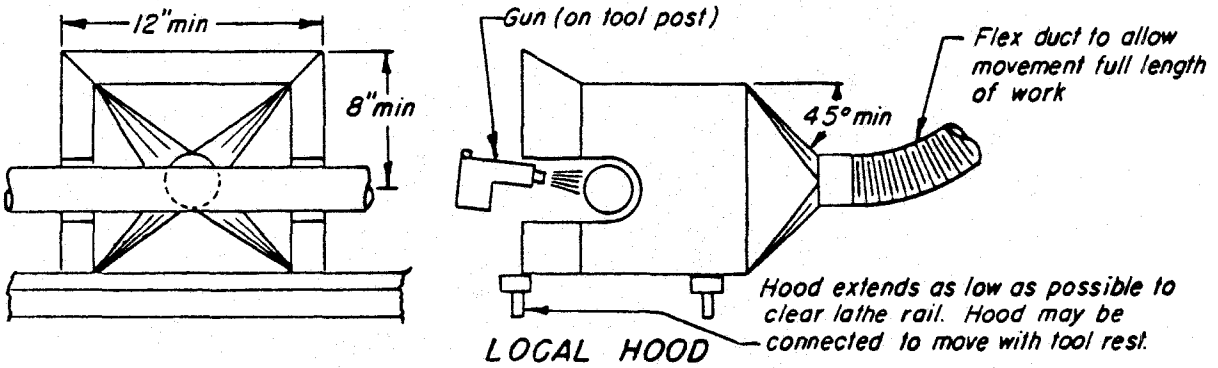


METALLIZING BOOTH

Non-toxic: Q = 125 cfm/sq ft face area

Toxic: Provide Bureau of Mines approved air-supplied respirator.
Q = 200 cfm/sq ft face area

Duct velocity = 3000 fpm minimum
Entry loss = 1.78 slot VP + 0.25 duct VP
Small lathe, etc., may be mounted in booth



LOCAL HOOD

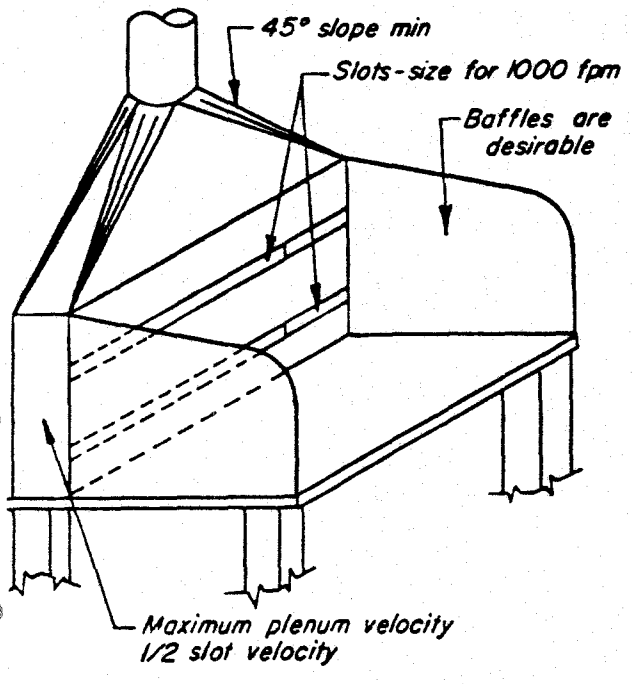
Note: Local hood not satisfactory for spraying toxic metals.

Q = 200 cfm/sq ft face openings
Duct velocity = 3500 fpm minimum
Entry loss = 0.25 VP

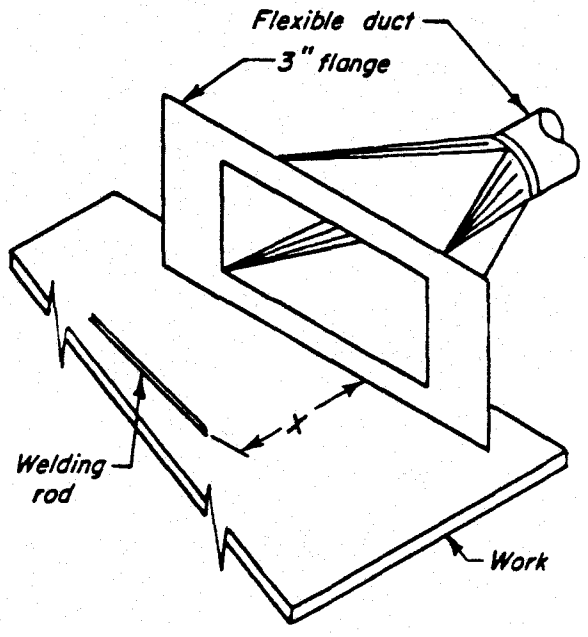
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
METAL SPRAYING	
DATE 1-64	VS-415

PRODUCED 1048
JM - 83

MT-PWHD-004584



Q = 350 cfm/lineal ft of hood
Hood length = required working space
Bench width = 24" maximum
Duct velocity = 1000 - 3000 fpm
Entry loss = 1.78 slot VP + 0.25 duct VP



PORTABLE EXHAUST

X, inches	cfm
6	250
9	400
12	1000

Face velocity = 1500 fpm
Duct velocity = 3000 fpm minimum
Entry loss = 0.25 duct VP
Also see "Granite Cutting" VS-909

GENERAL VENTILATION, where local exhaust cannot be used:

Rod, diam	cfm/welder*
5/32	1000
3/16	1500
1/4	3500
3/8	4500

*For toxic materials higher airflows are necessary.

OTHER TYPES OF HOODS

ooth:
Q=100 cfm/sq ft of face opening
See
"Spray Painting" VS-603, VS-604
"Metal Spraying" VS-415

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

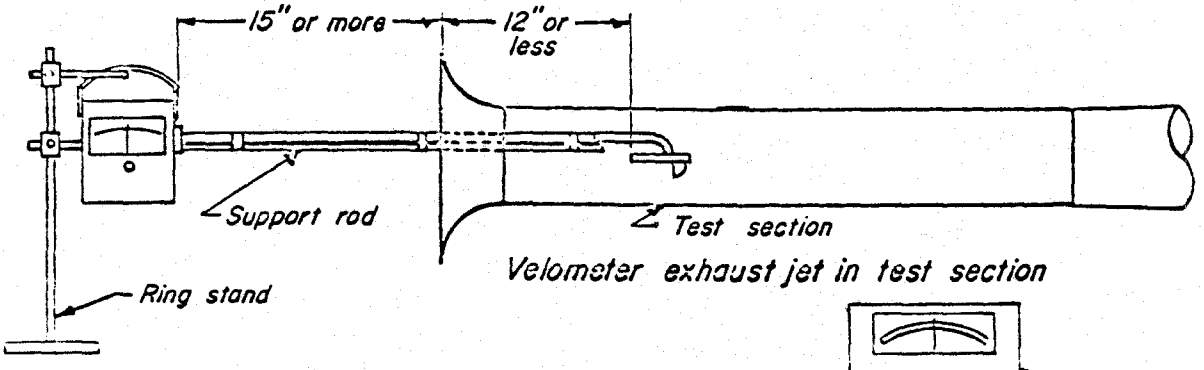
SOLDERING AND ARC WELDING

DATE 1-70 | VS-416

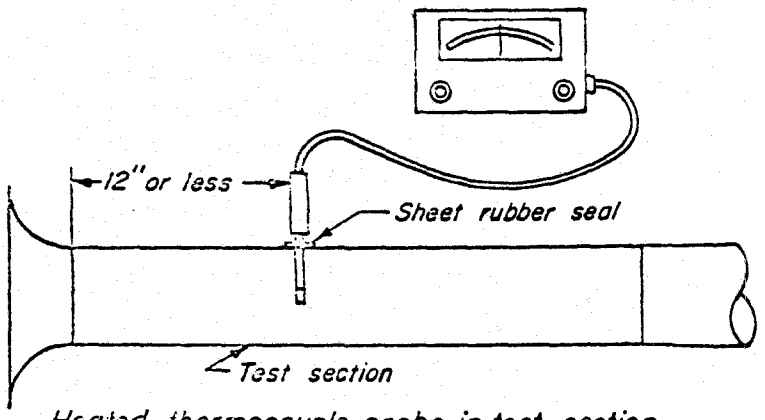
1049

PRODUCED JM - 83

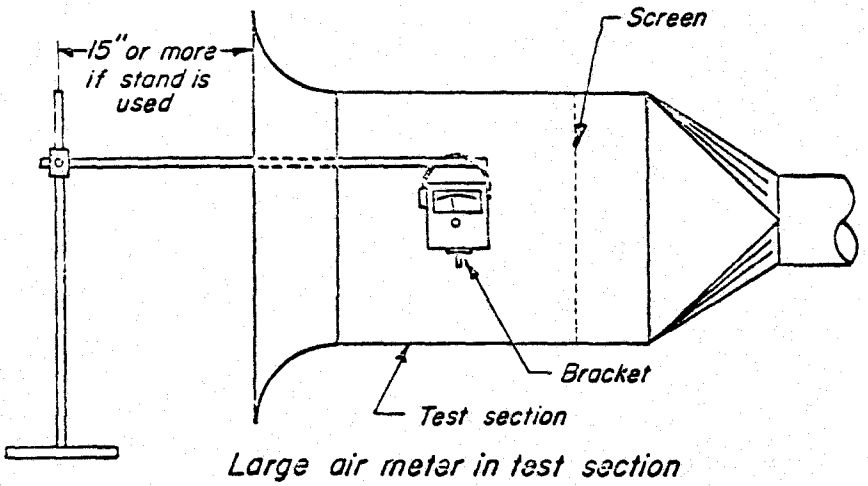
MT-PWHD-004585



Velometer exhaust jet in test section



Heated thermocouple probe in test section



Large air meter in test section

Keep test section entrance clear of obstructions and free of drafts

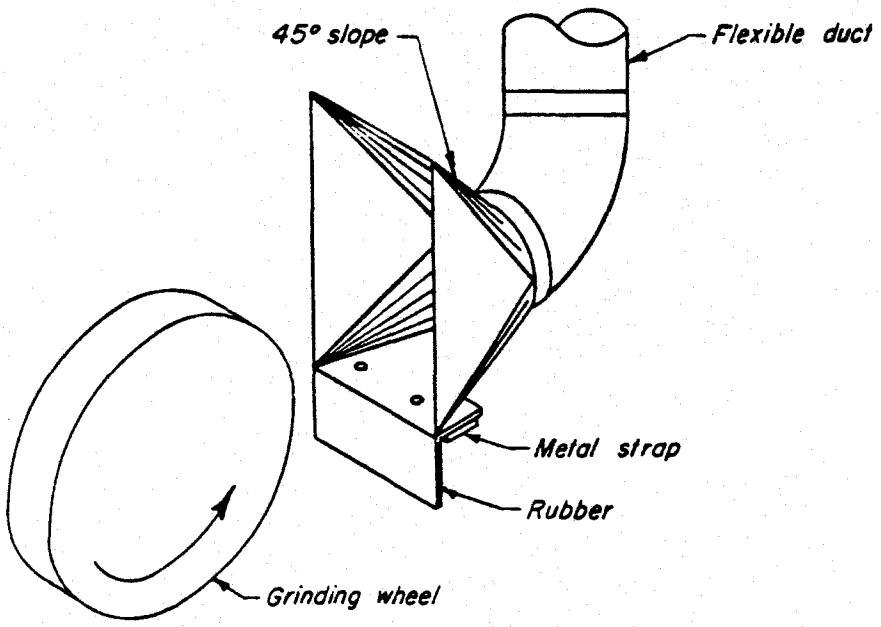
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

CALIBRATION

DATE 1-70 | Fig. 9-13

1050 REPRODUCED JM - 83

MT-PWHD-004586

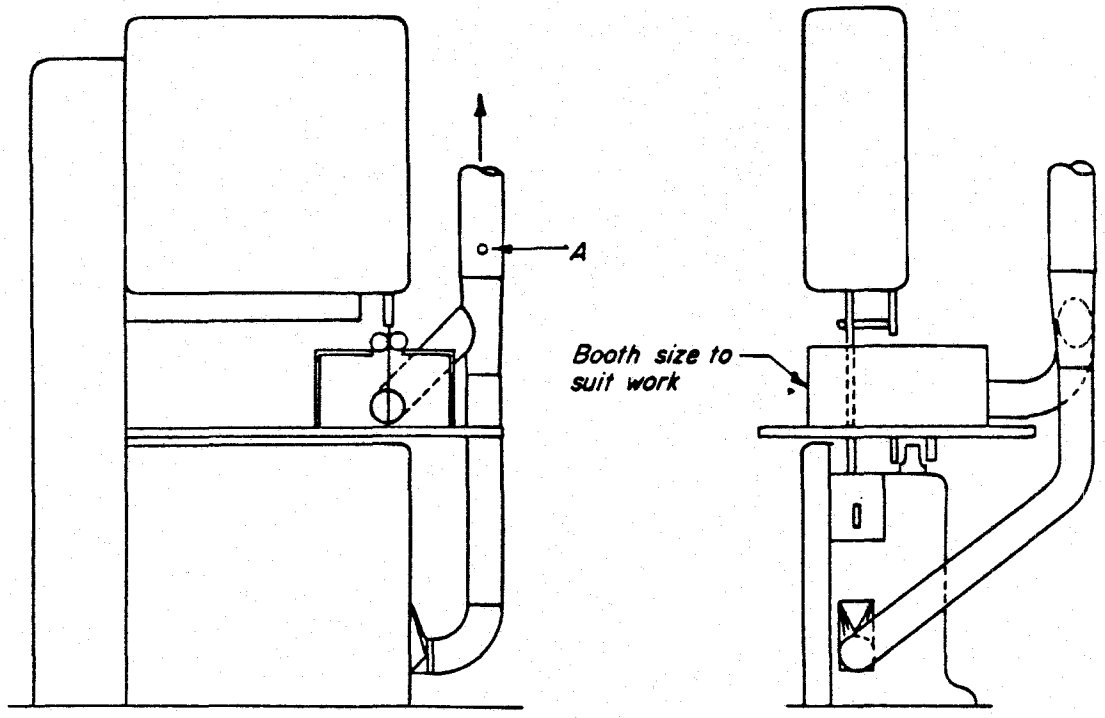


Q = 220 cfm for wheels up to 5" diam
300 cfm for wheels 5" to 10" diam
Entry loss = 0.25 VP
Duct velocity = 3500 fpm minimum

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
SURFACE GRINDER	
DATE 1-66	VS-417

PRODUCED
JM - 83 1051

MT-PWHD-004587

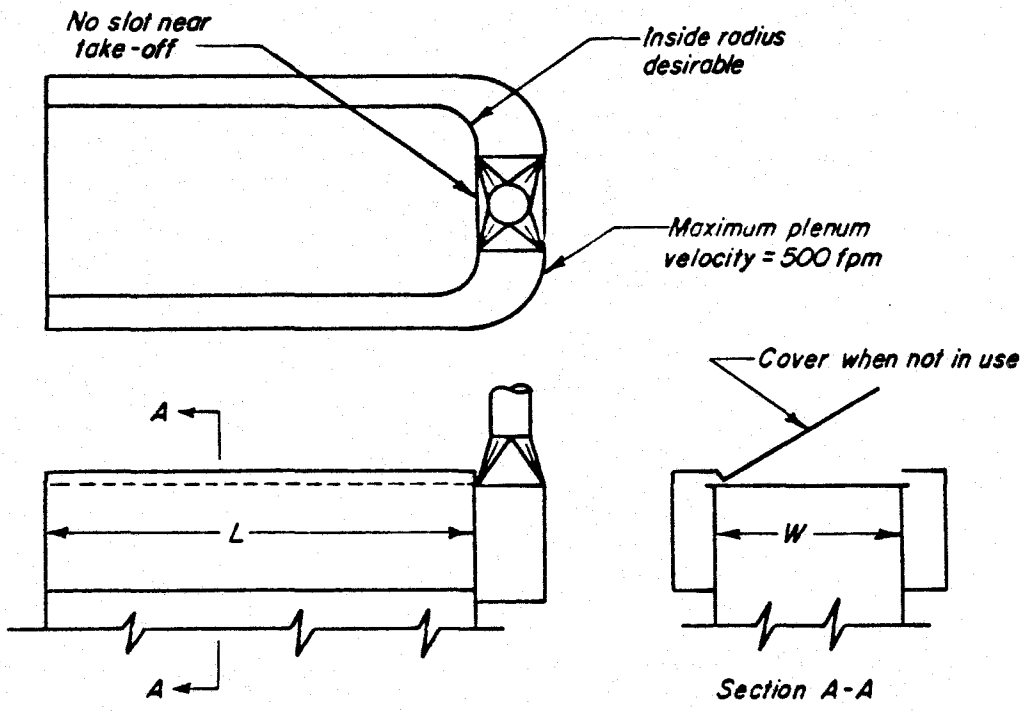


Q, booth = 225 cfm/sq ft open area
Q, bottom = 350 cfm
Duct velocity = 4000 fpm
Entry loss = 1.75 VP in riser (point A)

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
METAL CUTTING BANDSAW	
DATE *1-70*	*VS-418*

105 PRODUCED JM - 83

MT-PWHD-004588



$Q = 50LW$

Slot velocity = 1000 fpm maximum

Entry loss = 1.78 slot VP + 0.25 duct VP

Duct velocity = 2500-3000 fpm

Also provide: 1. Separate flue for combustion products if direct-fired unit.

2. For cleaning operation, an air-line respirator is necessary.

3. For pit units, the pit should be mechanically ventilated.

NOTE: Provide downdraft grille for parts that cannot be removed dry; Q = 50 cfm/sq ft grille area.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

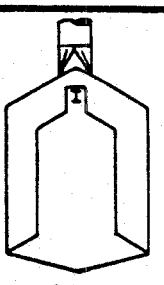
SOLVENT DEGREASING TANKS

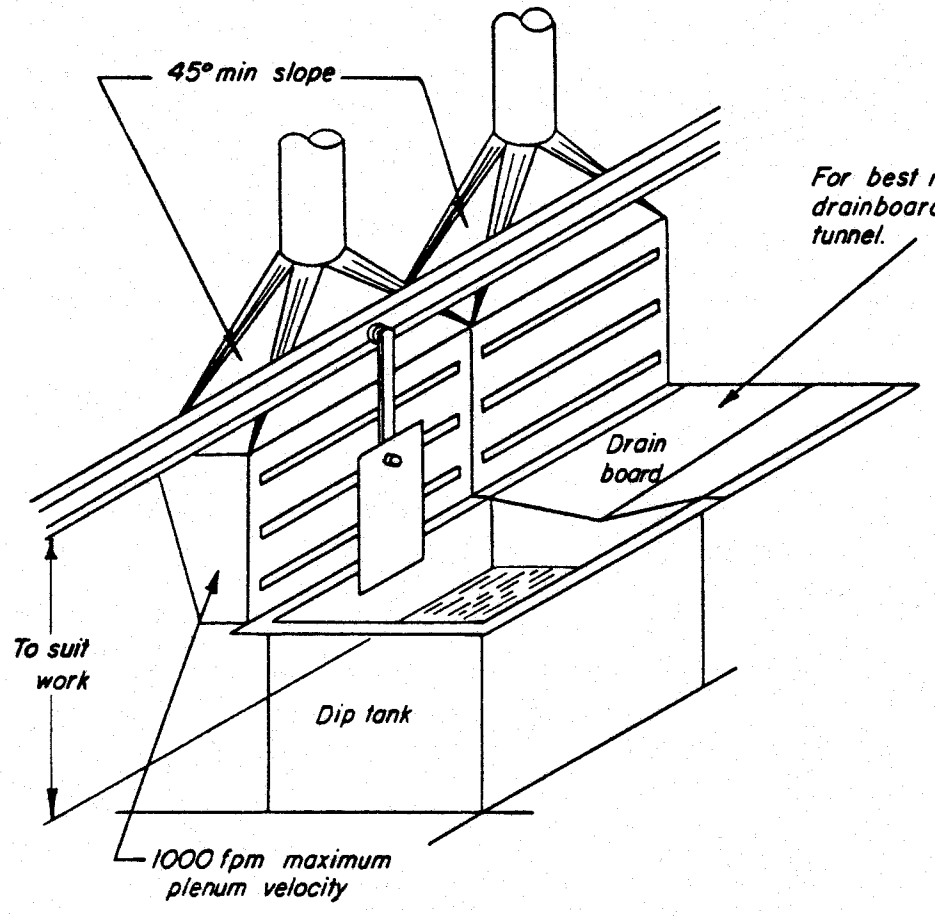
DATE	1-70	VS-501

PRODUCED 1053M - 83

MT-PWHD-004589

Locate takeoffs 15" on center
Q = 50 cfm/sq ft drain board area, but not less than 100 fpm indraft through openings
Entry loss = 0.25 duct VP
Duct velocity = 1000 - 3000 fpm





Q = 125 cfm/sq ft of tank and drainboard area
Slot velocity = 2000 fpm
Entry loss = 1.78 slot VP + 0.25 duct VP
Duct velocity = 1000 - 3000 fpm

NOTE: For details on drying oven, See VS-602

For air drying in a room or enclosure, see Section 2 for dilution ventilation required.

For construction and safety requirements consult American Insurance Association

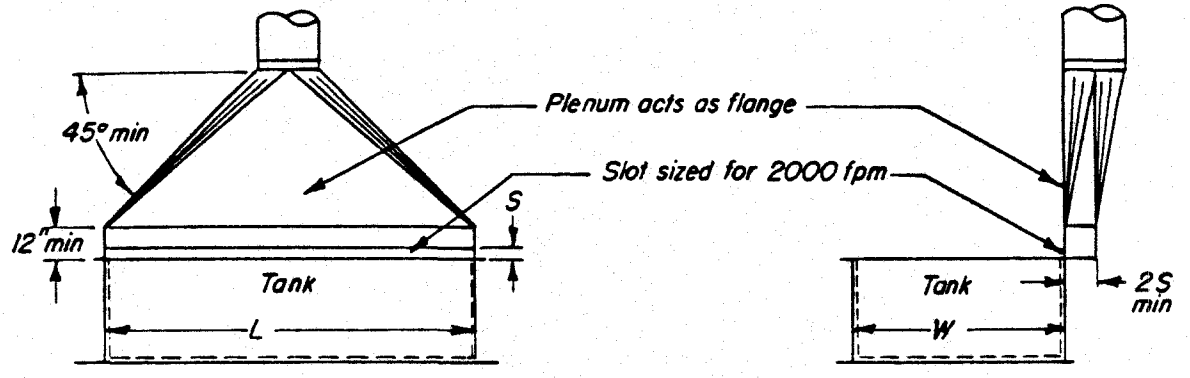
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

DIP TANK

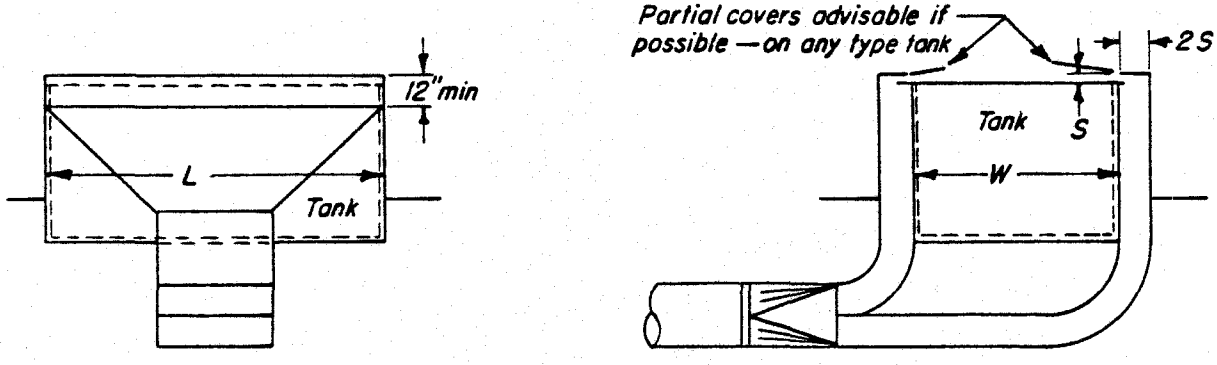
DATE 1-70 | VS-502

PRODUCED
105 JM - 83

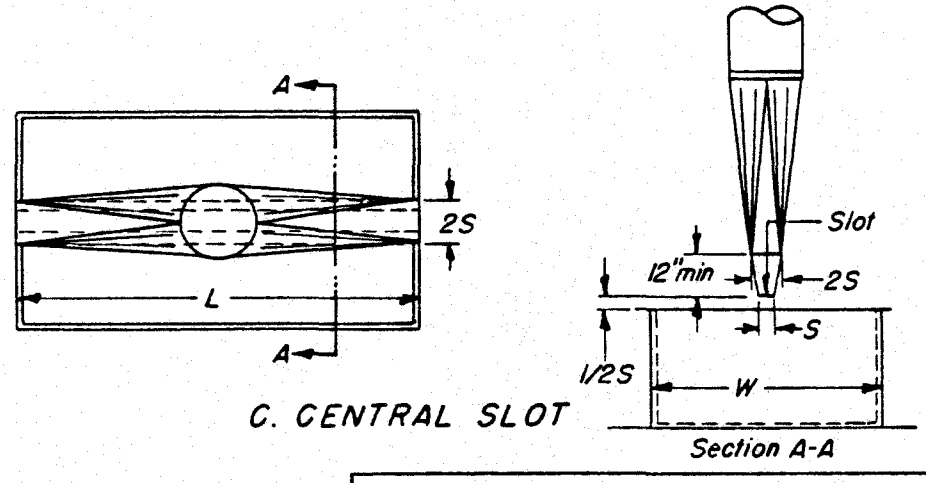
MT-PWHD-004590



A. UPWARD PLENUM



B. DOWNWARD PLENUM



C. CENTRAL SLOT

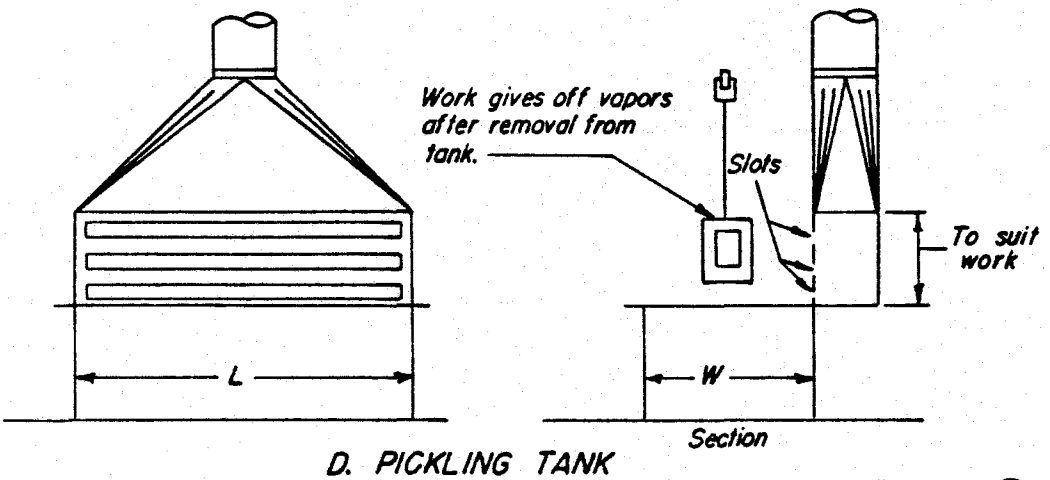
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

OPEN SURFACE TANKS

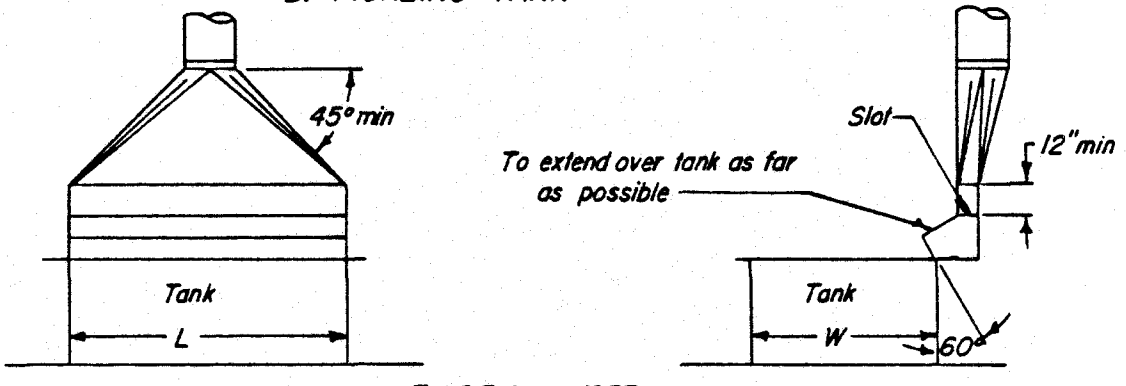
DATE 1-64 | VS-503

1055 PRODUCED JM - 83

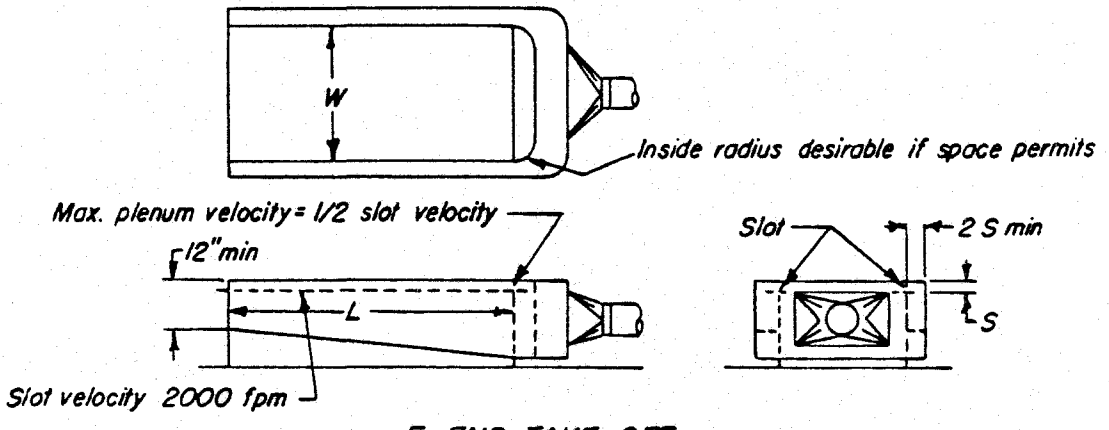
MT-PWHD-004591



D. PICKLING TANK



E. SEMI-LATERAL

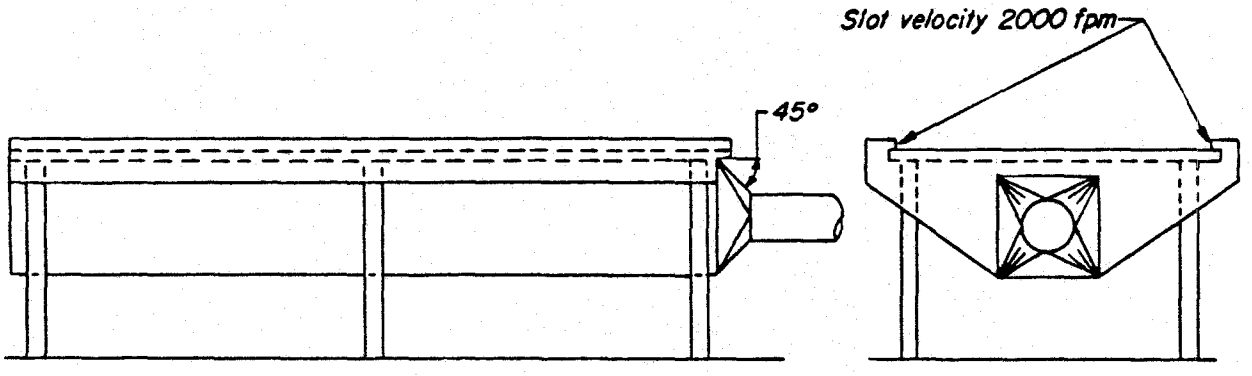


F. END TAKE-OFF

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
OPEN SURFACE TANKS	
DATE 1-66	VS-504

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Q = 50-100 cfm/sq ft of table top.
Duct velocity = 2500-3000 fpm
Entry loss = 1.78 slot VP + 0.25 duct VP

Note: See "Open Surface Tanks", VS-503 and VS-504 for other suitable slot types. Air quantities may be calculated on dilution basis if data is available. Maximum plenum velocity = 1/2 slot velocity. Large plenum essential for good distribution.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
TABLE SLOT	
DATE 1-70	VS-505

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OPEN SURFACE TANK DESIGN DATA (107)

A. Duct velocity = 2000 fpm minimum.
B. Entry loss = 1.78 slot VP plus duct entry loss.
C. Maximum plenum velocity = $\frac{1}{2}$ slot velocity. See Section 4.
D. Slot velocity = 2000 fpm unless distribution provided by well-designed, tapered takeoff.
E. Provide ample area at small end of plenum.
F. If L = 6 feet or greater, multiple takeoffs are desirable.
   If L = 10 feet or greater, multiple takeoffs are necessary.
G. Tank width (W) means the effective width over which the hood must pull air to operate (i.e., where the hood face is set back from the edge of the tank, this set back must be added in measuring tank width).
   If W = 20 inches, slot on one side suitable.
   If W = 20 to 36 inches, slots on both sides are desirable.
   If W = 36 to 48 inches, slots on both sides are necessary unless all other conditions are optimum.
   If W = 48 inches or greater, local exhaust is not usually practical. Enclosure is best. (Also see Push-Pull, Figure 4-17.)

   It is not practicable to ventilate across the long dimension of a tank whose ratio $\frac{W}{L}$ exceeds 2.0. It is undesirable to do so when $\frac{W}{L}$ exceeds 1.0.

H. Liquid level to be at least 6 inches below bottom of slot.
I. Hood types A, C, D and E are preferred--plenum acts as baffle to room air currents.
J. Provide enclosures or removable covers on tank if possible.
K. Provide ductwork with cleanouts and drains and corrosion-resistant coating if necessary. Use flexible connection at fan inlet.
L. Install baffles to reduce crossdrafts. If impossible, increase control velocity by vector analysis. Baffle is a vertical plate the same length as tank and with top of plate as high as tank is wide. If exhaust hood is on side of tank against a building wall or close to it, it is perfectly baffled.

Volume Calculation for Good Conditions (No crossdrafts, adequate and well-distributed makeup air):

1. Determine hazard potential from Table 5-5-1 using information from Threshold Limit Value, Solvent Flash Point or Solvent Drying Time Tables* (pps 13-1 to 13-11) or Table 5-5-6.
2. Determine contaminant evolution rate from Table 5-5-2 employing number denoting highest range (see Table 5-5-6).
3. From Table 5-5-3 choose minimum control velocity according to hazard potential, evolution rate and hood design (see Table 5-5-5 for typical processes).
4. From Table 5-5-4 select the cfm/sq ft for tank dimensions and tank location.
5. Multiply tank area by value obtained from Table 5-5-4 to calculate required air volume.

Example Problem:

Given: Chrome Plating Tank 6' × 2.5'.
High production decorative chrome.
Free standing in room.
No cross drafts.

a. Tank Hood. See VS-503. Use hood "A" along 6' side. Hood acts as baffle.
   W = 2.5'
   L = 6.0'
   W/L = 0.42

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* Dry Time Relation

Below 5 Fast
5-15 Medium
15-75 Slow
75 over - Nil

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b. Component - Chromic Acid

Hazard potential: A (From Table 5-5-1; From Appendix: TLV = 0.1 mg/m^3
Flash point = Negligible)

Rate of Evolution: 1 (From Table 5-5-2; From Table 5-5-6; Gassing rate = high)

Class: A-1
Control Velocity = 150 fpm (From Table 5-5-3)

Minimum Exhaust Rate = 225 cfm/ft^2 (From Table 5-5-4; Baffled tank, $\frac{W}{L}$ = 0.42)

Minimum Exhaust Volume = 225 × 15 sq ft = 3375 cfm

c. Hood Design

Design slot velocity = 2000 fpm

Slot Area = $\frac{Q}{V} = \frac{3375 \text{ cfm}}{2000 \text{ fpm}}$ = 1.69 sq ft.

Slot Width = $\frac{A}{L} = \frac{1.69 \text{ sq ft}}{6 \text{ ft}}$ = 0.28 ft = 3.375 in.

Plenum depth = (2) (slot width) = (2)(3.375) = 6.75"

Duct area = $\frac{Q}{V} = \frac{3375 \text{ cfm}}{2500 \text{ fpm}}$ = 1.35 sq ft. Use 16 in. duct, area = 1.396 sq ft.

Final duct velocity = $\frac{Q}{A} = \frac{3375}{1.396}$ = 2420 fpm

Hood SP = Entry loss + Acceleration
= 1.78 VP_s + 0.25 VP_d + 1.0 VP_d (see Section 4)
= (1.78 × 0.25") + (0.25 × 0.37") + 0.37"
= 0.45 + 0.09 + 0.37
Hood SP = 0.91"

TABLE 5-5-1—DETERMINATION OF HAZARD POTENTIAL

HAZARD POTENTIAL	HYGIENIC STANDARDS		FLASH POINT (See Appendix)
	Gas and Vapor (See Appendix)	Mist (See Appendix)	
A	0-10 ppm	0-.1 mg/M^3	–
B	11-100 ppm	.11-1.0 mg/M^3	Under 100 F
C	101-500 ppm	1.1-10 mg/M^3	100-200 F
D	Over 500 ppm	Over 10 mg/M^3	Over 200 F

TABLE 5-5-2—DETERMINATION OF RATE OF GAS, VAPOR OR MIST EVOLUTION

Rate	Liquid Temperature of	Degrees Below Boiling Point	Relative Evaporation (Time for 100% Evaporation)	Gassing
1	Over 200	0-20	Fast (0-3 hours)	High
2	150-200	21-50	Medium (3-12 hours)	Medium
3	94-149	51-100	Slow (12-50 hours)	Low
4	Under 94	Over 100	Nil (Over 50 hours)	Nil

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TABLE 5-5-3—MINIMUM CONTROL VELOCITY (FPM) FOR UNDISTURBED LOCATIONS

Class (See Tables 5-5-1 and 5-5-2)	Enclosing Hood		Lateral Exhaust (See VS-503-504) (Note 1)	Canopy Hoods (See Fig. 4-14 & VS-903)	
	One Open Sides	Two Open Sides		Three Open Sides	Four Open Sides
A-1, and A-2 (Note 2)	100	150	150	Do not use	Do not use
A-3 (Note 2), B-1, B-2 and C-1	75	100	100	125	175
B-3, C-2, and D-1 (Note 3)	65	90	75	100	150
A-4 (Note 2), C-3, and D-2 (Note 3)	50	75	50	75	125
B-4, C-4, D-3 (Note 3), and D-4 ADEQUATE GENERAL ROOM VENTILATION REQUIRED (See Sec. 2)					

Notes: 1. Use aspect ratio to determine air volume, see Table 5-5-4 for computation.
2. Do not use canopy hood for Hazard Potential A processes.
3. Where complete control of hot water is desired, design as next highest class.

TABLE 5-5-4—MINIMUM RATE, CFM PER SQUARE FOOT OF TANK AREA FOR LATERAL EXHAUST

Required Minimum Control Velocity, fpm (From Table 5-5-3)	Cfm per sq ft to maintain required minimum control velocities at following $\frac{\text{tank width}}{\text{tank length}}\left(\frac{W}{L}\right)$ ratios.				
	0.0-0.09	0.1-0.24	0.25-0.49	0.5-0.99	1.0-2.0
Hood along one side or two parallel sides of tank* when one hood is against a wall or baffle. Also for a manifold along tank centerline.*					
50	50	60	75	90	100
75	75	90	110	130	150
100	100	125	150	175	200
150	150	190	225	260	300
Hood Along one side or two parallel sides of free standing tank not against wall or baffle					
50	75	90	100	110	125
75	110	130	150	170	190
100	150	175	200	225	250
150	225	260	300	340	375
* Use $\frac{W}{2}$ as tank width in computing when manifold is along centerline or two parallel sides of tank.					

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TABLE 5-5-5
Typical Processes
MINIMUM CONTROL VELOCITY (fpm) FOR UNDISTURBED LOCATIONS

Operation	Contaminant	Hazard	Contaminant Evolution	Lateral Exhaust Control Velocity See VS-503-504	Collector Recommended
Anodizing Alum.	Chromic-Sulf. Acids	A	1	150	X
Alum. Bright Dip	Nitric+Sulf. Acids	A	1	150	X
	Nitric+Phosphoric Acids	A	1	150	X
Plating -					
Chromium	Chromic Acid	A	1	150	X
Copper Strike	Cyanide Mist	C	2	75	X
Metal Cleaning (Boiling)	Alkaline Mist	C	1	100	X
Hot Water (If Vent Desired)					
Not Boiling	Water Vapor	D	2	50*	
Boiling		D	1	75*	
Stripping -					
Copper	Alkaline-Cyanide Mists	C	2	75	X
Nickel	Nitrogen Oxide Gases	A	1	150	X
Pickling - Steel	Hydrochloric Acid	A	2	150	X
	Sulfuric Acid	B	1	100	X
Salt Solution (Bonderizing & Parkerizing)					
Not Boiling	Water Vapor	D	2	50*	
Boiling		D	1	75*	
Salt Baths (Molten)	Alkaline Mist	C	1	100	X

* Where complete control of water vapor is desired, design as next highest class.

TABLE 5-5-6—AIRBORNE CONTAMINANTS RELEASED BY METALLIC SURFACE TREATMENT, ETCHING, PICKLING, ACID DIPPING AND METAL CLEANING OPERATIONS

Process	Type	Notes	Component of Bath which May be Released to Atmosphere (13)	Physical and Chemical Nature of Major Atmospheric Contaminant	Class (12)	Usual Temp. Range-F
Surface Treatment	Anodizing Aluminum		Chromic-Sulfuric Acids	Chromic Acid Mist	A-1	95
	Anodizing Aluminum		Sulfuric Acid	Sulfuric Acid Mist	B-1	60- 80
	Black Magic		Conc. Sol. Alkaline Oxidizing Agents	Alkaline Mist, Steam	C-1	260-350
	Bonderizing	1	Boiling Water	Steam	D-2,1 (14,15)	140-212
	Chemical Coloring		None	None	D-4	70- 90
	Descaling	2	Nitric-Sulfuric, Hydrofluoric Acids	Acid Mist, Hydrogen Fluoride Gas, Steam	B-2,1 (15)	70-150
	Ebonol		Conc. Sol. Alkaline Oxidizing Agents	Alkaline Mist, Steam	C-1	260-350
	Galvanic-Anodize	3	Ammonium Hydroxide	Ammonia Gas, Steam	B-3	140
	Hard Coating Aluminum		Chromic-Sulfuric Acids	Chromic Acid Mist	A-1	120-180
	Hard Coating Aluminum		Sulfuric Acid	Sulfuric Acid Mist	B-1	120-180
	Jetal		Conc. Sol. Alkaline Oxidizing Agents	Alkaline Mist, Steam	C-1	260-350
	Magcote	4	Sodium Hydroxide	Alkaline Mist, Steam	C-3,2 (15)	105-212
	Magnesium Pre-Dye Dip		Ammonium Hydroxide-Ammonium Acetate	Ammonia Gas, Steam	B-3	90-180
	Parkerizing	1	Boiling Water	Steam	D-2,1 (14.15)	140-212
	Zincete Immersion	5	None	None	D-4	70- 90

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TABLE 5-5-6—CONTINUED

Process	Type	Notes	Component of Bath which May be Released to Atmosphere (13)	Physical and Chemical Nature of Major Atmospheric Contaminant	Class (12)	Usual Temp. Range-F
Etching	Aluminum		Sodium Hydroxide-Soda Ash-Trisodium Phosphate	Alkaline Mist, Steam	C-1	160-180
	Copper	6	Hydrochloric Acid	Hydrogen Chloride Gas	A-2	70- 90
	Copper	7	None	None	D-4	70
Pickling	Aluminum		Nitric Acid	Nitrogen Oxide Gases	A-2	70- 90
	Aluminum		Chromic, Sulfuric Acids	Acid Mists	A-3	140
	Aluminum		Sodium Hydroxide	Alkaline Mist	C-1	140
	Cast Iron		Hydrofluoric-Nitric Acids	Hydrogen Fluoride-Nitrogen Oxide Gases	A-2,1 (15)	70- 90
	Copper		Sulfuric Acid	Acid Mist, Steam	B-3,2 (15)	125-175
	Copper	8	None	None	D-4	70-175
	Duralumin		Sodium Fluoride, Sulfuric Acid	Hydrogen Fluoride Gas, Acid Mist	A-3	70
	Inconel		Nitric, Hydrofluoric Acids	Nitrogen Oxide, HF Gases, Steam	A-1	150-160
	Inconel		Sulfuric Acid	Sulfuric Acid Mist, Steam	B-2	160-180
	Iron and Steel		Hydrochloric Acid	Hydrogen Chloride Gas	A-2	70
	Iron and Steel		Sulfuric Acid	Sulfuric Acid Mist, Steam	B-1	70-175
	Magnesium		Chromic-Sulfuric, Nitric Acids	Nitrogen Oxide Gases, Acid Mist, Steam	A-2	70-160
	Monel and Nickel		Hydrochloric Acid	Hydrogen Chloride Gas, Steam	A-2	180
	Monel and Nickel		Sulfuric Acid	Sulfuric Acid Mist, Steam	B-1	160-190
	Nickel Silver		Sulfuric Acid	Acid Mist, Steam	B-3,2 (15)	70-140
	Silver		Sodium Cyanide	Cyanide Mist, Steam	C-3	70-210
	Stainless Steel	9	Nitric, Hydrofluoric Acids	Nitrogen Oxide, Hydrogen Fluoride Gases	A-2	125-180
	Stainless Steel	9,10	Hydrochloric Acid	Hydrogen Chloride Gas	A-2	130-140
	Stainless Steel	9,10	Sulfuric Acid	Sulfuric Acid Mist, Steam	B-1	180
	Stainless Steel Immunization		Nitric Acid	Nitrogen Oxide Gases	A-2	70-120
	Stainless Steel Passivation		Nitric Acid	Nitrogen Oxide Gases	A-2	70-120
Acid Dipping	Aluminum Bright Dip		Phosphoric, Nitric Acids	Nitrogen Oxide Gases	A-1	200
	Aluminum Bright Dip		Nitric, Sulfuric Acids	Nitrogen Oxide Gases, Acid Mist	A-2,1 (15)	70- 90
	Cadmium Bright Dip		None	None	D-4	70
	Copper Bright Dip		Nitric, Sulfuric Acids	Nitrogen Oxide Gases, Acid Mist	A-2,1 (15)	70- 90
	Copper Semi-Bright Dip		Sulfuric Acid	Acid Mist	B-2	70
	Copper Alloys Bright Dip		Nitric, Sulfuric Acids	Nitrogen Oxide Gases, Acid Mist	A-2,1 (15)	70- 90
	Copper Matte Dip		Nitric, Sulfuric Acids	Nitrogen Oxide Gases, Acid Mist	A-2,1 (15)	70- 90
	Magnesium Dip		Chromic Acid	Acid Mist, Steam	A-2	190-212
	Magnesium Dip		Nitric, Sulfuric Acids	Nitrogen Oxide Gases, Acid Mist	A-2,1 (15)	70- 90
	Monel Dip		Nitric, Sulfuric Acids	Nitrogen Oxide Gases, Acid Mist	A-2,1 (15)	70- 90
	Nickel and Nickel Alloys Dip		Nitric, Sulfuric Acids	Nitrogen Oxide Gases, Acid Mist	A-2,1 (15)	70- 90
	Silver Dip		Nitric Acid	Nitrogen Oxide Gases	A-1	70- 90
	Silver Dip		Sulfuric Acid	Sulfuric Acid Mist	B-2	70- 90
	Zinc and Zinc Alloys Dip		Chromic, Hydrochloric Acids	Hydrogen Chloride Gas (If HCl attacks Z_n)	A-4,3 (15)	70- 90
Metal Cleaning	Alkaline Cleaning	11	Alkaline Sodium Salts	Alkaline Mist, Steam	C-2,1 (15)	160-210
	Degreasing		Trichloroethylene-Per-chloroethylene	Trichloroethylene-Per chloroethylene Vapors	B (16)	188-250
	Emulsion Cleaning		Petroleum-Coal Tar Solvents	Petroleum-Coal Tar Vapors	B-3,2 (15)	70-140
	Emulsion Cleaning		Chlorinated Hydrocarbons	Chlorinated Hydrocarbon Vapors	(17)	70-140

Notes: 1 Also Aluminum Seal, Magnesium Seal, Magnesium Dye Set, Dyeing Anodized Magnesium, Magnesium Alkaline Dichromate Soak, Coloring Anodized Aluminum
2 Stainless Steel before Electropolishing
3 On Magnesium
4 Also Manodyz, Dow-12
5 On Aluminum
6 Dull Finish
7 Ferric Chloride Bath
8 Sodium Dichromate, Sulfuric Acid Bath and Ferrous Sulfate, Sulfuric Acid Bath
9 Scale Removal
10 Scale Loosening
11 Soak and Electrocleaning

12 Class as described in Section 2 for use in Table 3 based on hazard potential (Table 1) and rate of evolution (Table 2) for usual operating conditions. Higher temperatures, agitation or other conditions may result in a higher rate of evolution.
13 Hydrogen gas also released by many of these operations.
14 Rate where essentially complete control of steam is required. Otherwise, adequate dilution ventilation may be sufficient.
15 The higher rate is associated with the higher value in the temperature range.
16 For vapor degreasers, rate is determined by operating procedure. Refer to Table 2, Note 2, for explanation. For other degreasing operations rate of vapor evolution is 1 for trichloroethylene, 2 for perchloroethylene.
17 Class of operation is determined by nature of the hydrocarbon. Refer to Appendix A.

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TABLE 5-5-7--AIRBORNE CONTAMINANTS RELEASED BY ELECTROPOLISHING, ELECTROPLATING AND ELECTROLESS PLATING OPERATIONS

Process	Type	Notes	Component of Bath which may be Released to Atmosphere (19)	Physical and Chemical Nature of Major Atmospheric Contaminant	Class (18)	Usual Temp. Range-F
Electro-Polishing	Aluminum	1	Sulfuric, Hydrofluoric Acids	Acid Mist, Hydrogen Fluoride Gas, Steam	A-2	140-200
	Brass, Bronze	1	Phosphoric Acid	Acid Mist	B-3	68
	Copper	1	Phosphoric Acid	Acid Mist	B-3	68
	Iron	1	Sulfuric, Hydrochloric, Perchloric Acids	Acid Mist, Hydrogen Chloride Gas, Steam	A-2	68-175
	Monel	1	Sulfuric Acid	Acid Mist, Steam	B-2	86-160
	Nickel	1	Sulfuric Acid	Acid Mist, Steam	B-2	86-160
	Stainless Steel	1	Sulfuric, Hydrofluoric, Chromic Acids	Acid Mist, Hydrogen Fluoride Gas, Steam	A-2,1 (20)	70-300
	Steel	1	Sulfuric, Hydrochloric, Perchloric Acids	Acid Mist, Hydrogen Chloride Gas, Steam	A-2	68-175
Strike Solutions	Copper		Cyanide Salts	Cyanide Mist	C-2	70- 90
	Silver		Cyanide Salts	Cyanide Mist	C-2	70- 90
	Wood's Nickel		Nickel Chloride, Hydrochloric Acid	Hydrogen Chloride Gas, Chloride Mist	A-2	70- 90
Electroless Plating	Copper		Formaldehyde	Formaldehyde Gas	A-1	75
	Nickel	2	Ammonium Hydroxide	Ammonia Gas	B-1	190
Electroplating Alkaline	Platinum		Ammonium Phosphate, Ammonia Gas	Ammonia Gas	B-2	158-203
	Tin		Sodium Stannate	Tin Salt Mist, Steam	C-3	140-170
	Zinc	3	None	None	D-4	170-180
Electroplating Fluoborate	Cadmium		Fluoborate Salts	Fluoborate Mist, Steam	C-3,2 (20)	70-170
	Copper		Copper Fluoborate	Fluoborate Mist, Steam	C-3,2 (20)	70-170
	Indium		Fluoborate Salts	Fluoborate Mist, Steam	C-3,2 (20)	70-170
	Lead		Lead Fluoborate-Fluoboric Acid	Fluoborate Mist, Hydrogen Fluoride Gas	A-3	70- 90
	Lead-Tin Alloy		Lead Fluoborate-Fluoboric Acid	Fluoborate Mist	C-3,2 (20)	70-100
	Nickel		Nickel Fluoborate	Fluoborate Mist	C-3,2 (20)	100-170
	Tin		Stannous Fluoborate, Fluoboric Acid	Fluoborate Mist	C-3,2 (20)	70-100
	Zinc		Fluoborate Salts	Fluoborate Mist, Steam	C-3,2 (20)	70-170
Electroplating Cyanide	Brass, Bronze	4, 5	Cyanide Salts, Ammonium Hydroxide	Cyanide Mist, Ammonia Gas	B-4,3 (20)	60-100
	Bright Zinc	5	Cyanide Salts, Sodium Hydroxide	Cyanide, Alkaline Mists	C-3	70-120
	Cadmium	5	None	None	D-4	70-100
	Copper	5, 6	None	None	D-4	70-160
	Copper	5, 7	Cyanide Salts, Sodium Hydroxide	Cyanide, Alkaline Mists, Steam	C-2	110-160
	Gold	5	Cyanide Salts	Cyanide Mist, Steam	C-4,3 (20)	75-214
	Indium	5	Cyanide Salts, Sodium Hydroxide	Cyanide, Alkaline Mists	C-3	70-120
	Silver	5	None	None	D-4	72-120
	Tin-Zinc Alloy	5	Cyanide Salts, Potassium Hydroxide	Cyanide, Alkaline Mists, Steam	C-3,2 (20)	120-140
	White Alloy	5, 8	Cyanide Salts, Sodium Stannate	Cyanide, Alkaline Mists	C-3	120-150
	Zinc	5, 9	Cyanide Salts, Sodium Hydroxide	Cyanide, Alkaline Mists	C-3,2 (7)	70-120
Electroplating Acid	Chromium		Chromic Acid	Chromic Acid Mist	A-1	90-140
	Copper	10	Copper Sulfate, Sulfuric Acid	Sulfuric Acid Mist	B-4,3 (20,21)	75-120
	Gold	11	Cyanide Salts	Cyanide Mist	C-3,2 (20)	70-160
	Indium	12	None	None	D-4	70-120
	Indium	13,14	Sulfamic Acid, Sulfamate Salts	Sulfamate Mist	C-3	70- 90
	Iron		Chloride Salts, Hydrochloric Acid	Hydrochloric Acid Mist, Steam	A-2	190-210
	Iron	12	None	None	D-4	70-120
	Nickel	3	Ammonium Fluoride, Hydrofluoric Acid	Hydrofluoric Acid Mist	A-3	102
	Nickel and Black Nickel	12,15	None	None	C-4 (22)	70-150
	Nickel	9,12	Nickel Sulfate	Nickel Sulfate Mist	B-2	70- 90
	Nickel	13,14	Nickel Sulfamate	Sulfamate Mist	C-3	75-160
	Palladium	15	None	None	D-4	70-120
	Rhodium	12,17	None	None	D-4	70-120
	Tin		Tin Halide	Halide Mist	C-2	70- 90
	Tin	12	None	None	D-4	70-120
	Zinc		Zinc Chloride	Zinc Chloride Mist	B-3	75-120
	Zinc	12	None	None	D-4	70-120

Notes:
1 Arsine may be produced due to the presence of arsenic in the metal or polishing bath.
2 Alkaline Bath
3 On Magnesium
4 Also Copper-Cadmium Bronze
5 HCN gas may be evolved due to the acidic action of CO_2 in the air at the surface of the bath.
6 Conventional Cyanide Bath
7 Except Conventional Cyanide Bath
8 Albaloy, Spekwhite, Bonwhite (Alloys of Copper, Tin, Zinc)
9 Using Insoluble Anodes
10 Over 90 F
11 Mild Organic Acid Bath
12 Sulfate Bath
13 Sulfamate Bath
14 Air Agitated
15 Chloride Bath
16 Nitrite Bath
17 Phosphate Bath
18 Class as described in Section 2 for use in Table 3 based on hazard potential (Table 1) and rate of evolution (Table 2) for usual operating conditions. Higher temperatures, agitation, high current density or other conditions may result in a higher rate of evolution.
19 Hydrogen gas also released by many of these operations.
20 The higher rate is associated with the higher value in the temperature range.
21 Baths operated at a temperature of over 140 F with a current density of over 45 amps per square foot and with air agitation will have a higher rate of evolution.
22 Local exhaust ventilation may be desired to control steam and water vapor.

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TABLE 5-5-8—AIRBORNE CONTAMINANTS RELEASED BY STRIPPING OPERATIONS

Coating to be Stripped	Base Metal (Footnote)	Component of Bath which may be released to Atmosphere (f)	Physical and Chemical Nature of Major Atmospheric Contaminant	Class (e)	Usual Temp. Range-F
Anodized Coatings	1,7	Chromic Acid	Acid Mist, Steam	A-2	120-200
Black Oxide Coatings	14	Hydrochloric Acid	Hydrogen Chloride Gas	A-3,2 (g)	70-125
Brass and Bronze	8,14 (a)	Sodium Hydroxide, Sodium Cyanide	Alkaline, Cyanide Mists	C-3,2 (g)	70- 90
Cadmium	8,14 (a)	Sodium Hydroxide, Sodium Cyanide	Alkaline, Cyanide Mists	C-3,2 (g)	70- 90
	2,4,14	Hydrochloric Acid	Acid Mist, Hydrogen Chloride Gas	A-3,2 (g)	70- 90
Chromium	7,8,14 (a)	Sodium Hydroxide	Alkaline Mist, Steam	C-3	70-150
	2,4,8,14	Hydrochloric Acid	Hydrogen Chloride Gas	A-2	70-125
	2,4,8,18 (a)	Sulfuric Acid	Acid Mist	B-2	70- 90
Copper	8,14	Sodium Hydroxide, Sodium Cyanide	Alkaline, Cyanide Mists	C-3,2 (g)	70- 90
	7,12,14 (b)	None	None	D-4	70- 90
	14 (a)	Alkaline Cyanide	Cyanide Mist	C-3,2 (g)	70-160
	1	Nitric Acid	Nitrogen Oxide Gases	A-1	70-120
	18 (a)	Sodium Hydroxide-Sodium Sulfide	Alkaline Mist, Steam	C-2	185-195
Gold	4,5,6,8,9,14 (a)	Sodium Hydroxide, Sodium Cyanide	Alkaline, Cyanide Mists	C-3,2 (g)	70- 90
	4,5,18 (a)	Sulfuric Acid	Acid Mist	B-3,2 (g)	70-100
Lead	13 (c)	Acetic Acid, Hydrogen Peroxide	Oxygen Mist	D-3	70- 90
	14 (a),(c)	Sodium Hydroxide	Alkaline Mist, Steam	C-3,2 (g)	70-140
Nickel	2,4	Sulfuric, Mitric Acids	Nitrogen Oxide Gases	A-2,1 (g)	70- 90
	2,4 (a)	Hydrochloric Acid	Hydrogen Chloride Gas	A-3	70- 90
	2,4,14 (a)	Sulfuric Acid	Acid Mist	B-3	70- 90
	7	Hydrofluoric Acid	Hydrogen Fluoride Gas	A-3,2 (g)	70- 90
	14	Fuming Nitric Acid	Nitrogen Oxide Gases	A-1	70- 90
	(a),(d)	Hot Water	Steam	D-2 (h)	200
	1,18,19 (a)	Sulfuric Acid	Acid Mist, Steam	B-3,2 (g)	70-150
Phosphate Coatings	15	Chromic Acid	Acid Mist, Steam	A-3	165
	16	Ammonium Hydroxide	Ammonia Gas	B-3,2 (g)	70- 90
Rhodium	10	Sulfuric, Hydrochloric Acids	Acid Mist, Hydrogen Chloride Gas	A-3,2 (g)	70-100
Silver	1	Nitric Acid	Nitrogen Oxide Gases	A-1	70- 90
	2,11	Sulfuric, Nitric Acids	Nitrogen Oxide Gases, Steam	A-1	180
	8,14 (a)	Sodium Hydroxide, Sodium Cyanide	Alkaline, Cyanide Mists	C-3	70- 90
	17 (a)	Sodium Cyanide	Cyanide Mist	C-3	70- 90
Tin	2,3,4	Ferric Chloride, Copper Sulfate, Acetic Acid	Acid Mist	B-4,3 (g)	70- 90
	(a)	Sodium Hydroxide	Alkaline Mist	C-3	70- 90
	2,4,14	Hydrochloric Acid	Hydrogen Chloride Gas	A-3,2 (g)	70- 90
	14 (a)	Sodium Hydroxide	Alkaline Mist, Steam	C-2	70-200
Zinc	1	Nitric Acid	Nitrogen Oxide Gases	A-1	70- 90
	8,14	Sodium Hydroxide, Sodium	Alkaline, Cyanide Mists	C-3	70- 90

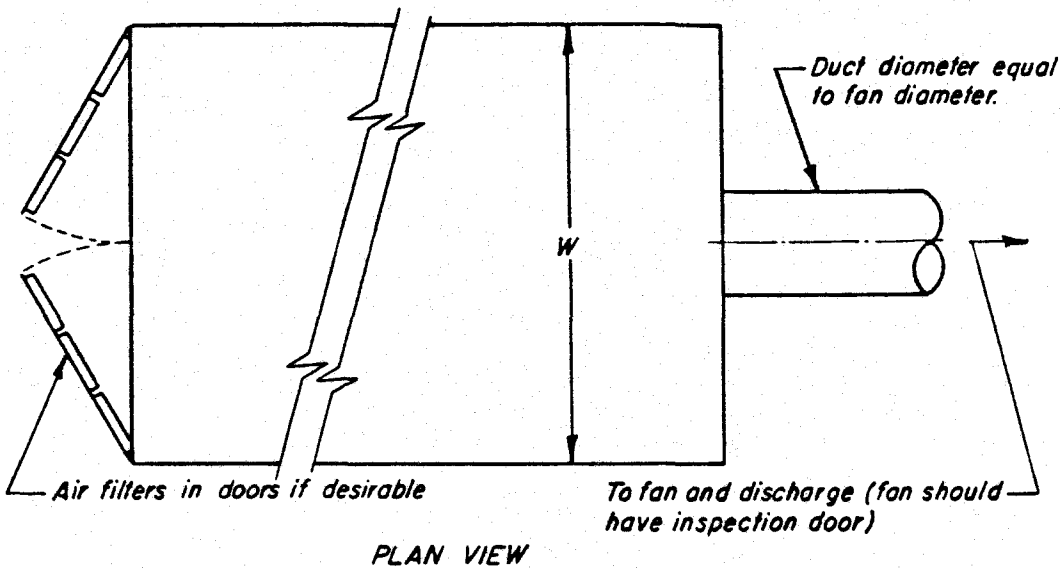
Footnotes: 1. Aluminum
2. Brass
3. Bronze
4. Copper
5. Copper Alloys
6. Ferrous Metals
7. Magnesium
8. Nickel
9. Nickel Alloys
10. Nickel Plated Brass
11. Nickel Silver
12. Non Ferrous Metals
13. Silver
14. Steel
15. Steel (Manganese Type Coatings)
16. Steel (Zinc Type Coatings)
17. White Metal
18. Zinc
19. Zinc Base Die Castings

(a) Electrolytic Process
(b) Refers only to steel (14) when Chromic, Sulfuric Acids Bath is used.
(c) Also Lead Alloys
(d) Sodium Nitrate Bath
(e) Class as described in Section 2 for use in Table 3 based on hazard potential (Table 1) and rate of evolution (Table 2) for usual operating conditions. Higher temperatures, agitation or other conditions may result in a higher rate of evolution.

Footnotes: (f) Hydrogen gas also released by some of these operations.
(g) The higher rate is associated with the higher value in the temperature range.
(h) Rate where essentially complete control of steam is required. Otherwise, adequate dilution ventilation may be sufficient.

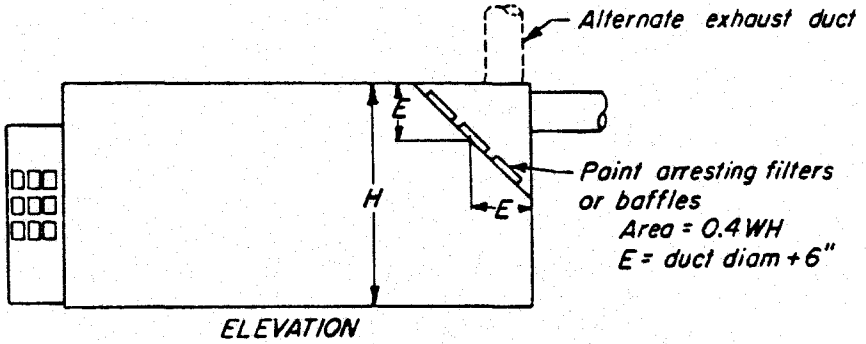
PRODUCED
1064 JM - 83

MT-PWHD-004600



PLAN VIEW

Q = 100 cfm/sq ft of cross-section area
Entry loss = 0.50 VP plus resistance of each filter bank when dirty
Duct velocity = 1000 - 3000 fpm
Air filters to be sized for 275 cfm/sq ft of filter
Paint filters: combustibility Class 2 or better
size and number of filter for minimum area shown



ELEVATION

Typical filter installation

For construction and safety requirements consult American Insurance Association

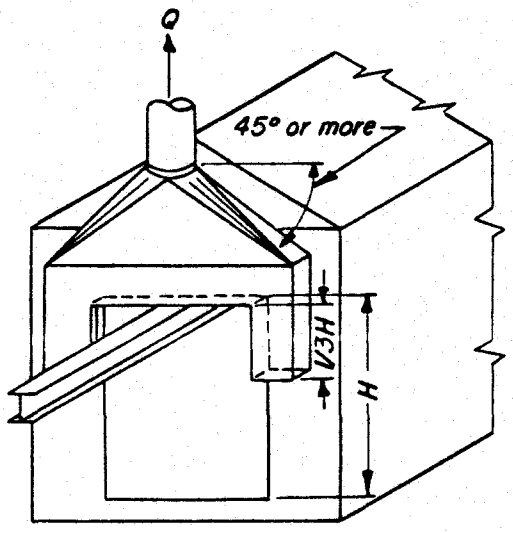
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AUTO SPRAY PAINT BOOTH

DATE	1-70	VS-601

PRODUCED 1065
JM - 83

MT-PWHD-004601

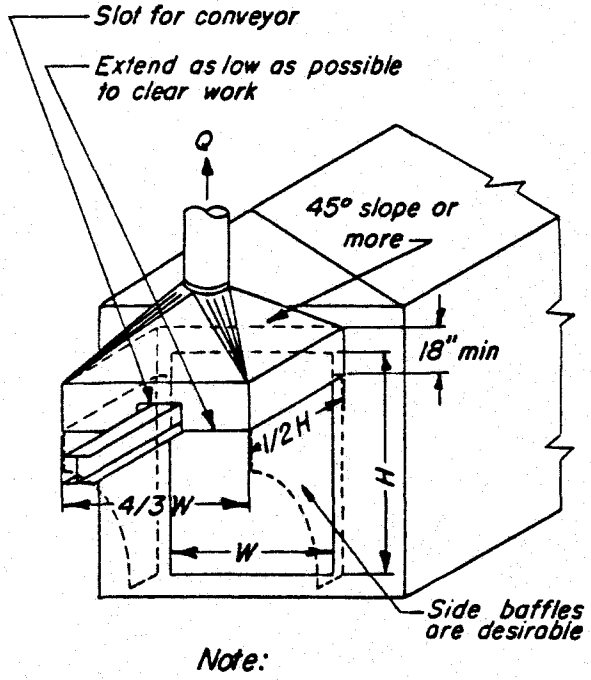


SLOT TYPE

Q = 100 cfm/sq ft door plus 1/2 products of combustion
Entry loss = 1.0 slot VP plus 0.25 duct VP
Duct velocity = 1000-3000 fpm

Size plenum for 500 fpm maximum

Slot on three sides size for 1000 fpm
Locate on inside or outside of door.



CANOPY TYPE

Q = 200 cfm/sq ft of hood face plus 1/2 products of combustion
Entry loss = 0.25 VP
Duct velocity = 1000-3000 fpm

Note:
For dryers, include volume of water vapor liberated.
For flammable solvent drying refer to Section 2, "Dilution Ventilation for Fire and Explosions".

Note:
Hoods at each end of oven. Reduce size of doors as much as possible. Separate vent must be added for products of combustion.

For construction and safety requirements consult American Insurance Association

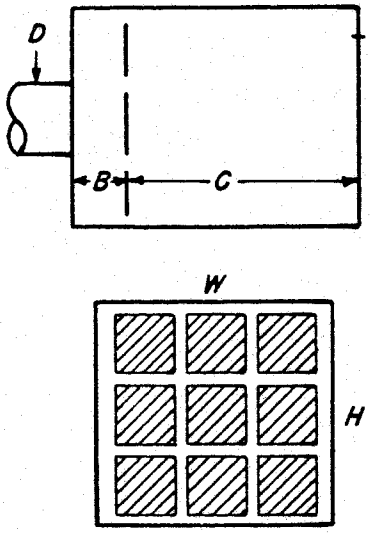
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DRYING OVEN VENTILATION

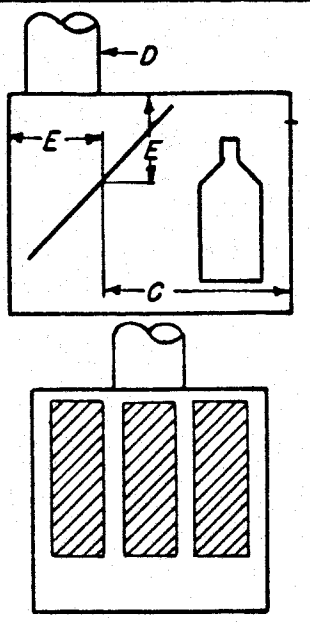
DATE 1-70 | VS-602

1066 PRODUCED JM - 83

MT-PWHD-004602



1. Split Baffle or Filters
B = 0.75 D
Baffle or filter area = 0.75 WH
Filter combustibility Class 2 or better.
Consult AIA or insurance underwriters



2. Angular Baffle
E = D + 6"
Baffle area = 0.40 WH

DESIGN DATA

Any combination of duct connections and baffles may be used. Large, deep booths do not require baffles. Consult manufactures for water-curtain designs. Use explosion proof fixtures and non-sparking fan. Electrostatic spray booth requires automatic high-voltage disconnects for conveyor failure, fan failure or grounding.

Walk-in booth
W = work size + 6'
H = work size + 3' (minimum = 7')
C = work size + 6'
Q = 100 cfm/sq ft booth cross section
May be 75 cfm/sq ft for very large, deep, booth. Operator may require approved respirator.
Entry loss = Baffles: 1.78 slot VP + 0.50 duct VP
= Filters: dirty filter resistance + 0.50 duct VP
Duct velocity = 1000 - 3000 fpm

Operator outside booth
W = work size + 2'
H = work size + 2'
C = 0.75 x larger front dimension
Q = 100 - 150 cfm/sq ft of open area, including conveyor openings.

Note: Baffle arrangements shown are air distribution only. Filters and/or other air cleaning devices may be required to meet air pollution codes or local conditions.

For construction and safety requirements consult American Insurance Association

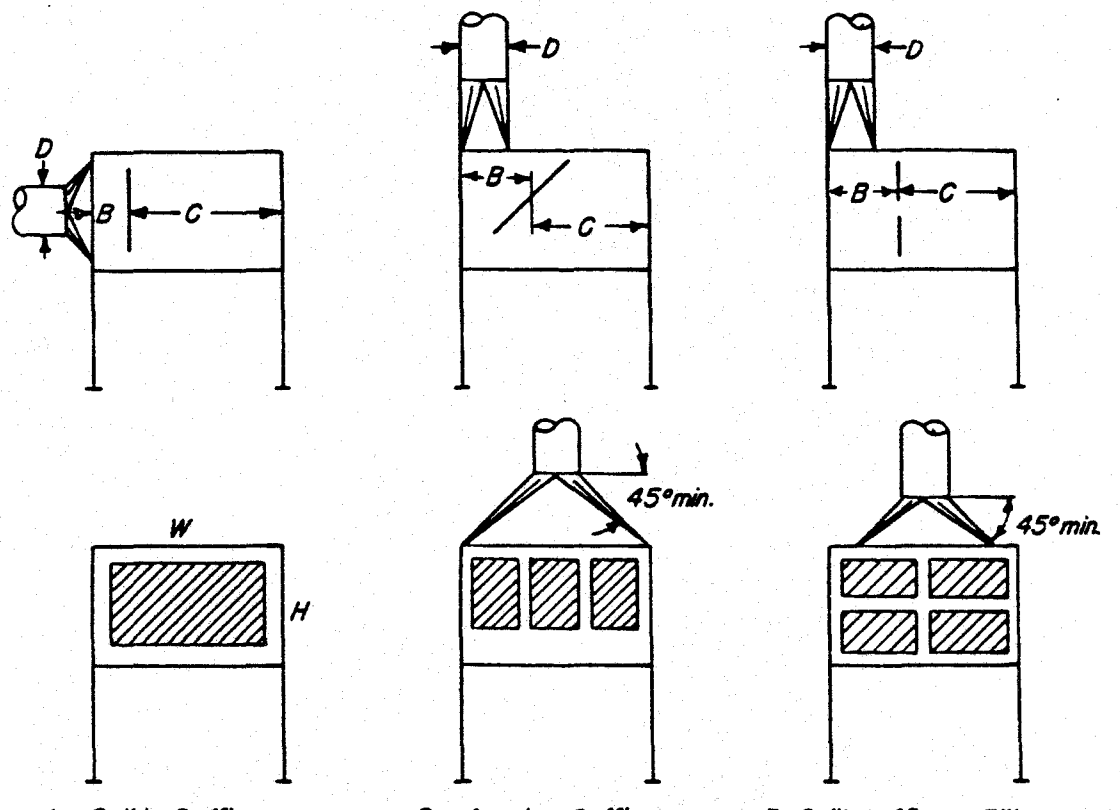
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LARGE PAINT BOOTH

DATE 1-72 | VS-603

PRODUCED 1067
JM - 83

MT-PWHD-004603



1. Solid Baffle
   B = 0.75D
   Baffle area = 0.60WH

2. Angular Baffle
   B = D + 6"
   Baffle area = 0.60WH

3. Split Baffle or Filters
   B = D + 6"
   Baffles or filters = 0.75WH
   Filter combustibility Class 2 or better. Consult NBFU or insurance underwriters.

Design data —
Any combination of branch ducts and baffles may be used.
W = work size + 12"
H = work size + 12"
C = 0.75 W or H, whichever is larger.
Q = 200 cfm/sq ft (200WH) — for face area up to 4 sq ft
= 150 cfm/sq ft — for face area over 4 sq ft
Entry loss = Baffles: 1.78 slot VP + 0.50 duct VP
= Filters: Dirty filter resistance + 0.50 duct VP
Duct velocity = 1000 - 3000 fpm

Note: Baffle arrangements shown are for air distribution only. Filters and/or other air cleaning devices may be required to meet air pollution codes or local conditions.

For construction and safety requirements consult American Insurance Association.

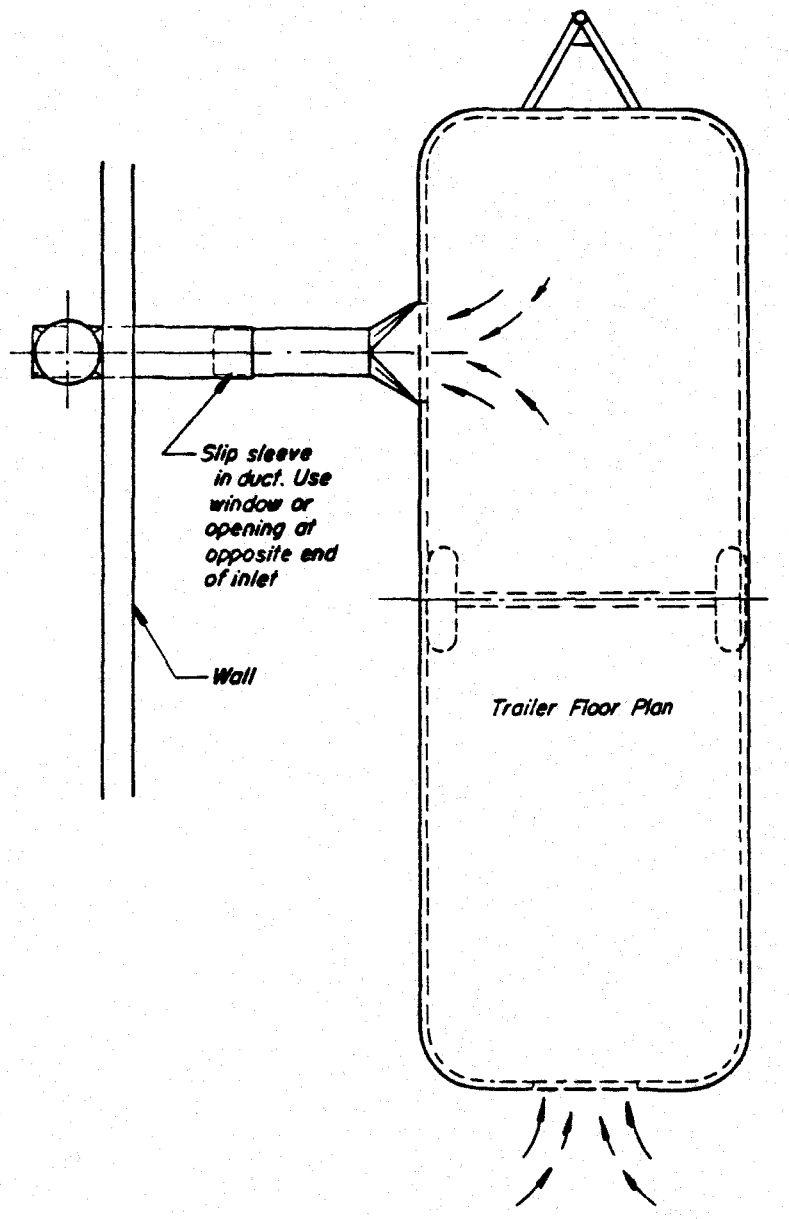
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SMALL PAINT BOOTH

DATE 1-72 | VS-604

1068 PRODUCED JM - 83

MT-PWHD-004604



Q = 50 cfm / sq ft of cross - sectional trailer area
Entry loss = 0.25 VP
Duct velocity = 1000 - 3000 fpm

NOTE: Operator must wear an air-supplied respirator

For construction and safety requirements consult American Insurance Association

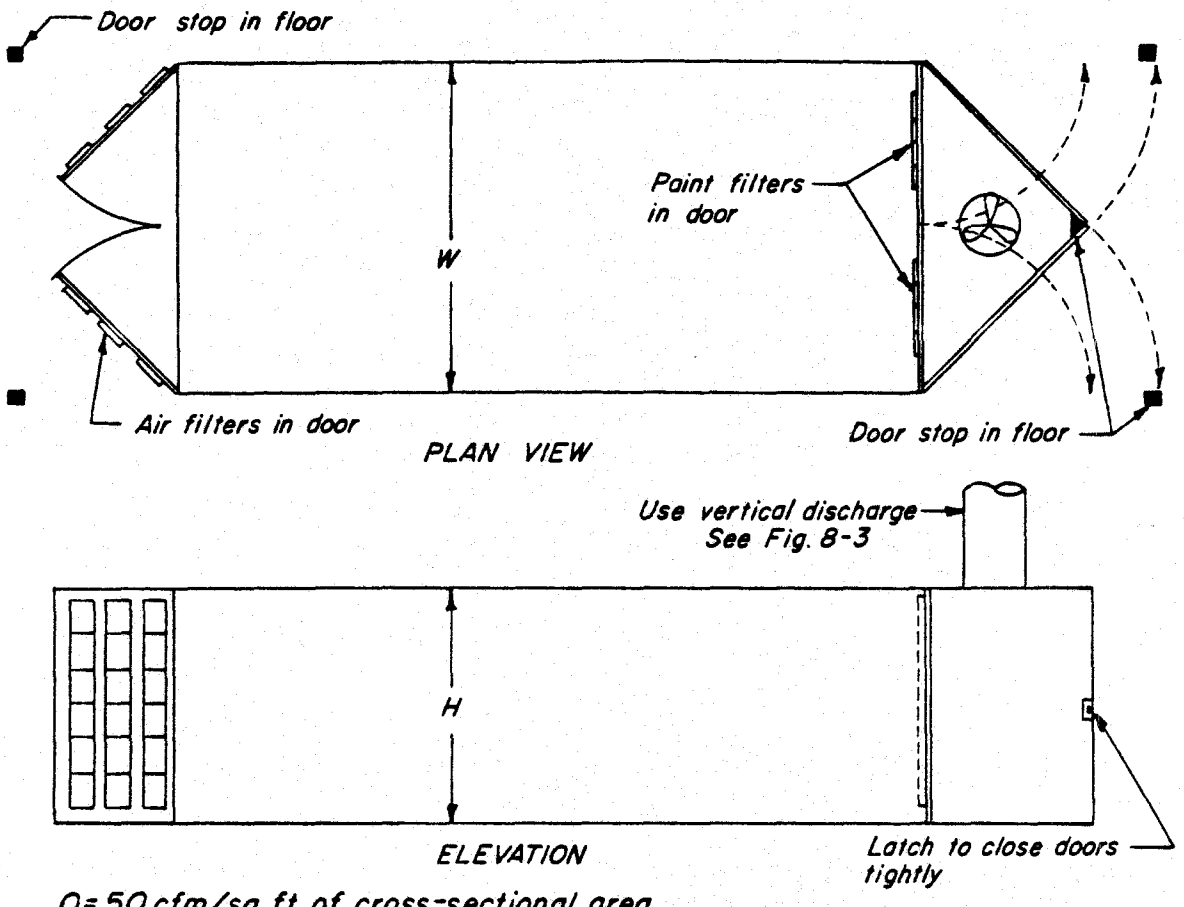
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TRAILER INTERIOR SPRAY PAINTING

DATE 1-70 | VS-605

REPRODUCED JM - 83

MT-PWHD-004605



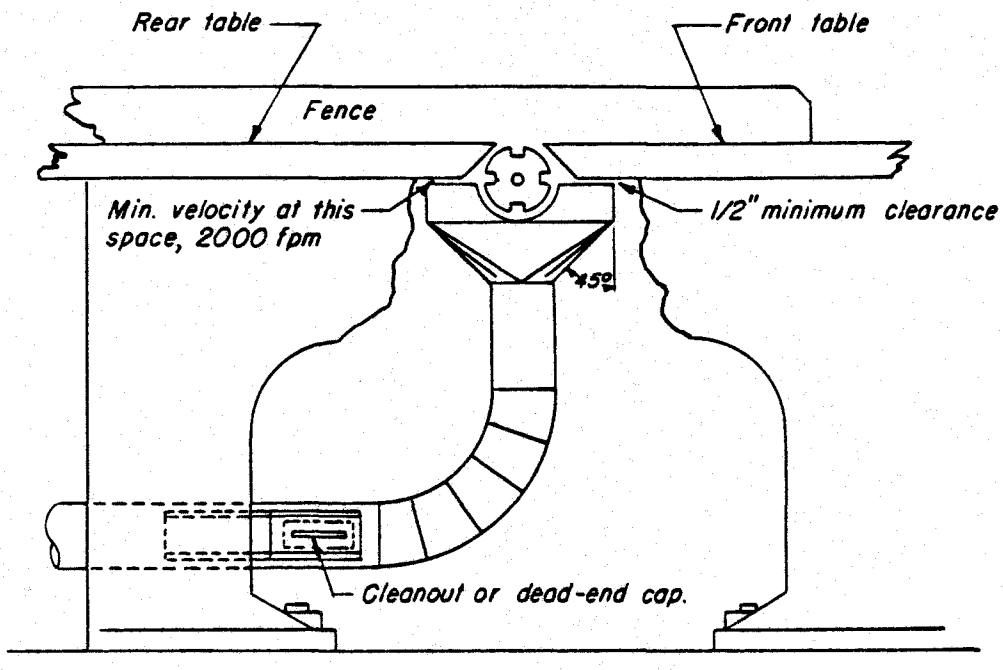
Q = 50 cfm/sq ft of cross-sectional area
(when WxH is greater than 150 sq ft)
Entry loss = 0.50 VP plus resistance of each filter bank when dirty
Duct velocity = 1000 - 3000 fpm
Air filters: Size for 275 cfm/sq ft of filters
Paint filters: Combustibility Class 2 or better, consult mfr for size and number

Note:
Fan interlock with make-air supply and compressed air to spray gun is desirable
For construction and safety requirements consult American Insurance Association

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
LARGE DRIVE-THROUGH SPRAY PAINT BOOTH	
DATE 1-70	VS-606

1070 PRODUCED JM - 83

MT-PWHD-004606



Knife length, inches	Exhaust volume, cfm
Up to 6 incl.	350
over 6 to 12 incl.	440
over 12 to 20 incl.	550
over 20	800

Duct velocity = 3500 fpm
Entry loss = 1.0 slot VP + 0.25 duct VP

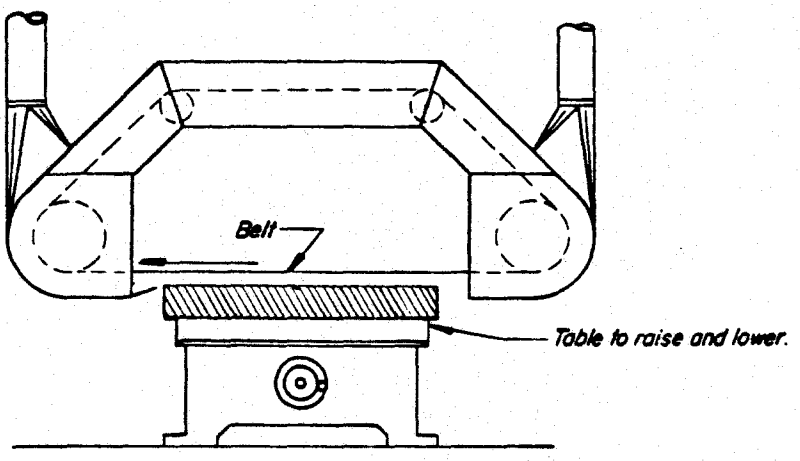
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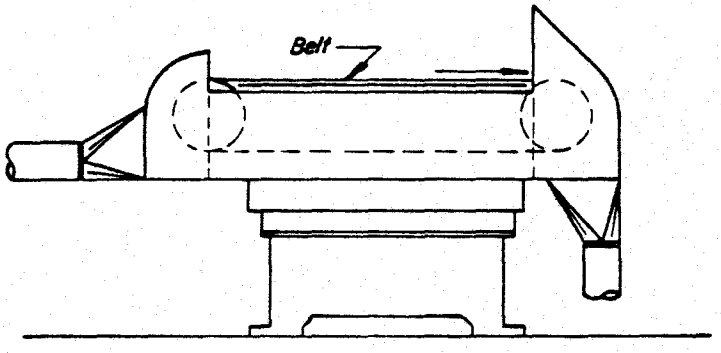
JOINTERS

DATE 1-64 | VS-701

PRODUCED 107 JM - 83

MT-PWHD-004607





HORIZONTAL BELT SANDERS

Belt width, inches	Exhaust volume, cfm		
	Head end	Tail end	Total
Up to 6 incl.	440	350	790
over 6 to 9 incl.	550	350	900
over 9 to 14 incl	800	440	1240
over 14	1100	550	1650

Duct velocity = 3500 fpm
Entry losses = 0.40 VP for tapered take-off

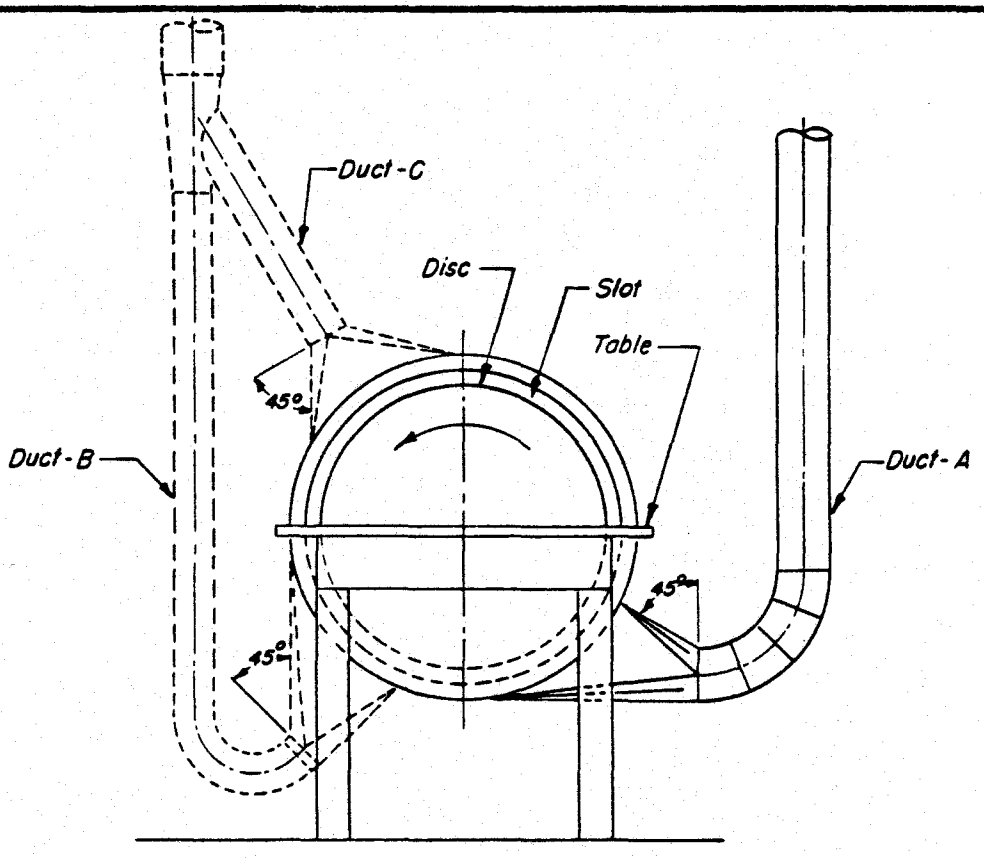
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HORIZONTAL BELT SANDERS

DATE 1-64 | VS-702

PRODUCED
1072 JM - 83

MT-PWHD-004608



Disc diameter, inches	Total exhaust volume cfm	Applies to duct
Up to 12 incl.	350	A
over 12 to 18 incl.	440	A
over 18 to 26 incl.	550	A
over 26 to 32 incl.	700*	A-B
over 32 to 38 incl.	900*	A-B
over 38 to 48 incl.	1250**	A-B-C

* Two bottom branches.
** One top and two bottom branches.

Duct velocity = 3500 fpm
Entry loss: Depends on hood design.
1.0 slot VP + 0.25 duct VP

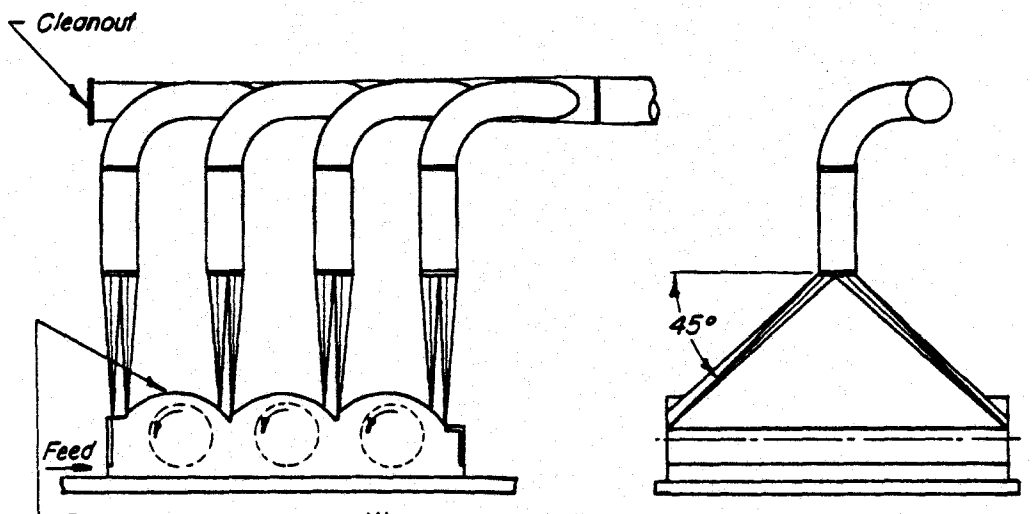
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DISC SANDERS

DATE 1-64 | VS-703

1073
PRODUCED
JM - 83

MT-PWHD-004609



Drum covers necessary. Hinge or otherwise provide for maintenance.

Exhaust Volumes

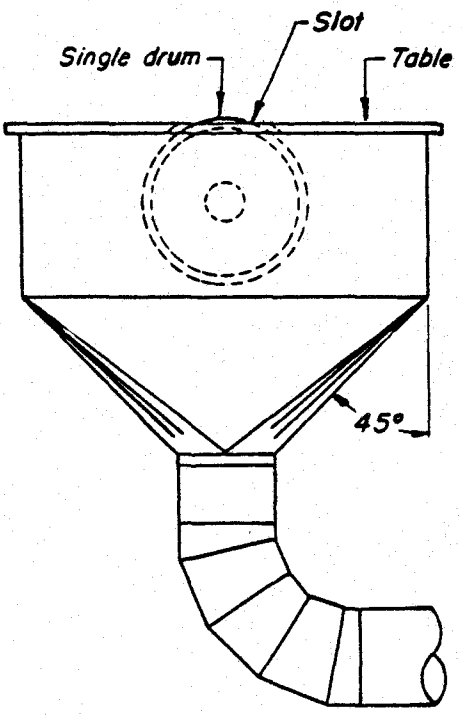
Drum length, inches	Total exhaust for machine cfm/drum*
Up to 31"	550
31" to 49"	785
49" to 67"	1100
over 67"	1400
Brush rolls	350 cfm at brush
*One hood per drum is minimum Additional hood at feed side is desirable	

Duct velocity = 3500 fpm
Entry loss = 0.25 duct VP

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MULTIPLE DRUM SANDER	
DATE 1-64	VS-704

PRODUCED 1994 JM - 83

MT-PWHD-004610



Drum surface, sq inches	Exhaust volume, cfm
Up to 200 incl. (and less than 10" dia.)	350
over 200 to 400 incl.	550
over 400 to 700 incl.	785
over 700 to 1400 incl.	1100
over 1400 to 2400 incl.	1400

Duct velocity = 3500 fpm
Entry loss: Depends on hood design.
1.78 slot VP plus 0.25 duct VP

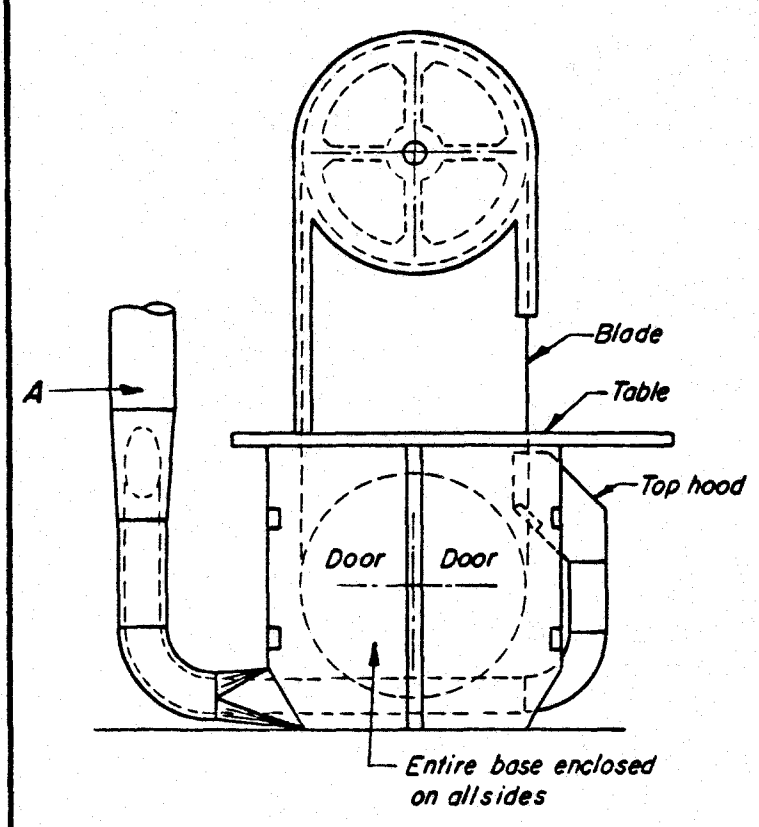
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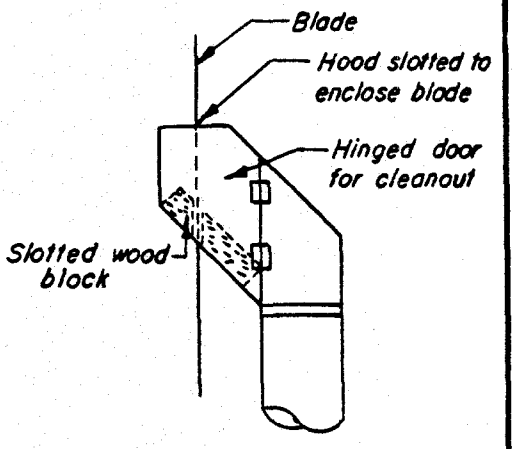
SINGLE DRUM SANDER

DATE 1-64 | VS-705

PRODUCED 1075
JM - 83

MT-PWHD-004611





TOP HOOD DETAIL

Blade width, inches	Exhaust volume, cfm		
	Bottom	Top	Total
Up to 2	350	350	700
over 2 to 3	350	550	900
over 3 to 4	550	800	1350
over 4 to 6	550	1100	1650
over 6 to 8	550	1400	1950

Duct velocity = 3500 fpm
Entry loss = 1.75 VP in duct riser (Point A)

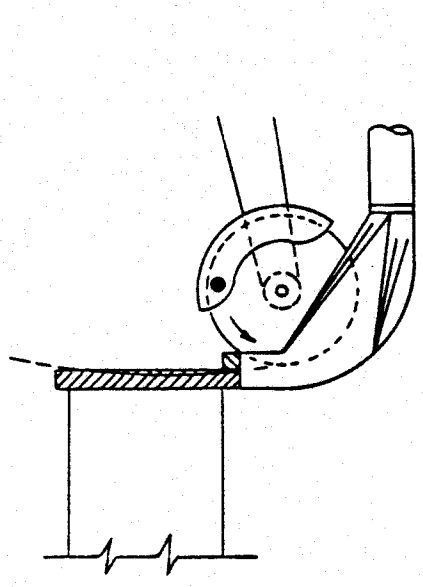
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BAND SAW

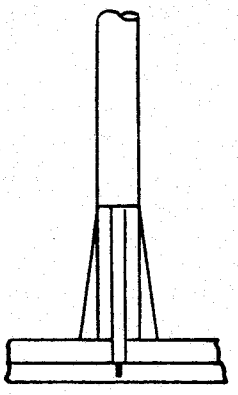
DATE 1-66 | VS-706

1076 PRODUCED JM - 83

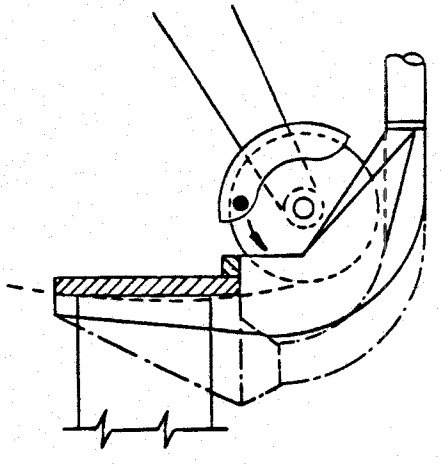
MT-PWHD-004612



TYPE HOOD WHERE TABLE IS NOT CUT THRU



FRONT VIEW OF HOOD



TYPE HOOD WHERE TABLE IS CUT THRU

Saw diameter, inches	Exhaust volume, cfm
Up to 20 incl.	350
over 20	440

Duct velocity = 3500 fpm
Entry loss = 1.78 slot VP + 0.25 duct VP

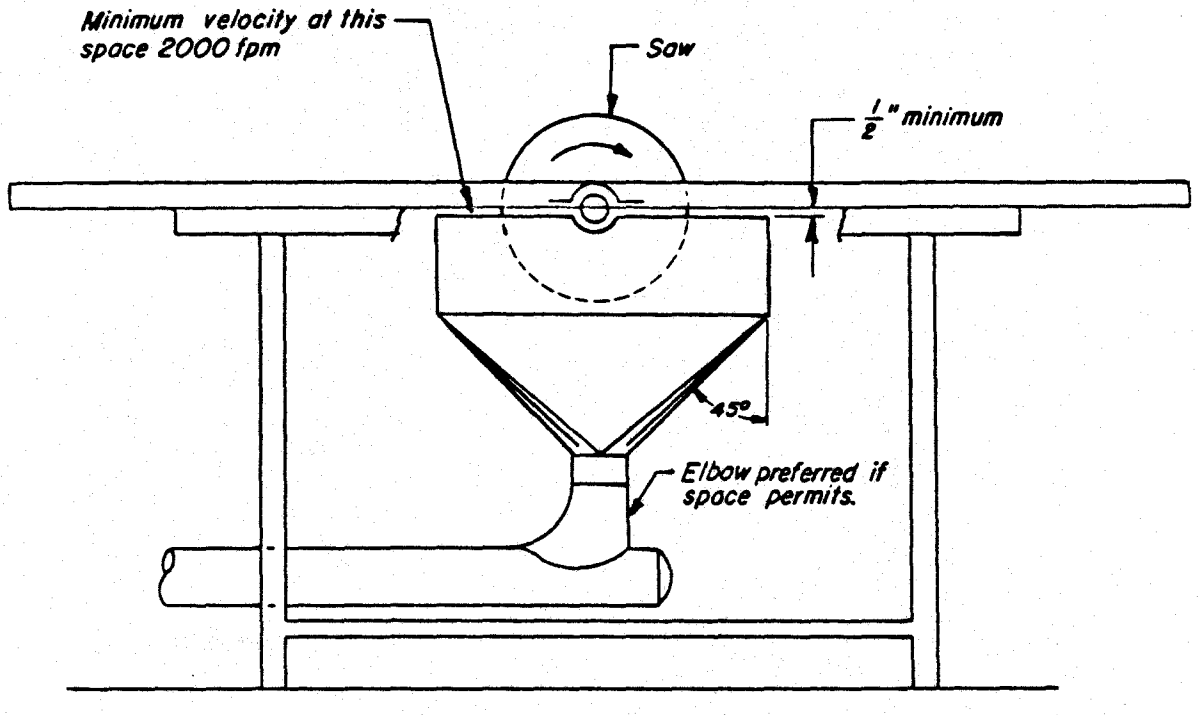
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SWING SAWS

DATE 1-64 | VS-707

PRODUCED 1077
JM - 83

MT-PWHD-004613



Table, rip, mitre and variety saws.

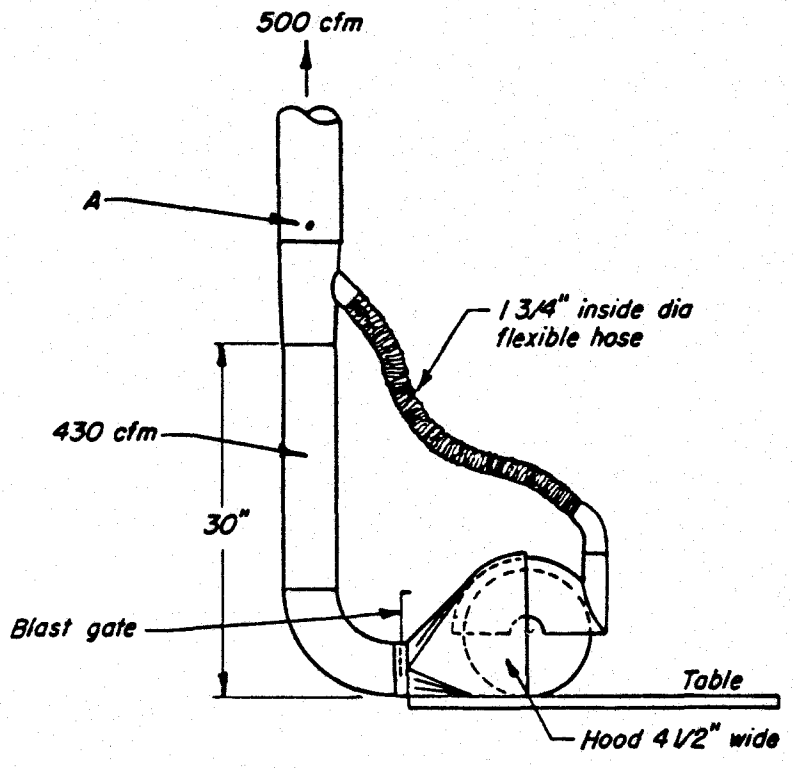
Saw diameter, inches	Exhaust volume, cfm
Up to 16 incl.	350
over 16 to 24 incl.	440
over 24	550
variety with dado	550

Duct velocity = 3500 fpm
Entry loss = 1.0 slot VP + 0.25 duct VP

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TABLE SAW	
DATE 1-68	VS-708

PRODUCED JM - 83
1078

MT-PWHD-004614



Duct velocity = 3500 fpm
Entry loss = 3.5 VP in duct riser (Point A)

For booth enclosure, see VS-401

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
RADIAL SAW	
DATE 1-68	VS-709

1079
PRODUCED
JM - 83

MT-PWHD-004615

TABLE 5-7-1

MISCELLANEOUS WOODWORKING MACHINERY NOT GIVEN IN VS PRINTS

The following list of recommended exhaust volumes are for average-sized woodworking machines and are based on many years of experience. It must be noted that some modern high speed or extra large machines will produce such a large volume of waste that greater exhaust volumes must be used. Similarly, some small machines of the home workshop or bench type may use less exhaust air than listed.

Self-feed Table Rip Saw

Saw Diameter, Inches	Exhaust Volume, cfm		
	Bottom	Top	Total
Up to 16 inclusive	440	350	790
Over 16	550	350	900
Self-feed, not on table	800	550	1350

Gang Rip Saws:

Saw Diameter, Inches	Exhaust Volume, cfm		
	Bottom	Top	Total
Up to 24, inclusive	550	350	900
Over 24 to 36, Incl.	800	440	1240
Over 36 to 48, Incl.	1100	550	1650
Over 48	1400	550	2060

Vertical Belt Sanders (rear belt and both pulleys enclosed) and Top Run Horizontal Belt Sanders

Belt width, Inches	Exhaust Volume, cfm
Up to 6, incl.	440
Over 6 to 9, incl.	550
Over 9 to 14, incl.	800
Over 14	1100

Swing Arm Sander: 440 cfm

Single Planers or Surfacers:

	Exhaust Volume, cfm
Up to 20" knives	785
Over 20" to 26" knives	1100
Over 26" to 32" knives	1400
Over 32" to 38" knives	1765
Over 38" knives	2200

Double Planers or Surfacers:

	Exhaust Volume, cfm		
	Bottom	Top	Total
Up to 20" knives	550	785	1335
Over 20" to 26" knives	785	1100	1885
Over 26" to 32" knives	1100	1400	2500
Over 32" to 38" knives	1400	1800	3200
Over 38" knives	1400	2200	3600

Molders, Matchers & Sizers:

Size, Inches	Exhaust Volume, cfm			
	Bottom	Top	Right	Left
Up to 7, incl	440	550	350	350
Over 7 to 12, incl.	550	800	440	440
Over 12 to 18, incl	800	1100	550	550
Over 18 to 24, incl.	1100	1400	800	800
Over 24	1400	1770	1100	1100

PRODUCED JM - 83
1080

MT-PWHD-004616

PRODUCED
JM - 83

SHM7901E

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FOR THE COUNTY OF LOS ANGELES

3/1/79 Dead

FILE COPY

WALTER C. RIGSBY, JOSEPH K. KLOSE and SHELDON H. MANNING,

Plaintiffs,

vs.

JOHNS-MANVILLE, etc., et al.,

Defendants.

No. C 151 947

EXHIBIT HHH

2 of 2

EXHIBITS TO THE DEPOSITION OF SHELDON H. MANNING, VOLUME VI, taken Tuesday, March 6, 1979, at Los Angeles, California, before Lucia Moskal, CSR, a Notary Public.

Reported by:
Lucia Moskal, CSR 1222

No. LA [illegible]-79

RENDEL B. HUTCHINGS
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LOS ANGELES 90065 3436 N. Figueroa 223-1191
WEST LOS ANGELES 90049 654 N. Sepulveda 472-9578
SANTA ANA 92701 523 N. Grand 547-6169
SAN DIEGO 92101 326 Broadway 233-6227

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H-5

	Exhaust Volume, cfm
Sash stickers:	550
Woodshapers:	440 to 1400
Tenoner:	Same as moulder
Automatic lathe:	800 to 5000
Forming Lathe:	350 to 1400
Chain mortise:	350
Dowel machine:	350 to 800
Panel raiser:	550
Dove-tail and lock corner:	550 to 800
Pulley Pockets:	550
Pulley stile:	550
Glue jointer:	800
Gainer:	350 to 1400
Router:	350 to 800
Hogs:	
Up to 12 in. wide	1400
Over 12 in wide	3100
Floorsweep:	
(6 in. to 8 in. diam.)	800 to 1400

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1081

MT-PWHD-004619

LOW VOLUME-HIGH VELOCITY EXHAUST SYSTEMS

The low volume high velocity exhaust system is the unique application of exhaust which uses small volumes of air at relatively high velocities to control dust from portable hand tools and machining operations. Control is achieved by exhausting the air directly at the point of dust generation using close-fitting, custom-made hoods. Capture velocities are relatively high but the exhaust volume is low due to the small distance required. For flexibility, small diameter, light-weight plastic hoses are used with portable tools resulting in very high duct velocities. This method allows the application of local exhaust ventilation to portable tools which otherwise would require relatively large air volumes and large ductwork when controlled by conventional exhaust methods.

This technique has found a variety of applications although its use is not common. Rock drilling dust has been controlled by using hollow core drill steel with suitable exhaust holes in the drill bits. Air is exhausted either by a multi-stage turbine of the size generally used in industrial vacuum cleaners or, in the case of one manufacturer (71), by the exhaust air from the pneumatic tool which operates a Venturi to withdraw air from the drill. Application has been made with flexible connections to a central vacuum system to aid in the control of graphite dust at conventional machining operations. One to two inch diameter flexible hose was used with simple exhaust hoods mounted directly at the cutting tool. In a similar application for the machining of beryllium (72), a central vacuum system using 1 1/2" I.D. flexible hoses was employed. The exhaust hoods were made of lucite or transparent material and were tailor-made to surround the cutting tools and much of the work. Exhaust volumes vary from 120 to 150 cfm with inlet velocities of 11,000 to 14,000 fpm. In another application (73), a portable orbital sanding machine has been fitted with a small exhaust duct surrounding the edge of the plate. A fitting has been provided to connect this to the flexible hose of a standard domestic vacuum cleaner.

VS-801 to VS-806, 802, 803 and 804 illustrate a custom-made line of exhaust hoods available (74). The required air volumes range from 8 cfm for pneumatic chisels to 300 cfm for swing grinders. (See Table 5-8-1) Due to the high entering velocities involved, static pressures are in the range of 5" mercury (68" water gauge). This high pressure is necessary to create the high capture velocities at the dust source to control the dust.

TABLE 5-8-1. EXHAUST VOLUMES REQUIRED FOR LOW VOLUME-HIGH VELOCITY SYSTEM

	cfm	I.D. Plastic Hose Size
Pneumatic chisels	8- 60	3/8"-1 1/2"
Radial grinders	10- 45	5/8"- 7-8"
Surface grinders	10- 50	5/8"-1 1/2"
Disc sander, 5-9 inch diameter	10- 30	5/8"-1 1/2"
Vibratory Sander	100-200	1"-2"
Spindle grinding cone, 1-3 inch diameter	10- 40	5/8"-1 1/2"
Swing frame grinders	250-300	2"
Hand wire brushes	25- 30	5/8"
Surface wire brushes	35	3/4"
Internal grinders, 1 1/2 inch diameter	25	5/8"
Internal grinders, 4 inches diameter	37.5	3/4"

The dust is conveyed at high velocities in small diameter flexible hoses ranging from 3/8" to 2" I.D. The dust laden air is passed into primary and secondary cyclone collectors and through a fabric filtering unit (See Figure VS-807). Exhaust is provided by a multi-stage centrifugal turbine capable of producing static pressures of about 8" mercury (109" water) below atmospheric pressure. The fabric collector can be cleaned by a simple, manual valve which admits air into the clean side of the fabric bringing this side of the fabric to atmospheric pressure. Since the dirty side of the fabric is at a pressure far below atmospheric, this causes rapid air flow through the fabric and provides reverse cleaning.

Design Calculations

With the exception of the proprietary system mentioned, which can be purchased as a "package," the design calculations for these systems are largely empirical. In normal ventilation practice, air is considered to be

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MT-PWHD-004620

incompressible since static pressures vary only slightly from atmospheric pressure. However, in these systems the extreme pressures required introduce problems of air density, compressibility and viscosity which are not easily solved. Also, pressure drop data for small diameter pipe, especially flexible tubing, is not commonly available. For practical purposes, the turbine exhauster should be selected for the maximum simultaneous cfm exhaust required. Resistance in the pipe should be kept as low as possible; flexible tubing of less than 1" to 1 1/2" diameter should be limited to 10 feet or less. In most applications this is not a severe problem.

The main consideration in piping for such systems is to provide smooth internal configuration so as to reduce pressure loss at the high velocities involved, and to minimize abrasion. Ordinary screwed-fitting piping is to be avoided because the lip of the pipe or male fitting, being of smaller diameter than the female thread, presents a discontinuity which increases pressure loss and may be a point of rapid abrasion.

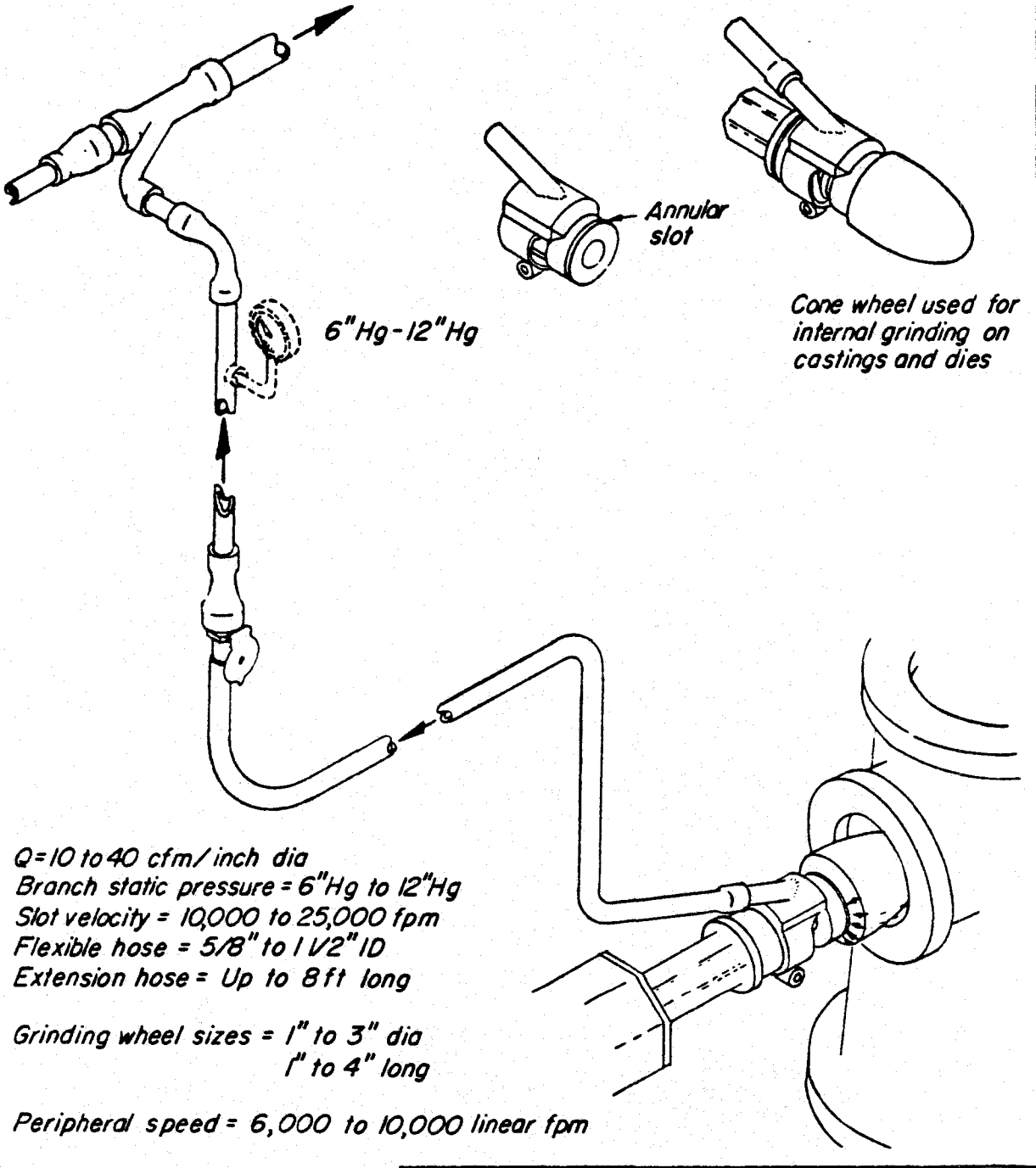
If a screwed-fitting system is to be used, cast-iron drainage fittings and Schedule 40 pipe should be provided. Fittings of this type are recessed so that the I.D. of the pipe and fitting is the same. Tubing systems of 16 gauge wall thickness up to and including 4 inch diameter, and 14 gauge for 5 inch and above, provide for 10 per cent less pressure loss than a Schedule 40 piping system and offer a lower installed cost in most cases. Commercially available tube fittings and clamps may be used, or a slip-on flange system, so that internal discontinuities are eliminated. In all cases, long-sweep elbows and bends should be provided.

For dust exhaust systems, a good collector should be mounted ahead of the exhauster to minimize erosion of the precision blades and subsequent loss in performance. Final balance of the system can be achieved by varying the length and diameters of the small flexible hoses.

It must be emphasized that although data are empirical, these systems require the same careful design as the more conventional ones. Abrupt changes of direction, expansions and contractions must be avoided and care must always be taken to minimize pressure losses.

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MT-PWHD-004621



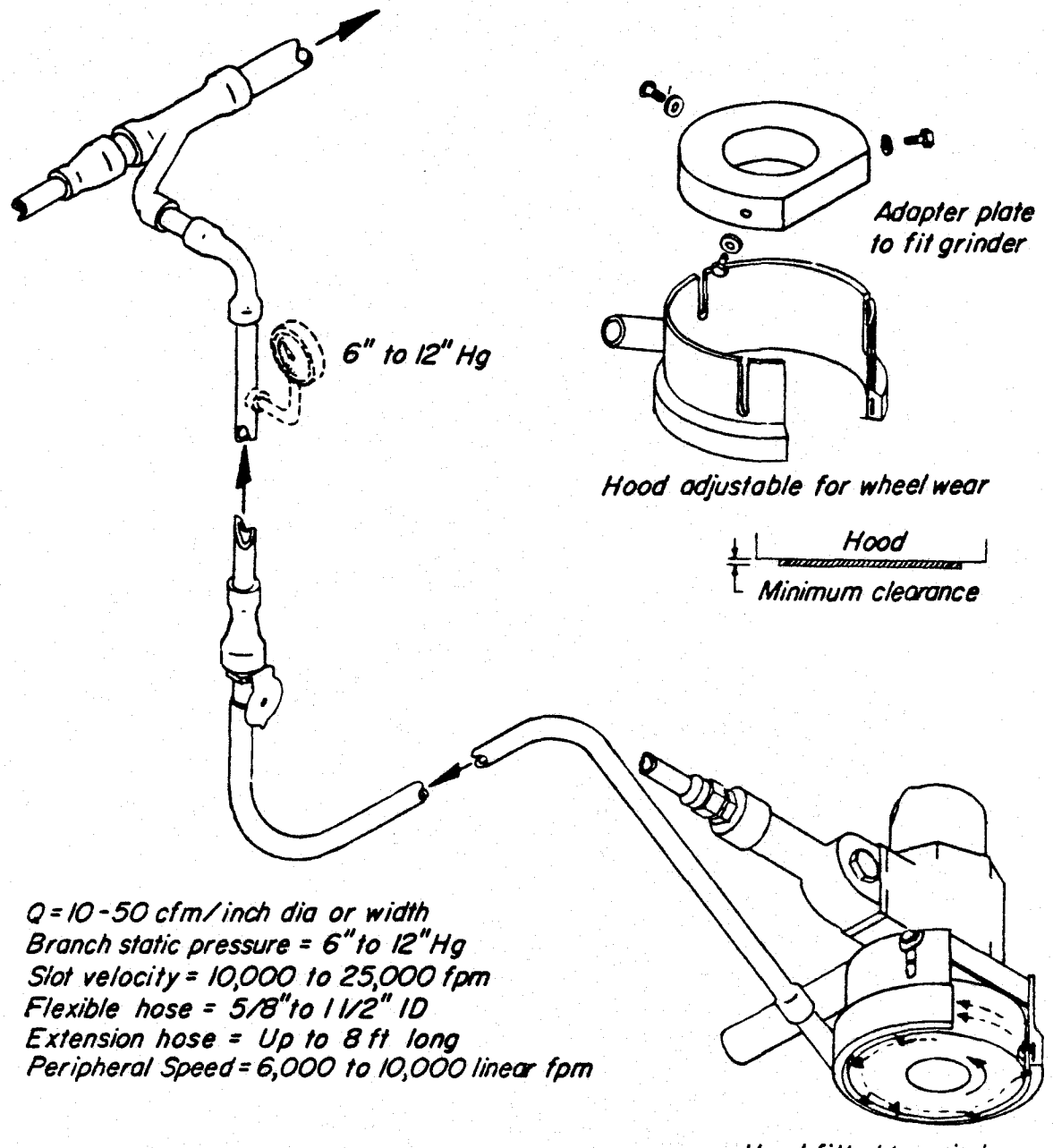
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EXTRACTOR HEAD FOR CONE WHEELS AND MOUNTED POINTS

DATE	1-72	VS-801

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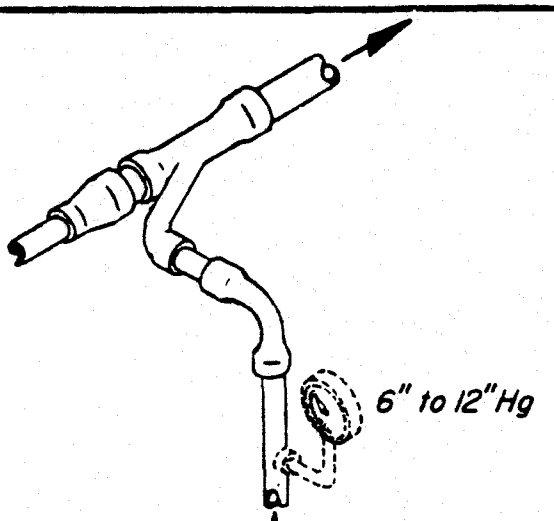
HOOD FOR CUP TYPE SURFACE GRINDERS AND WIRE BRUSHES

DATE 1-72	VS-802

PRODUCED
JM - 83

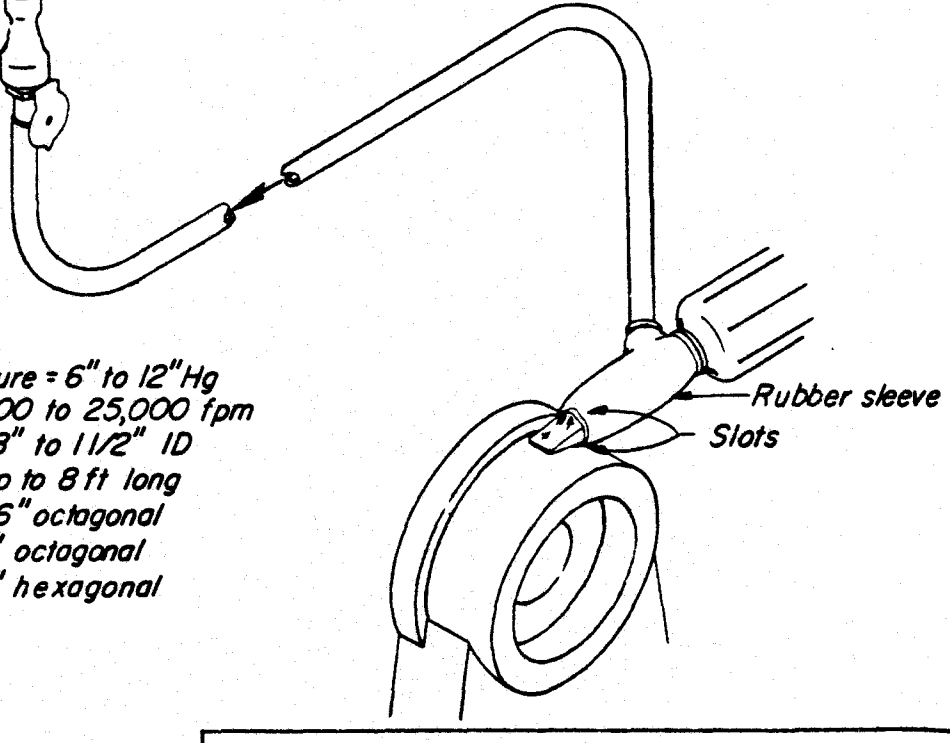
1085

MT-PWHD-004623



Dust is extracted through ports molded in the rubber sleeve; ports are on either side of the cutting edge of the chisel

6" to 12"Hg



Q = 8-60 cfm
Branch static pressure = 6" to 12"Hg
Slot velocity = 10,000 to 25,000 fpm
Flexible hose = 3/8" to 1 1/2" ID
Extension hose = Up to 8 ft long
Chisel sizes = 13/16" octagonal
7/8" octagonal
7/8" hexagonal

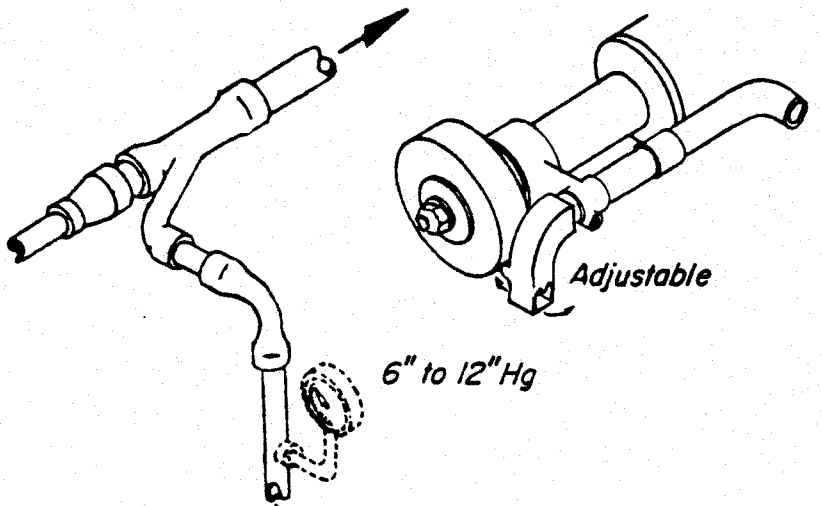
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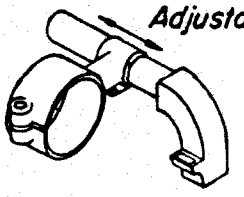
PNEUMATIC CHISEL SLEEVE

DATE	*1-72*	*VS-803*

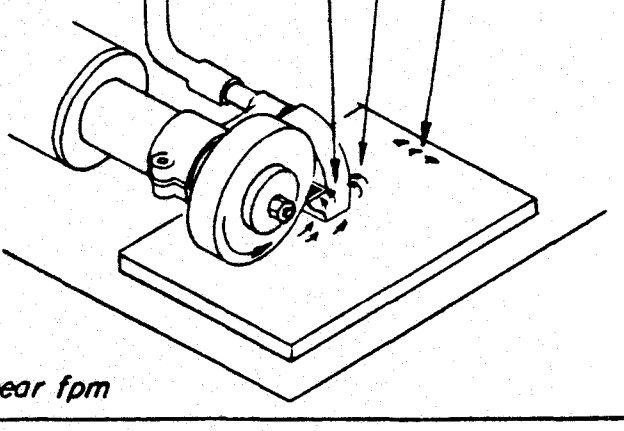
PRODUCED
1086 JM - 83

MT-PWHD-004624





These extractor heads have been specifically designed for work done inside castings or in awkward places when radial wheels of small diameter are most suitable. The heads are narrower than the grinding wheels and can precede the wheel when a groove is being ground.



Q = 10 - 45 cfm/inch dia
Branch static pressure = 6" to 12" Hg
Slot velocity = 10,000 to 25,000 fpm
Flexible hose = 5/8" to 7/8" ID
Extension hose = Up to 8 ft long

Grinding wheel sizes = 8" dia x 1" wide to 2" dia x 1/2" wide

Peripheral speed = 6,000 to 10,000 linear fpm

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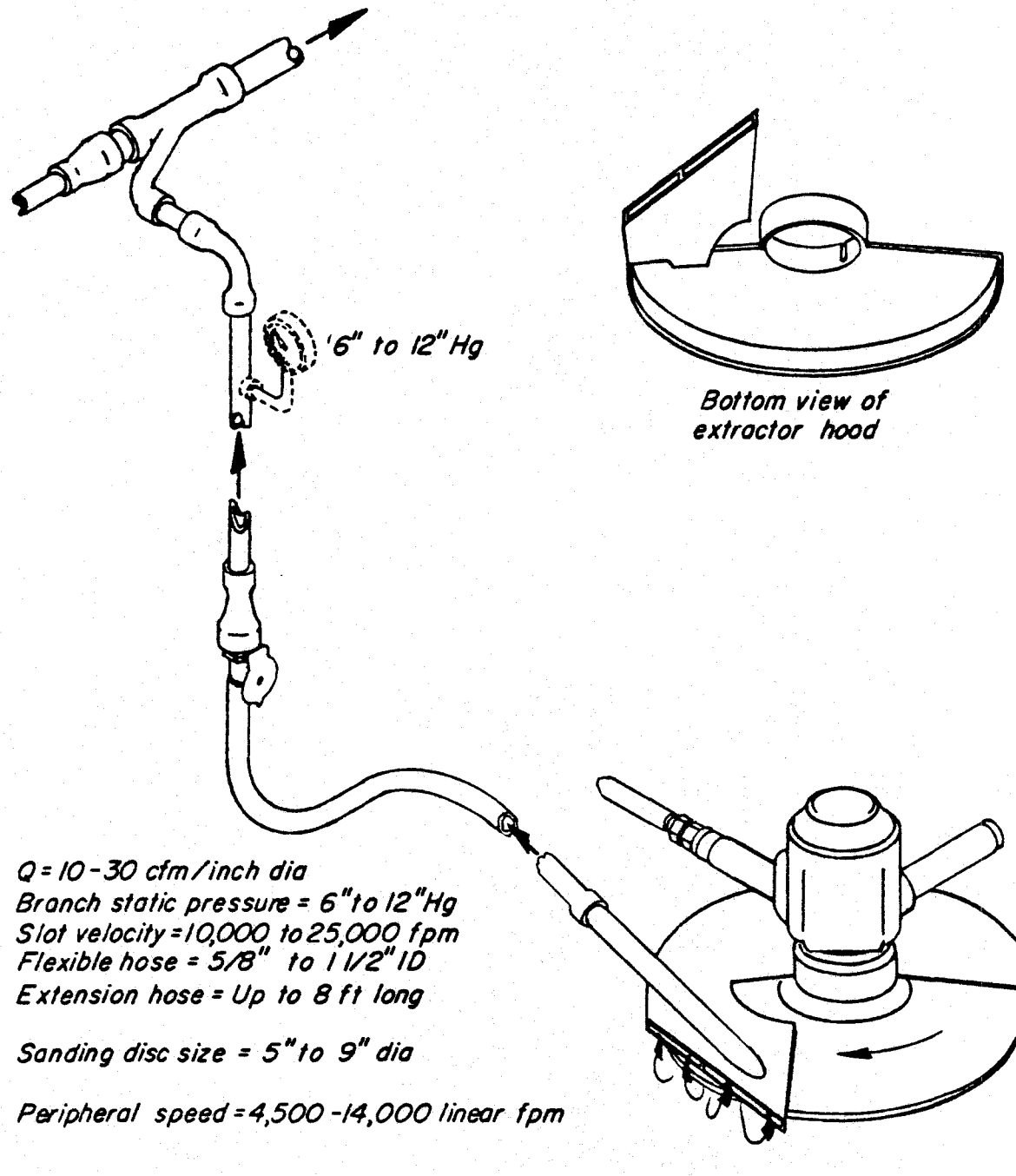
EXTRACTOR HEAD FOR SMALL RADIAL GRINDERS

DATE	*1-72*	*VS-804*

1087

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MT-PWHD-004625



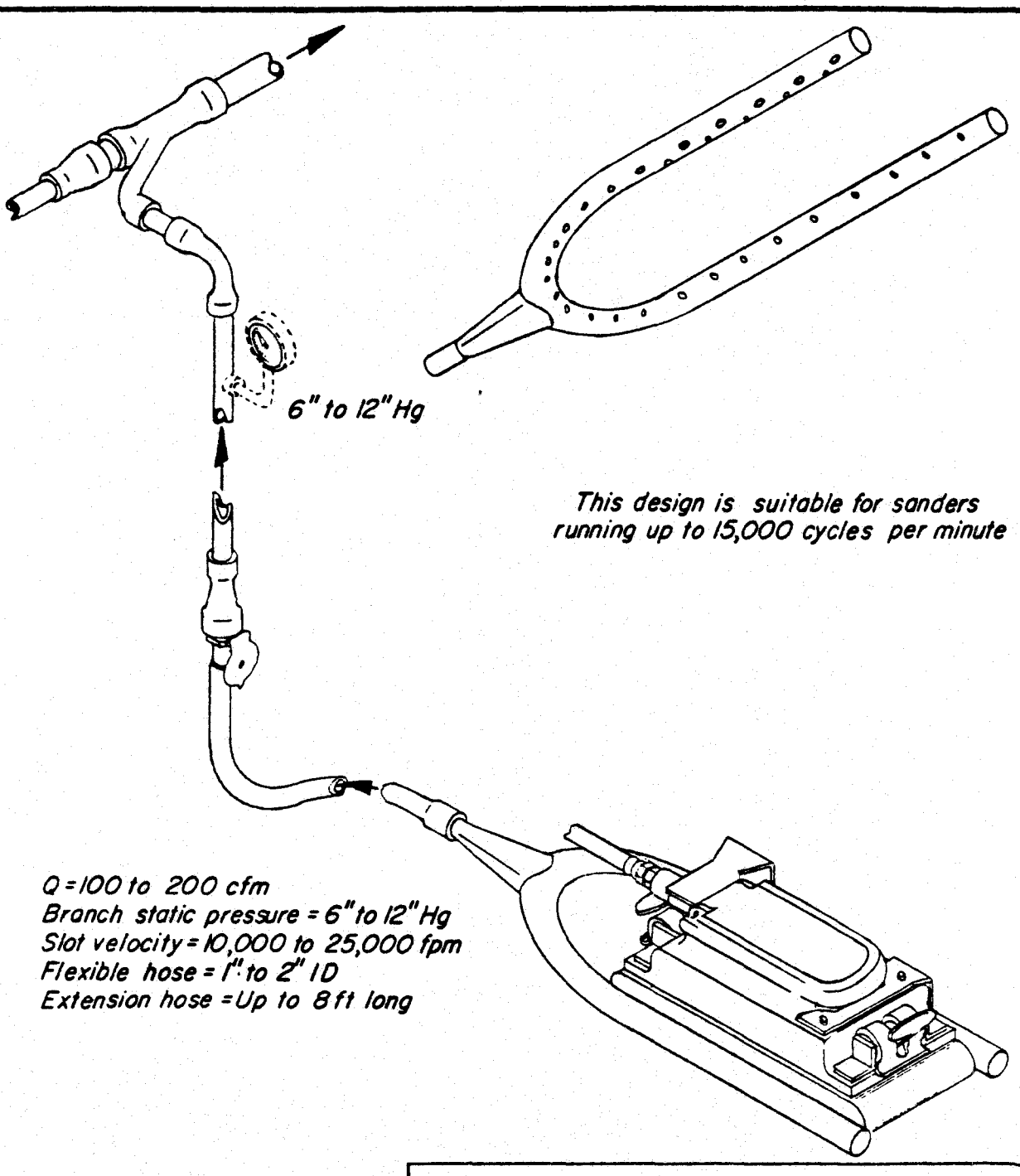
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EXTRACTOR HOOD FOR DISC SANDER

DATE 1-72 | VS-805

PRODUCED 1088 JM - 83

MT-PWHD-004626



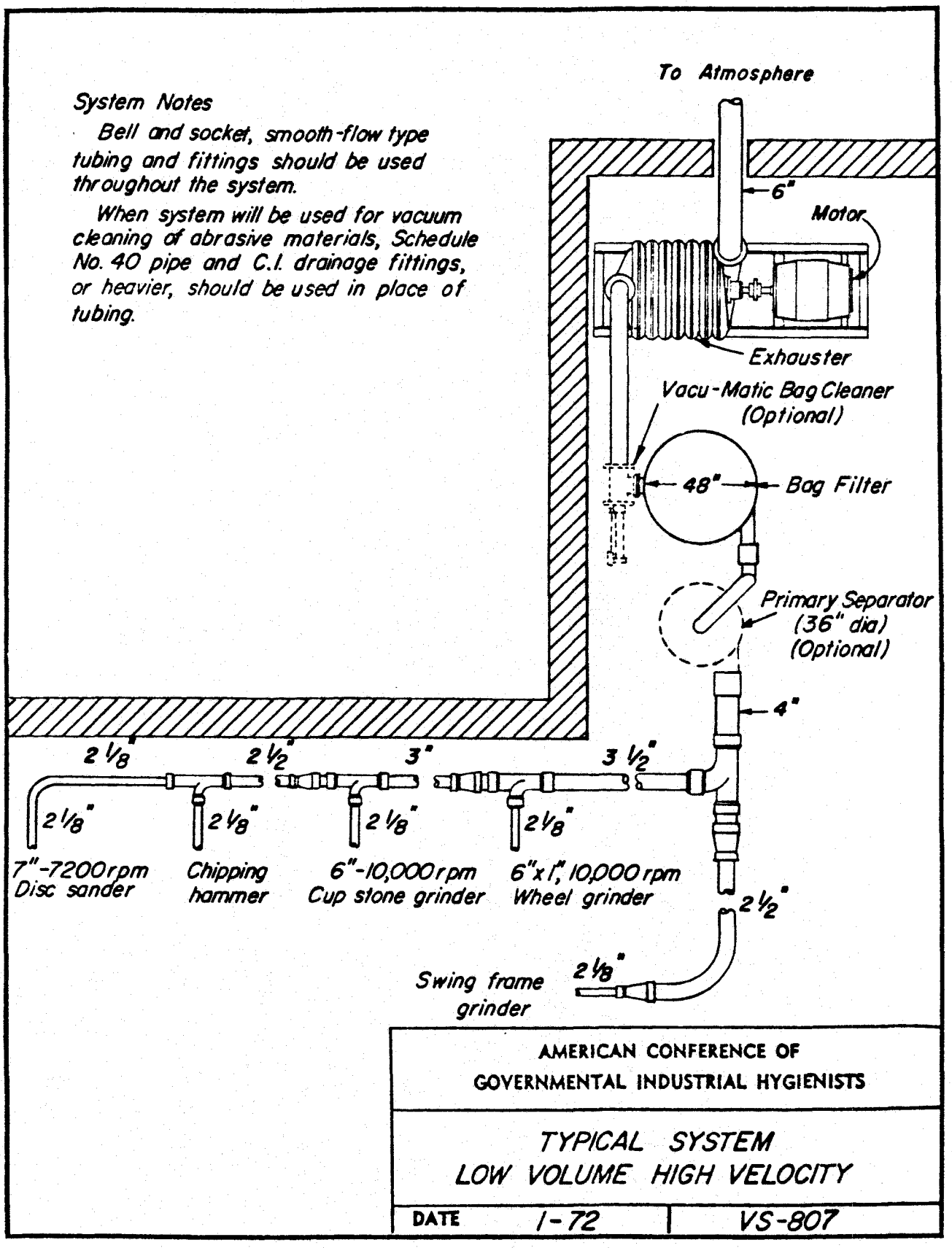
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EXTRACTOR TOOL FOR VIBRATORY SANDER

DATE	1-72	VS-806

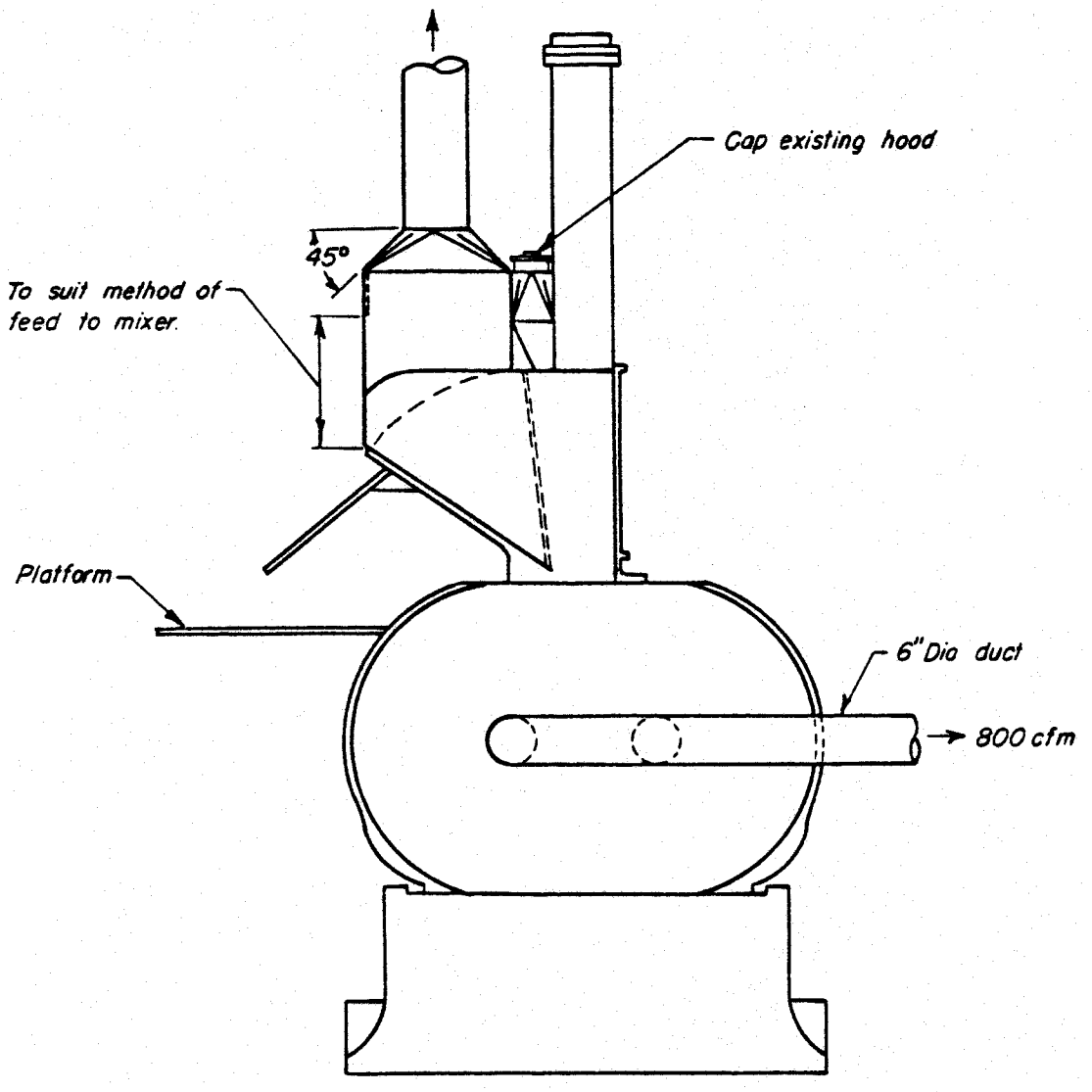
PRODUCED 1089 JM - 83

MT-PWHD-004627



1090 PRODUCED JM - 83

MT-PWHD-004628

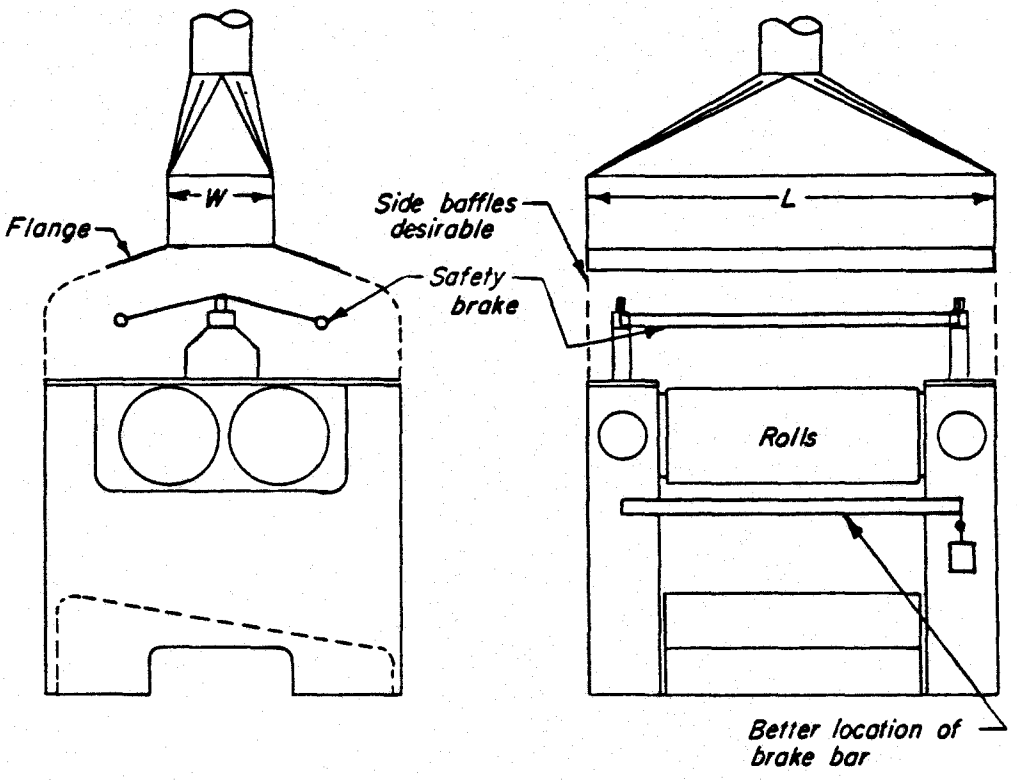


Q = 200 - 300 cfm/sq ft open face area.
500 cfm/ft of belt width if belt feeder used.
Duct velocity = 3500 fpm minimum.
Entry loss = 0.25 VP at hood
1.0 VP at trunnion

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BANBURY MIXER	
DATE 1-64	VS-901

PRODUCED JM - 83
1091

MT-PWHD-004629

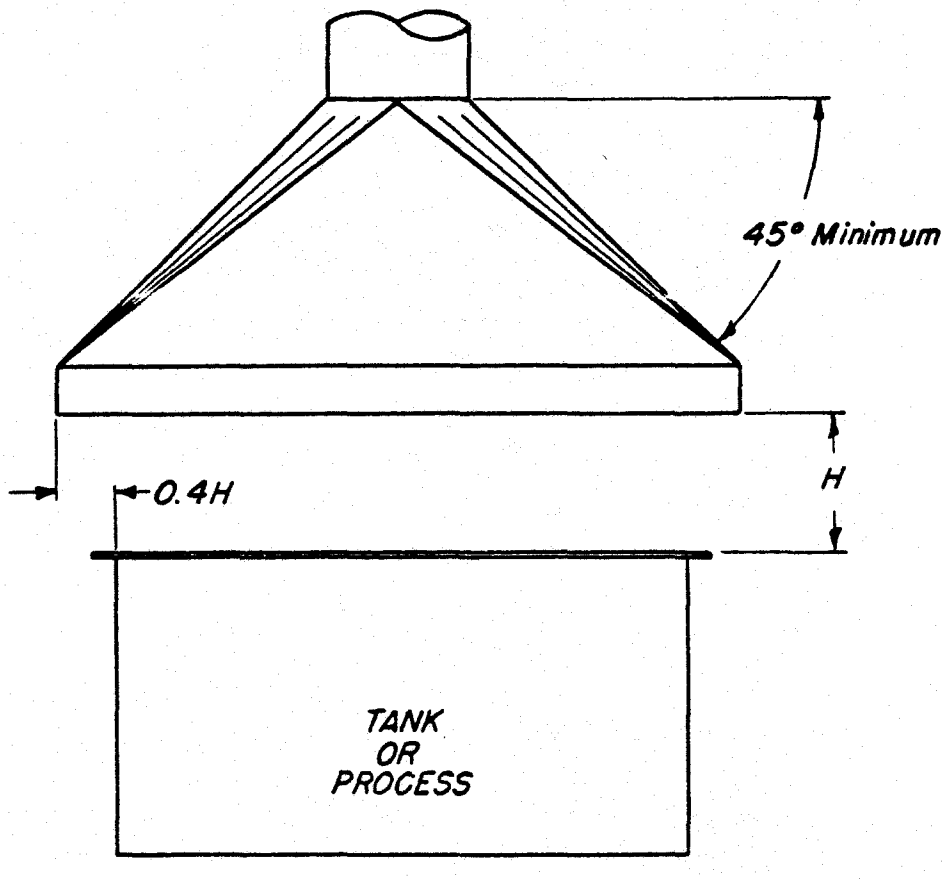


Q = 125 cfm/sq ft hood area (125 WL)
Duct velocity = 1000 - 3000 fpm
Entry loss = 0.25 duct VP

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RUBBER CALENDER ROLLS	
DATE 1-70	VS-902

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1092

MT-PWHD-004630



Not to be used where material is toxic and worker must bend over tank or process.
Side curtains are necessary when extreme cross-drafts are present.

$Q = 1.4PHV$	for open type canopy. P= perimeter of tank, feet. V= 50-500 fpm. See Section 4
$Q = (W+L)HV$	for two sides enclosed. W & L are open sides of hood. V = 50-500 fpm. See Section 4
$Q = WHV$ or LHV	for three sides enclosed. (Booth) V= 50-500 fpm. See Section 4

Entry loss = .25 duct VP
Duct velocity = 1000-3000 fpm

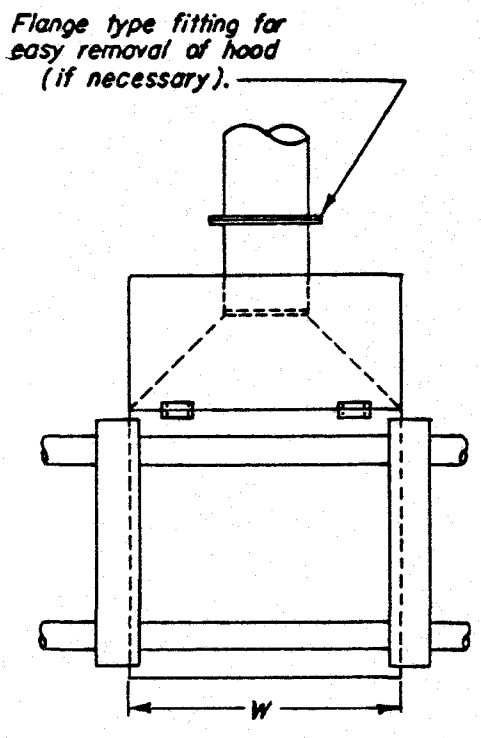
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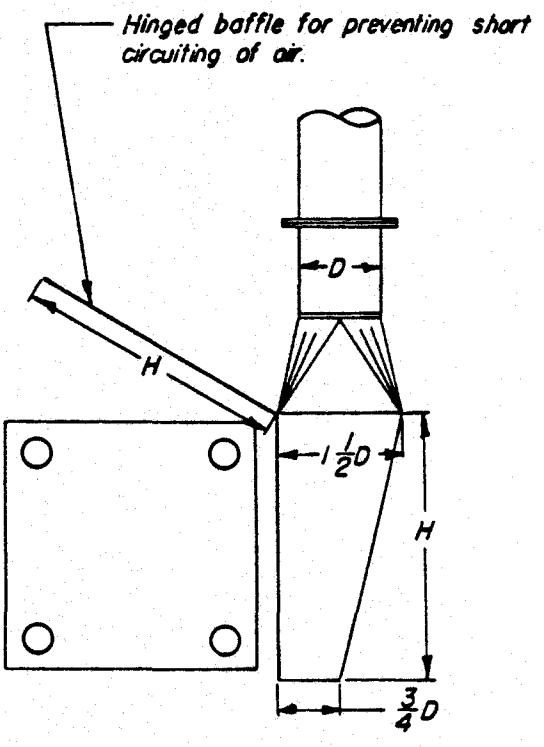
CANOPY HOOD

DATE 1-70 | VS-903

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JM - 1893

MT-PWHD-004631





Note : Place hood as close to machine as possible. If more than 4 inches from back of machine, hinged side baffles should be used.

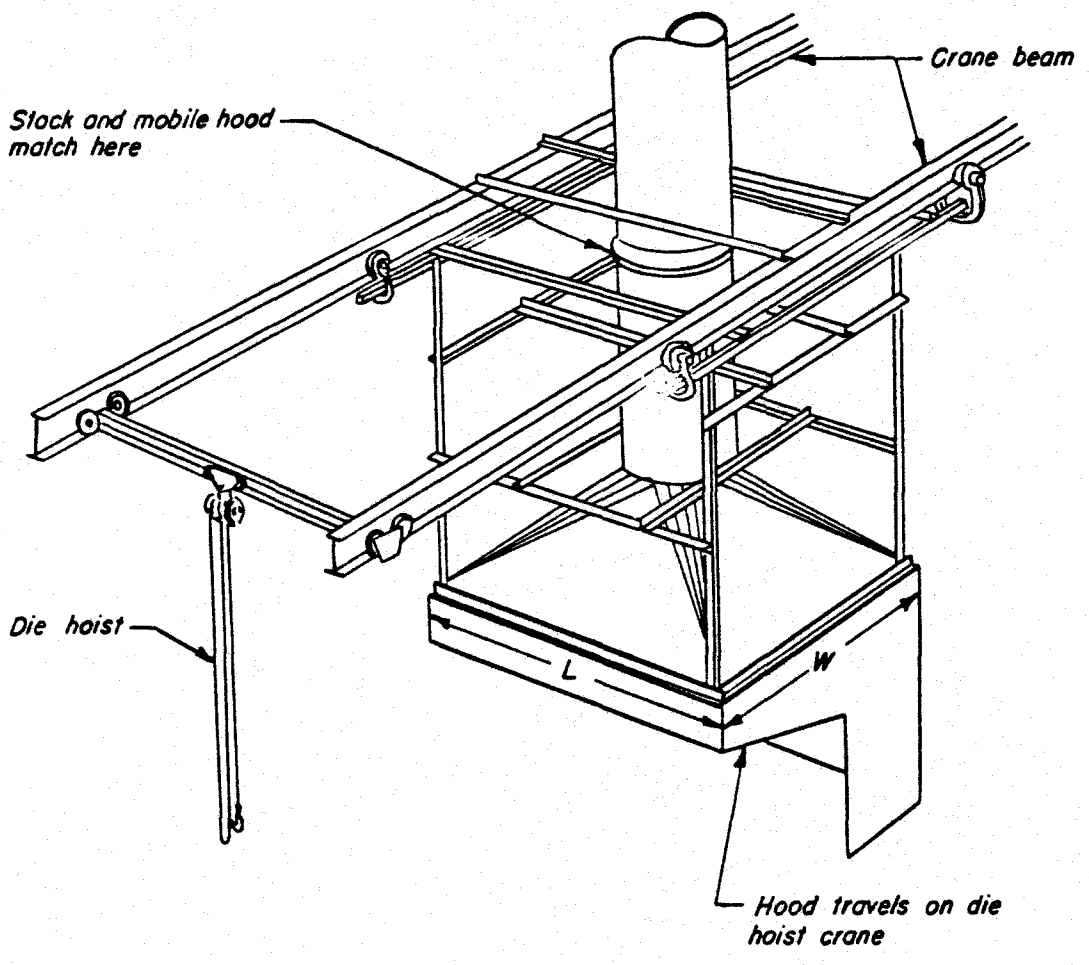
Note: Products of combustion require separate flue or may be vented into hood.

$Q = 300WH$
Entry loss = 0.25 duct VP
Duct velocity = 2500 - 3000 fpm

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DIE CASTING HOOD	
DATE 1-70	VS-904

PRODUCED 1094 IM - 83

MT-PWHD-004632



$Q = 300 WL$
Duct velocity = 1000 - 3000 fpm
Entry loss = 0.25 duct VP

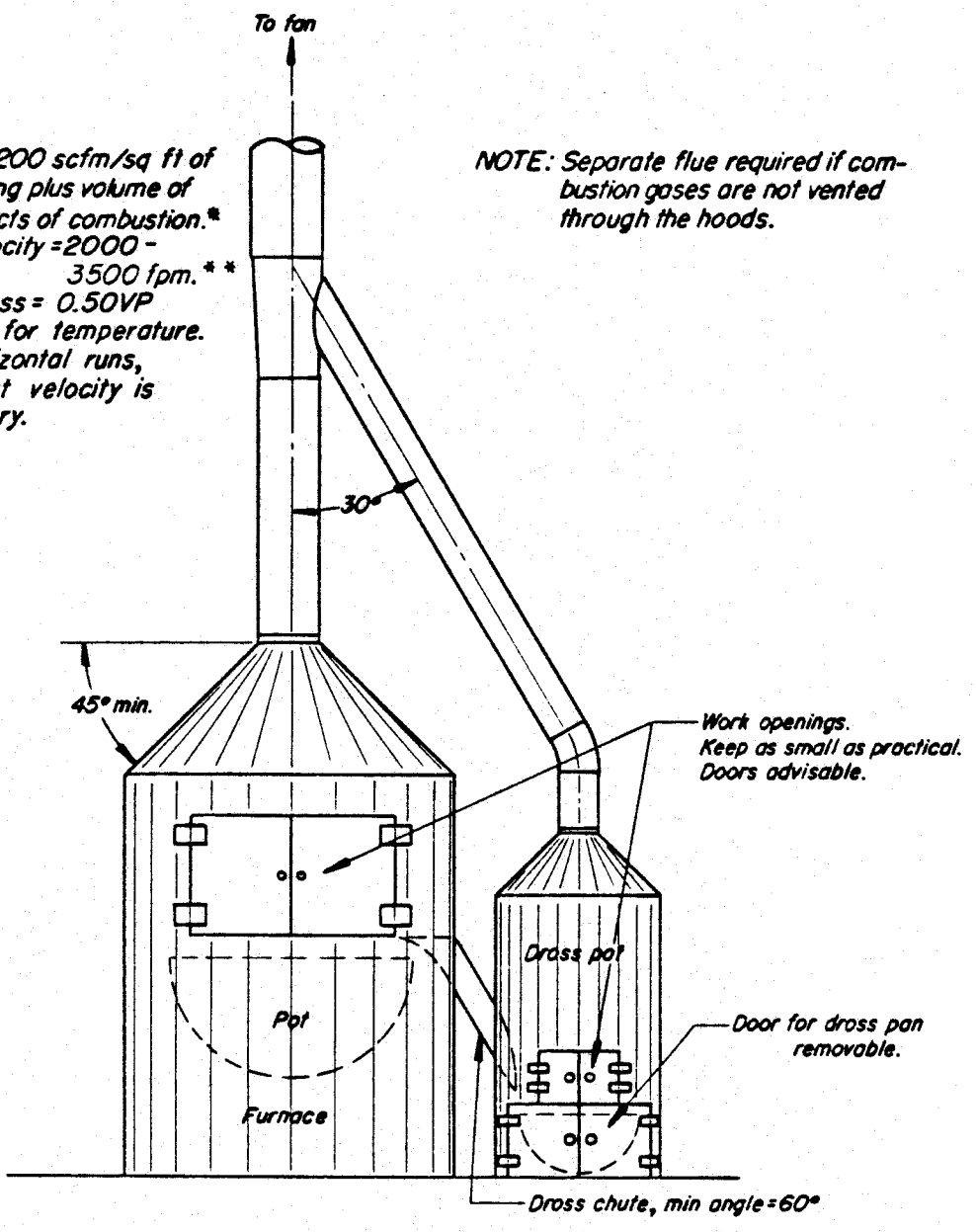
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DIE CASTING MACHINE OR MELTING FURNACE

DATE 1-70	VS-905

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JM - 83

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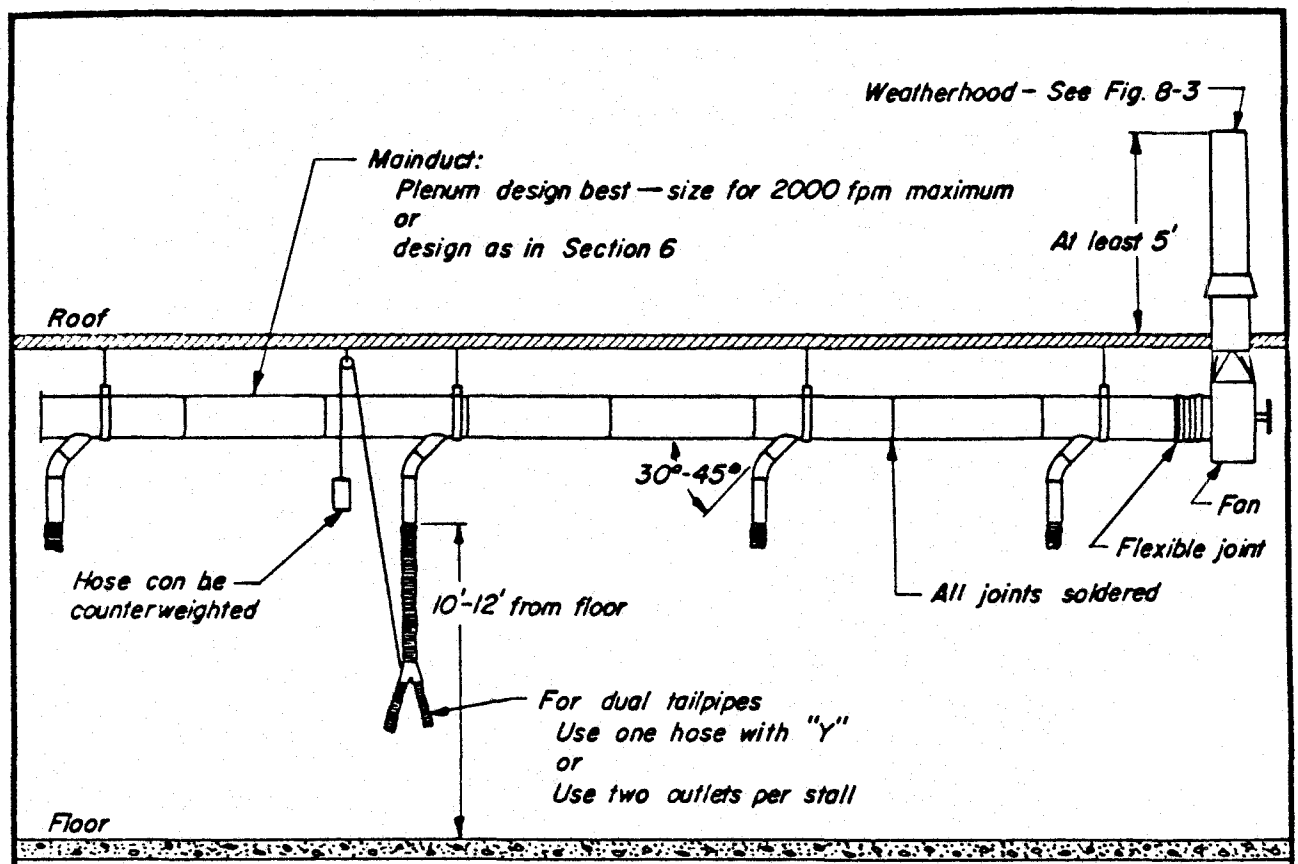


STATIONARY FURNACE OR MELTING POT

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MELTING POT & FURNACE NON-TILT	
DATE 1-70	VS-906

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1096

MT-PWHD-004634



Vehicle horsepower	cfm/vehicle	Flexible duct diam	Branch connection
Up to 200 hp	100	3"	4"
Over 200 hp	200	4"	4"
Diesel	400	4 1/2"	6"

On dynamometer test rolls

Automobiles and light duty trucks = 2 x cfm above

Heavy duty trucks = 1200 cfm minimum

For friction loss of flexible duct; consult manufacturers' data

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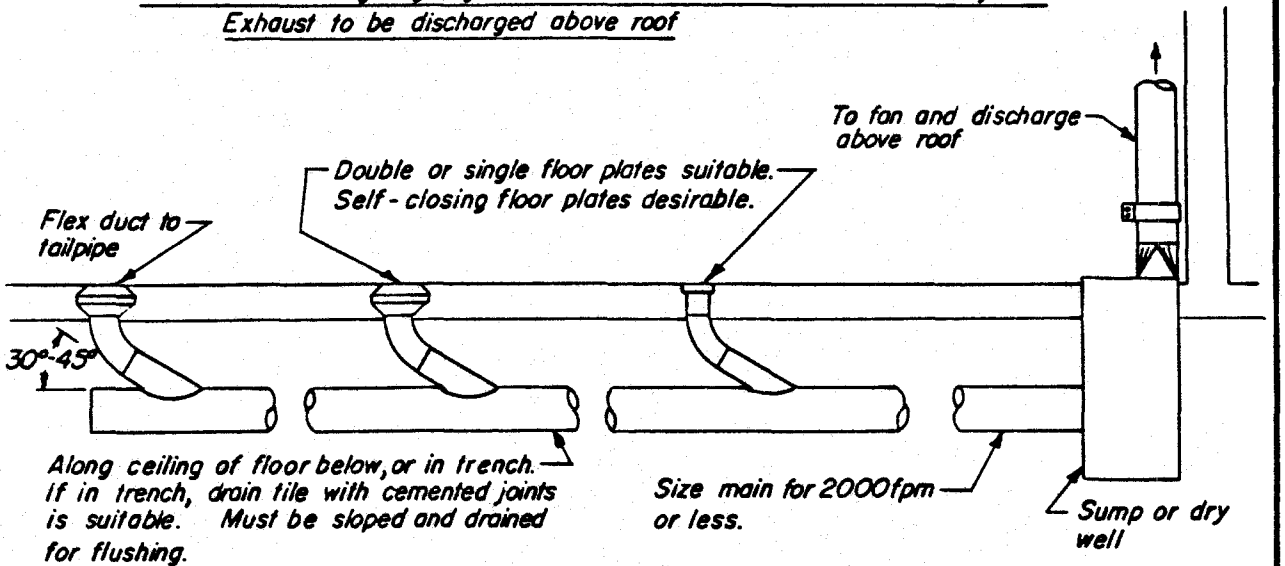
SERVICE GARAGE VENTILATION OVERHEAD

DATE 1-68 | VS-907

PRODUCED 1097 JM - 83

MT-PWHD-004635

Note: In ventilating a garage use either the overhead or under floor system.
Exhaust to be discharged above roof



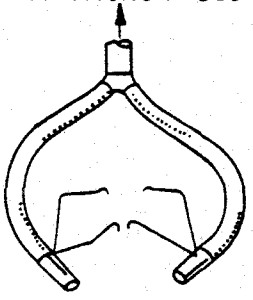
UNDER FLOOR SYSTEM

EXHAUST REQUIREMENTS *

Type	cfm per vehicle	Flex duct ID (min)
Automobiles and trucks up to 200 hp	100	3"
Automobiles and trucks over 200 hp	200	4" * *
Diesel	400	4 1/2"

* On dynamometer test rolls
Automobiles and light duty trucks = 2 x cfm above
Heavy duty trucks = 1200 cfm minimum.

**3" dia permissible for short runs with proper fan.
For friction loss of flexible duct; consult manufacturers' data.



Dilution ventilation is necessary for cars in motion or idling outside of stalls.

DILUTION RATES:

5000 cfm/running automobile
10,000 cfm (or more)/truck.
100 cfm/horsepower for diesel.

For parking garages, see Table 5-9-2

Use adapters on dual exhausts and special tailpipes.



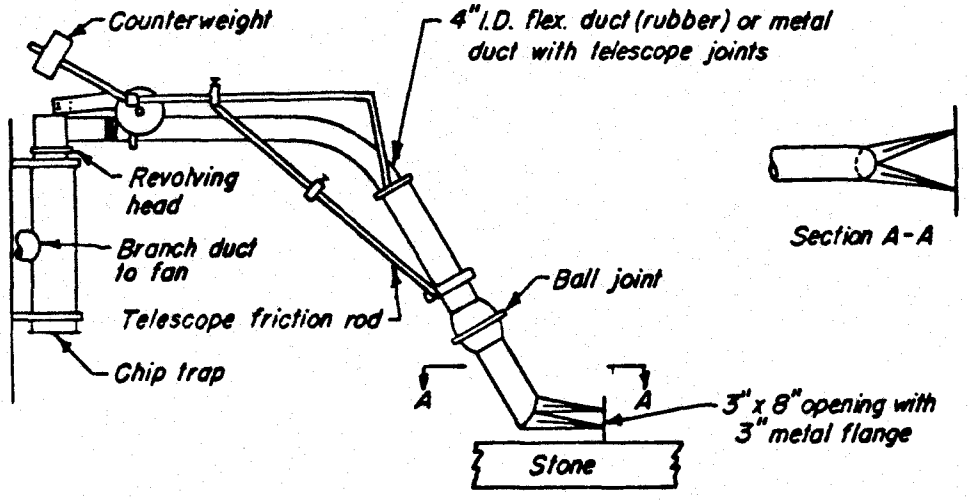
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SERVICE GARAGE VENTILATION UNDERFLOOR

DATE 1-70 | VS-908

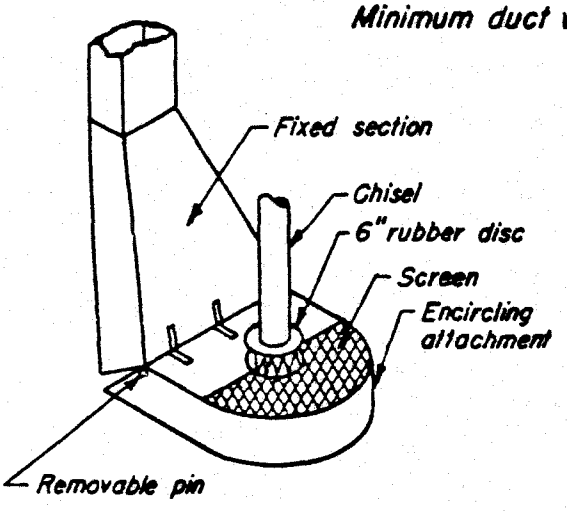
PRODUCED 1098JM - 83

MT-PWHD-004636



PNEUMATIC HAND TOOLS

Q = 540 cfm, tool 10" max distance from hood.
Resistance of unit = 8" wg at branch duct connection
Minimum duct velocity = 4000 fpm



SURFACING MACHINE HOOD

Tool diam	cfm	Branch diam
Up to 2-3/8"	500	4"
2-3/8" to 2-7/8"	1000	5-1/2"

Entry loss = 1.0 VP

Note:
Work may be done in a booth similar to spray booth; face velocity = 200 fpm
See VS-101

Abrasive blasting to be done in a room or cabinet; 500 fpm at all openings. See "Abrasive Blasting", VS-101

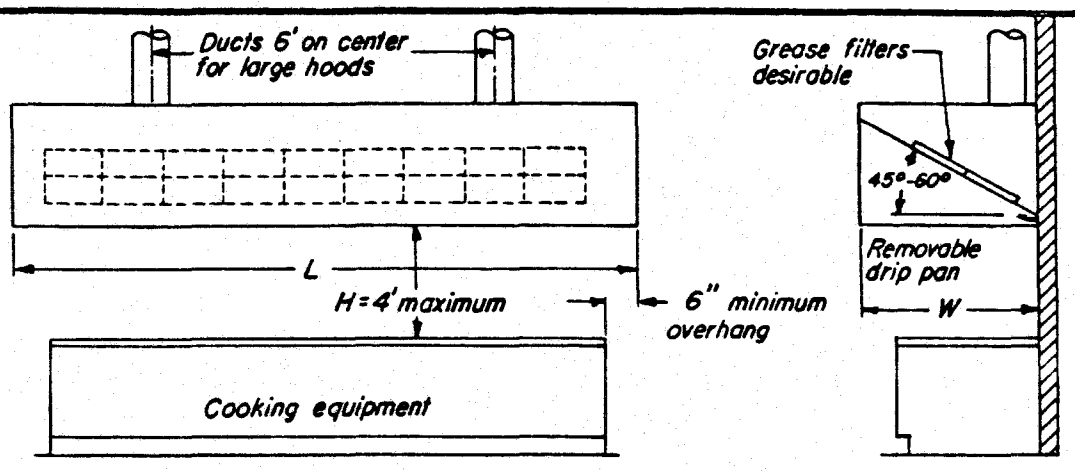
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GRANITE CUTTING AND FINISHING

DATE 1-68 | VS-909

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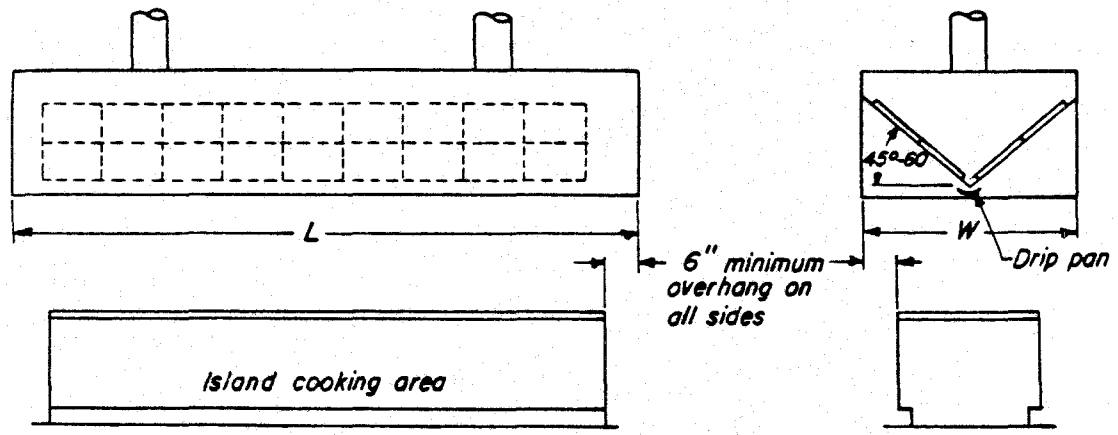
MT-PWHD-004637



HOOD AGAINST WALL

Q = 80 cfm/sq ft of hood area (80 WL)
Not less than 50 cfm/sq ft of face area (50PH)
Duct velocity = 1000 - 4000 fpm, to suit conditions
Entry loss = 0.25" (filter resistance) + 0.50 duct VP
Grease filters - See VS-911

P = perimeter of hood
= 2W + L



ISLAND TYPE HOOD

Q = 125 cfm/sq ft of hood area (125 WL)
Not less than 50 cfm/sq ft of face area (50 PH)
Duct velocity = 1000 - 4000 fpm, to suit conditions
Entry loss = 0.25" (filter resistance) + 0.50 duct VP
Grease filters - See VS-911

P = perimeter of hood
= 2W + 2L

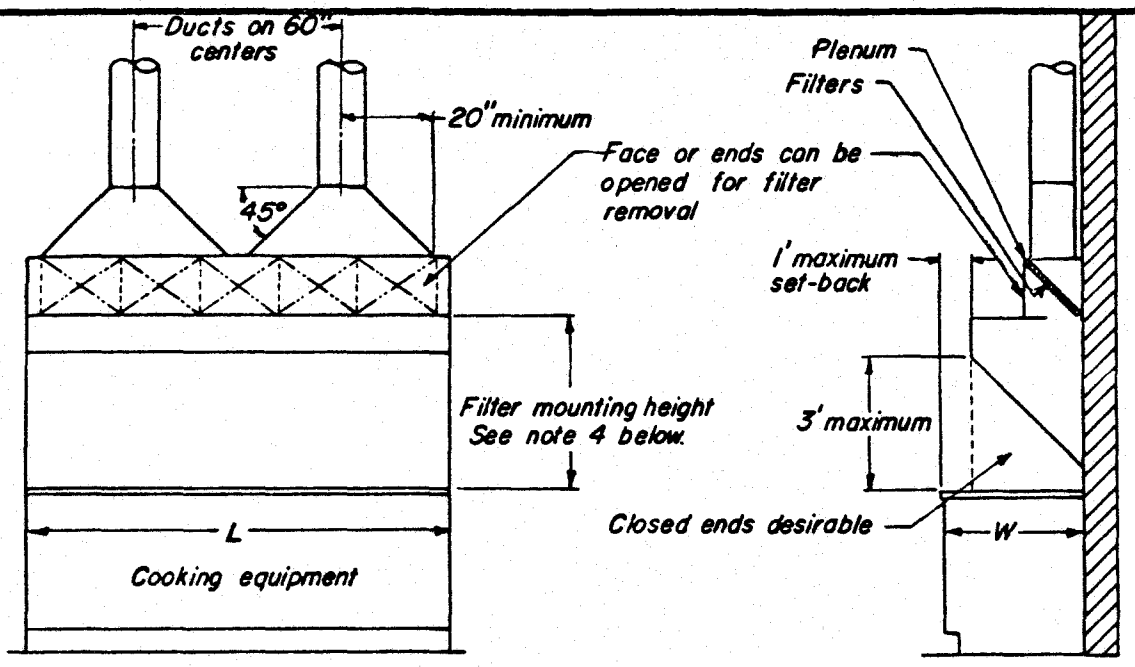
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KITCHEN RANGE HOODS

DATE 1-72 | VS-910

PRODUCED 11 DM - 83

MT-PWHD-004638



LOW SIDE WALL HOOD

Q= 200 cfm/lineal ft of cooking surface (200 L)
Duct velocity = 1000 - 4000 fpm, to suit conditions
Entry loss = 0.25" (filters) + 0.25 duct VP

NOTES FOR KITCHEN HOODS

Filters:

1. Select practical filter size.
2. Determine number of filters required from manufacturer's data. (Usually: 2 cfm maximum exhaust for each sq in of filter area)
3. Install at 45° - 60° to horizontal. Never horizontal.
4. Filter mounting height (Reference 66)
   a. No exposed cooking flame — 2½' minimum to lowest edge of filter.
   b. Charcoal and similar fires — 4½' minimum to lowest edge of filter.
   c. Other exposed fires — 3½' minimum to lowest edge of filter.
5. Shield filters from direct radiant heat.
6. Provide removable grease drip pan.
7. Clean pan and filters regularly.

Fan:

1. Use upblast discharge fan. Downblast is not recommended.
2. Select fan for design Q and SP resistance of filters and ductwork.
3. Adjust fan specification for expected exhaust air temperature.

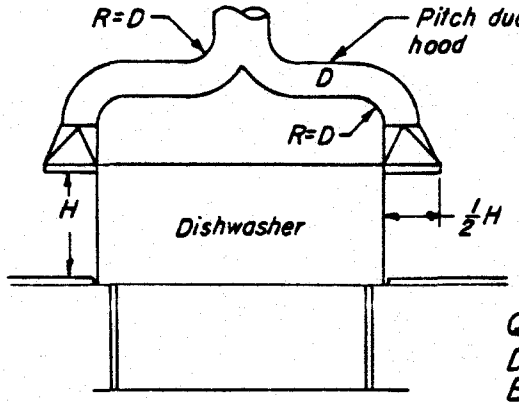
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

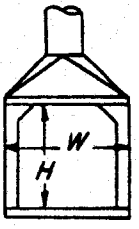
KITCHEN RANGE HOOD

DATE 1-72 | VS-911

PRODUCED JM-11-83

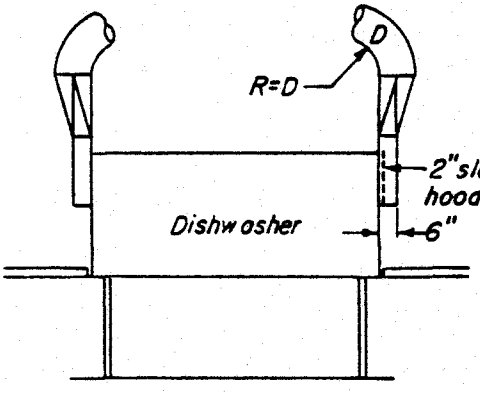
MT-PWHD-004639

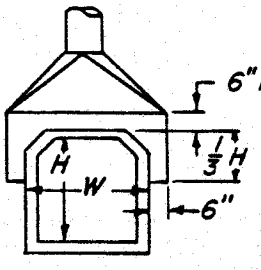




CANOPY HOODS

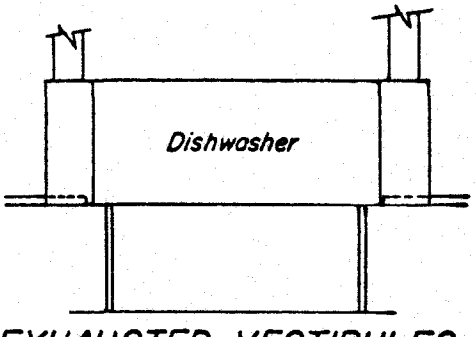
Q=250 cfm/sq ft of face area – each end
Duct velocity = 1000-3000 fpm
Entry loss = 0.25 duct VP

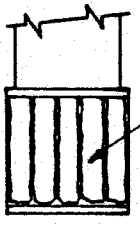




SLOT HOODS

Q=150 cfm/sq ft of door area (150WH)-each end
Duct velocity = 1000-3000 fpm
Entry loss = 1.00 slot VP + 0.25 duct VP





EXHAUSTED VESTIBULES

Q=150 cfm/sq ft of entrance and exit area
Duct velocity = 1000-3000 fpm
Entry loss = 0.50 duct VP

Note:
If direct exhaust connections are provided from washer body, cap these and use external hoods.

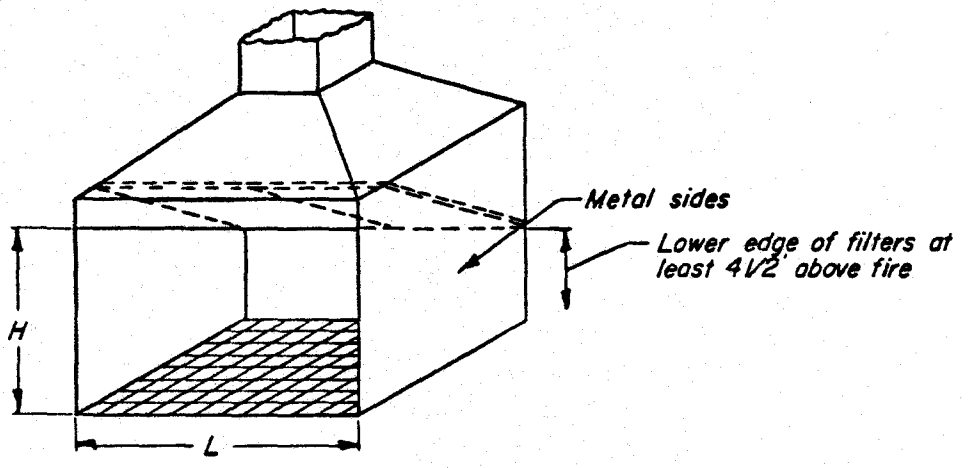
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DISHWASHER VENTILATION

DATE 1-70 | VS-912

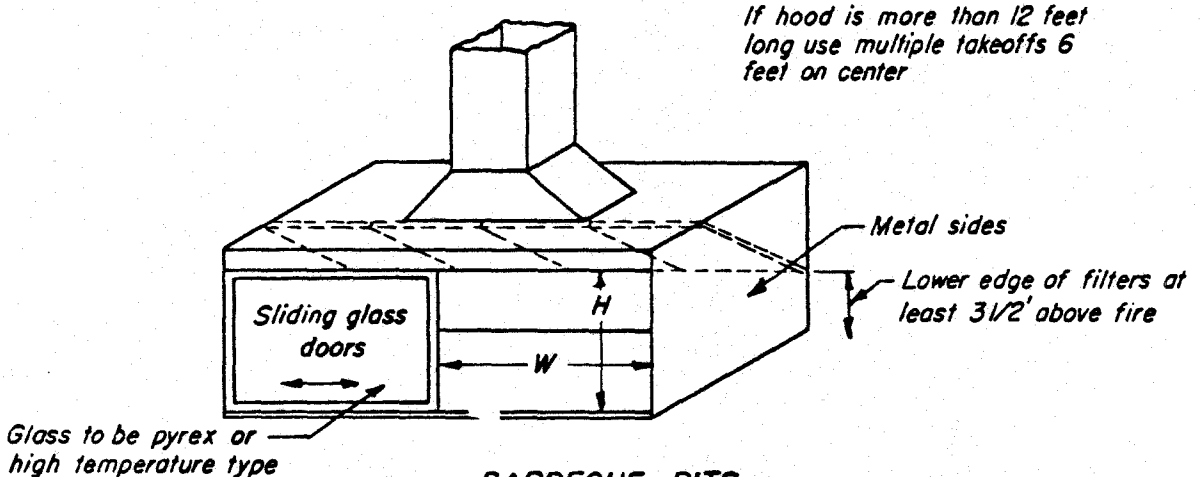
PRODUCED 1102 - 83

MT-PWHD-004640



CHARCOAL BROILER

Q = 100 L H
Duct velocity = 1000 - 3000 fpm
Entry loss = 0.25 (filters) + 0.25 duct VP



BARBEQUE PITS

Q = 100 WH (maximum open door area, sq ft)
Duct velocity = 1000 - 3000 fpm
Entry loss = 0.25 (filters) + 0.25 duct VP

Note:
See VS-911 for information about filters and fans

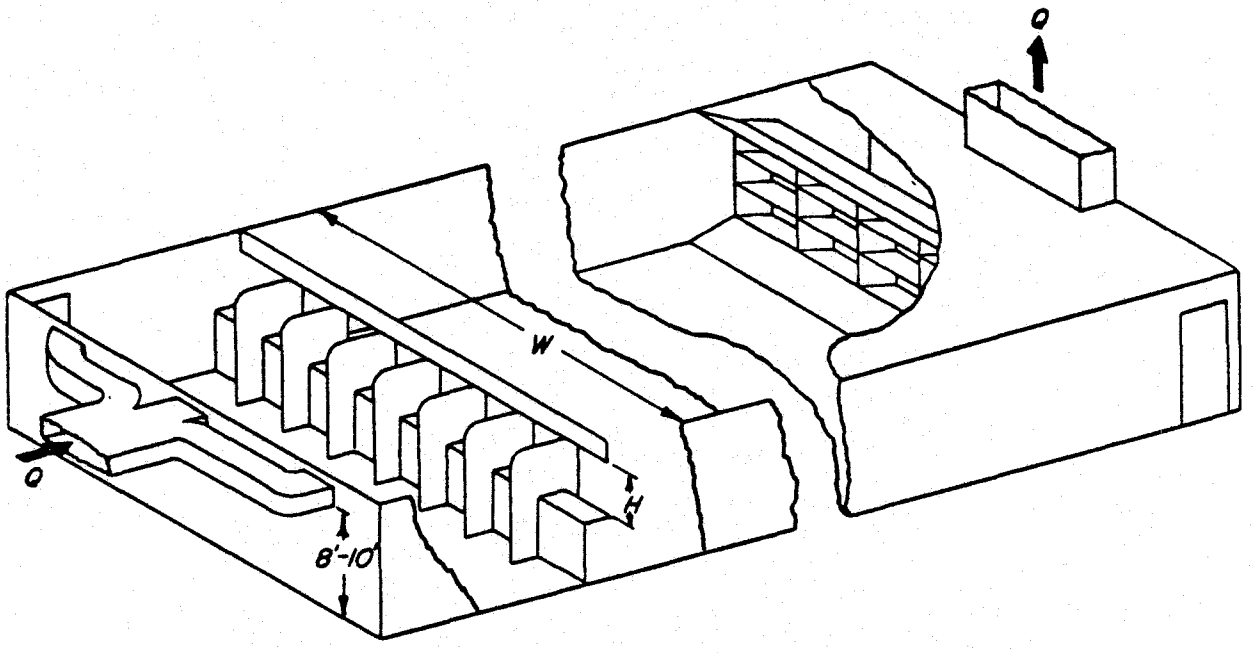
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CHARCOAL BROILER AND BARBEQUE PIT VENTILATION

DATE 1-70 | VS-913

PRODUCED JM - 83

MT-PWHD-004641



Q = 50 HW, but not less than 20 cfm/sq ft of room cross sectional area

Notes:

Make-up air:

Minimum temperature = 70 F

Sidewall grilles:

Maximum grille velocity = 400 fpm

Discharge air downward

Ceiling diffusers:

Size for uniform distribution

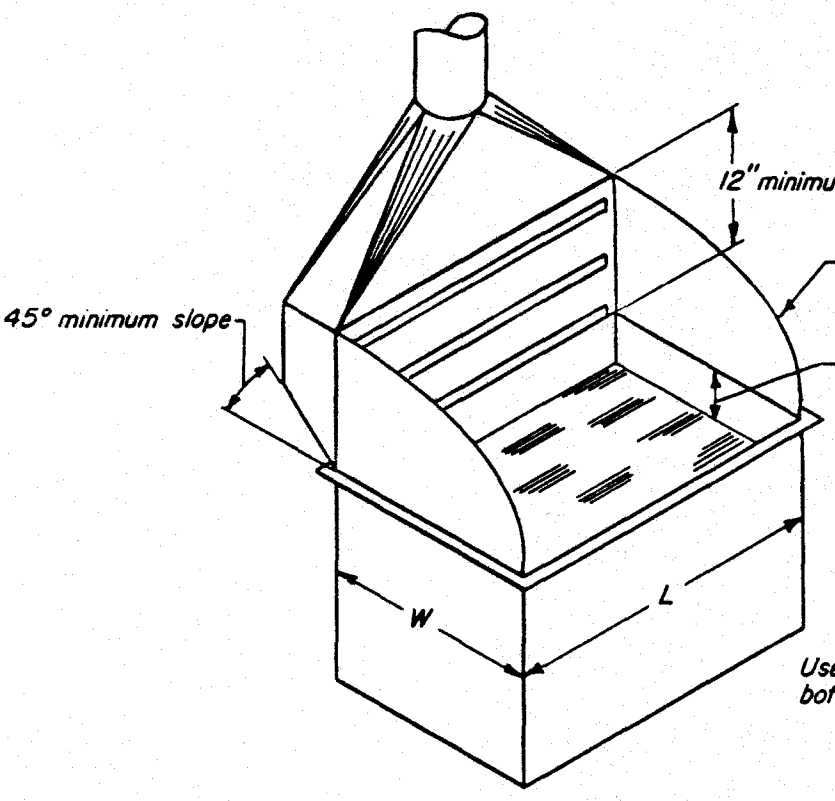
Bureau of Mines approved lead dust respirator is necessary during clean-up

Acoustical material on walls, ceiling and thick fabric on bench top are recommended

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INDOOR PISTOL AND SMALL BORE RIFLE RANGE VENTILATION	
DATE *1-68*	*VS-914*

PRODUCED JM 110483

MT-PWHD-004642



Q = 150 cfm/sq ft of bed (150LW)
Slot velocity = 2000 fpm
Entry loss = 1.78 slot VP + 0.25 duct VP
Duct velocity = 2500 - 3000 fpm
W not to exceed 36"

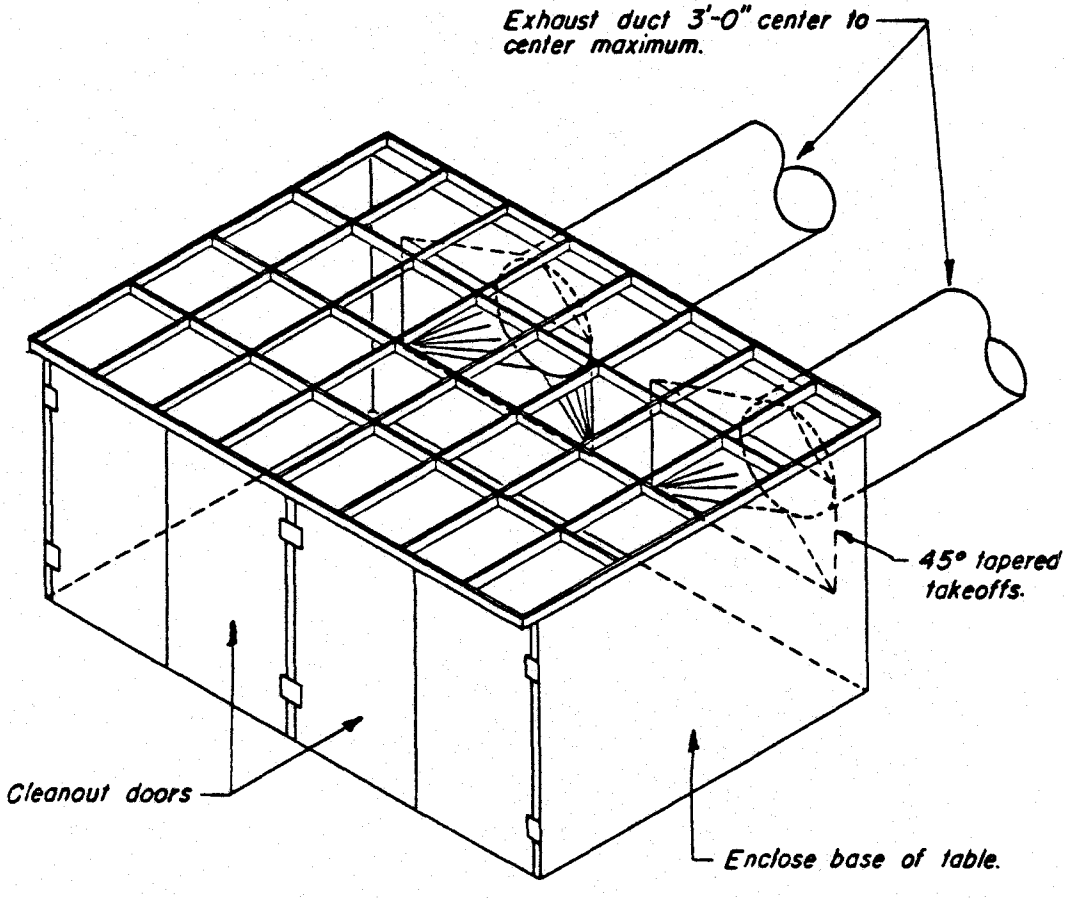
For circular beds or other hood designs, see VS-303, VS-504
Free board must be maintained to prevent material carryout.

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FLUIDIZED BEDS

DATE 1-70	VS-915

1105
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JM - 83
MT-PWHD-004643

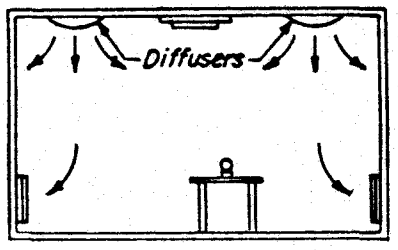


Q = 150 cfm/sq ft of gross table area
Duct velocity = 2000-4000 fpm *
Entry loss = 1.0VP through grating
0.25 duct VP - tapered takeoff
* For horizontal runs, transport velocity is necessary

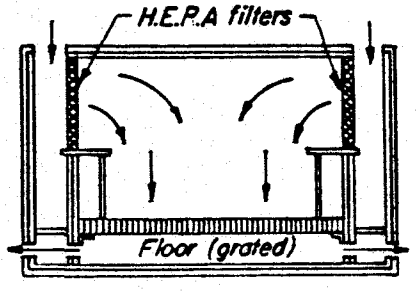
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TORCH CUTTING VENTILATION	
DATE 1-68	VS-916

REPRODUCED JM - 83

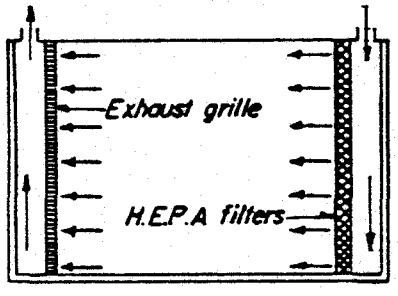
MT-PWHD-004644



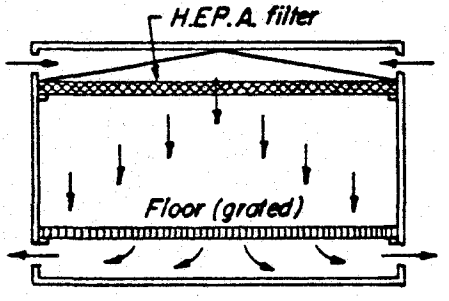
POOR



FAIR

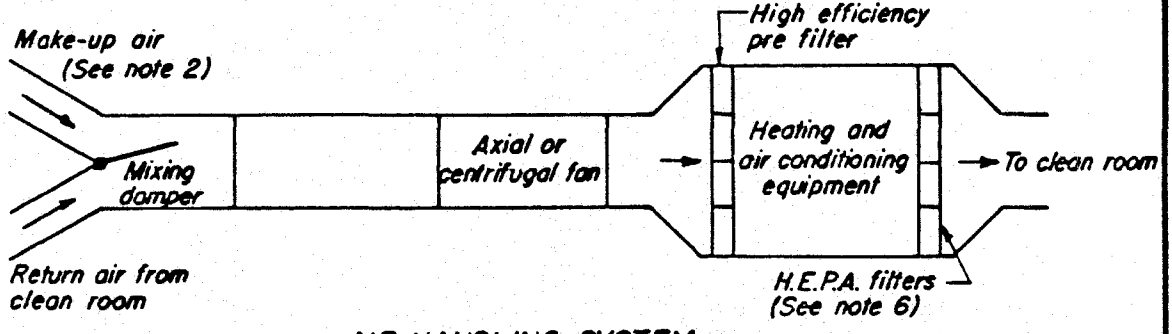


GOOD



BEST

CLEAN ROOM AIR FLOW



AIR HANDLING SYSTEM

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
CLEAN ROOM AIR FLOW	
DATE 1-68	VS-917

PRODUCED JM - 83

MT-PWHD-004645

NOTES

1. Air handling systems are usually designed to provide 20 air changes per hour in conventional clean rooms (poor and fair) or a room air velocity of 75-100 fpm in crossflow or downflow clean rooms (good and best). See VS-917

2. Make-up air equal to 25% of the total air flow is taken from outside or both outside and in-plant with not less than 15 cfm of outside air per person. A positive pressure in the clean room of 0.1 inches of water is maintained by gravity dampers located over exit doors. When exhaust ventilation is necessary for control of toxic contaminants additional make-up air may be required to maintain positive pressure.

3. Clean room temperatures are maintained at 72 F ± 5 F with a maximum rate of change of 2.5 F per hour and a maximum relative humidity of 40%(82).

4. Pre-filters are used to reduce the dust load on the HEPA filters. The efficiency of filters commonly used for this purpose is from 60-90% by the NBS atmospheric dust test.

5. High-Efficiency Particulate Air (HEPA) Filters are > 99.97% efficient by 0.3 micron DOP test. Initial HEPA filter resistance is not more than 0.9 inches of water for a 2' square filter assembly at a flow of 1000 cfm. Filters may be operated at differentials up to 10 inches of water. Replacement is determined by maximum acceptable reduction in flow caused by increases in filter resistance.

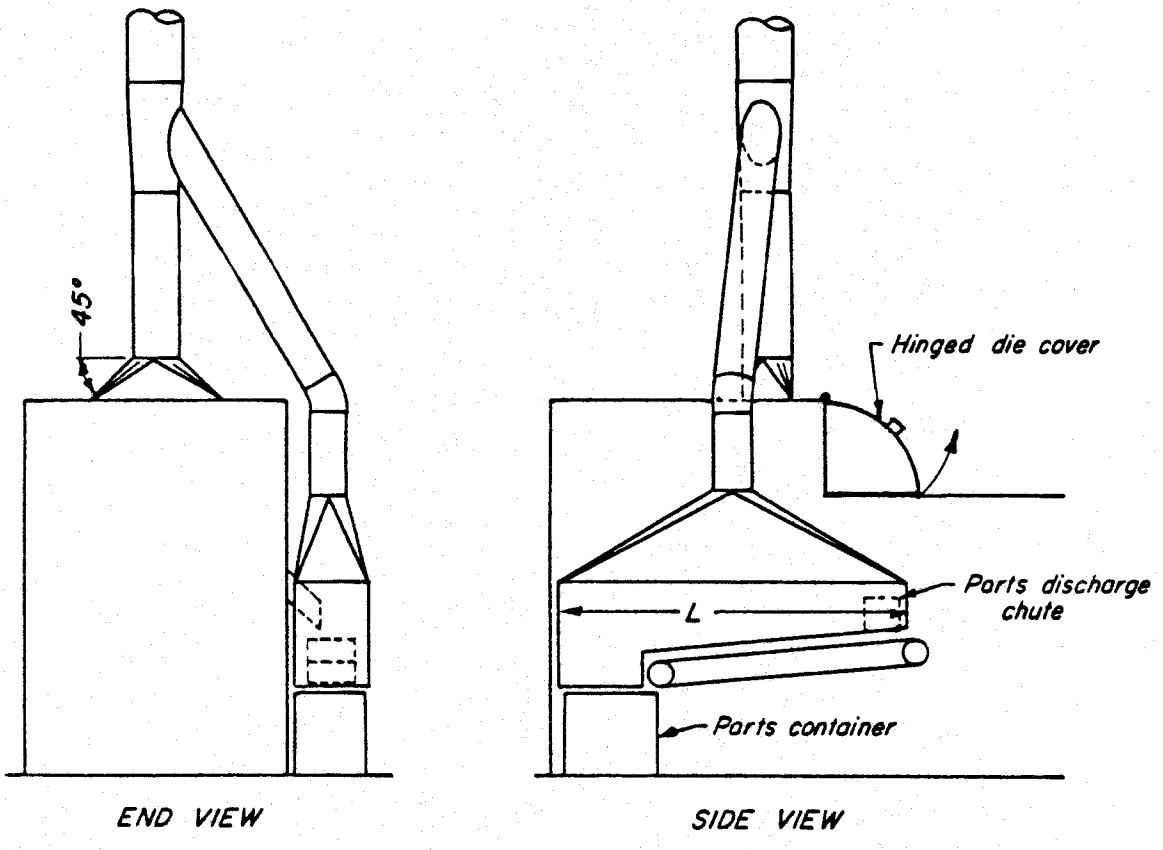
6. HEPA filters should be installed in the clean room wall or ceiling. The plenum or ducts upstream from the filters are designed so that their resistance in combination with the filter resistance will result in uniform air flow from face of filter bank. When room installation is not possible they may be located in the air handling system with no mechanical equipment following the filters.

7. Dust concentration limits at work bench level for USAF Standard and Federal Standard 209 Class 100,000 clean rooms are less than 100,000 ppcf > 0.5 μ and < 20,000 ppcf 1.0 μ (Ref. 82, 83 and 84.)

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CLEAN ROOM AIR FLOW DATA	
DATE *1-68*	*VS-918*

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Cold header:

Q = 750 cfm/sq ft of die opening
Duct velocity = 3500 fpm
Entry loss = 1.0 slot VP + 0.25 duct VP

Parts discharge and container:

Q = 100 cfm/ft of hood length
Duct velocity = 3500 fpm
Entry loss = 0.25 VP

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COLD HEADING MACHINE VENTILATION	
DATE *1-72*	*VS-919*

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MT-PWHD-004647

TABLE 5-9-1

GRAIN ELEVATORS, FEED MILLS, FLOUR MILLS (66)

The following data are offered as guides. Air volumes can vary considerably depending on degree of enclosure, flow rate of material and dustiness of the grain. Minimum duct velocity = 3500 fpm. Ventilation control is desirable for these operations to minimize the explosive characteristics of grain dusts and to preserve plant housekeeping standards.

<table>
<tr><th>Operation</th><th>Hood Design</th><th>Air Volume</th></tr>
<tr><td>Bag Loading</td><td>VS 301, 302
Booth VS-303</td><td>As shown
100 cfm/ft² open face area</td></tr>
<tr><td>Belt Discharge</td><td>To belt--VS-306

To bin--VS-304

To Elevator--VS-305, 306</td><td>150 cfm/ft of belt width up to 200 fpm belt speed
250 cfm/ft of belt width over 200 fpm belt speed
Increase 1/3 if material drop is over 10 ft</td></tr>
<tr><td>Bins</td><td>Direct exhaust. Use taper.</td><td>550 cfm/bin</td></tr>
<tr><td>Bucket Elevator</td><td>VS-305</td><td>100 cfm/ft² cross-section</td></tr>
<tr><td>Cleaning Machines</td><td>Consult manufacturer</td><td></td></tr>
<tr><td>Distributors</td><td>Enclose discharge 200 fpm in-draft through enclosure openings.</td><td>
<table>
<tr><th>No. of Spouts</th><th rowspan="2">Exhaust cfm</th><th colspan="4">Diameter of Spouts</th></tr>
<tr><th></th><th>6"</th><th>7"</th><th>8"</th><th>9"</th></tr>
<tr><td>0 - 6</td><td></td><td>550</td><td>675</td><td>950</td><td>1250</td></tr>
<tr><td>6 - 12</td><td></td><td>950</td><td>1250</td><td>1500</td><td>1900</td></tr>
<tr><td>12 - 24</td><td></td><td>1500</td><td>1900</td><td>2250</td><td>2750</td></tr>
</table>
</td></tr>
<tr><td>Feed Grinders</td><td>Consult manufacturer</td><td></td></tr>
<tr><td>Floor Dump</td><td>Booth</td><td>200 cfm/ft² open face area</td></tr>
<tr><td>Floor Sweep</td><td></td><td>950 cfm in 4" x 8" opening</td></tr>
<tr><td>Garner Bin</td><td>Direct exhaust. Use taper.</td><td>cfm = 1.25 x bushels/min.</td></tr>
<tr><td>Mixers</td><td>Ventilated cover</td><td>
<table>
<tr><th>Mixer Capacity</th><th>Exhaust, cfm</th></tr>
<tr><td>Up to 1/2 ton</td><td>300</td></tr>
<tr><td>1/2 ton - 1-1/2 ton</td><td>675</td></tr>
<tr><td>Over 1-1/2 tons</td><td>950</td></tr>
</table>
</td></tr>
<tr><td>Percentage Feeders</td><td>Enclosed conveyor</td><td>200 cfm at each feeder</td></tr>
<tr><td>Purifiers</td><td>Enclosure</td><td>30 - 40 cfm/ft² screen area</td></tr>
<tr><td>Roll Stands</td><td>Enclosure</td><td>60 cfm/lineal ft</td></tr>
<tr><td>Scales</td><td>Enclosure</td><td>
<table>
<tr><th>Scale Capacity, Bushels</th><th>Exhaust, cfm</th></tr>
<tr><td>Up to 5</td><td>250</td></tr>
<tr><td>6 to 10</td><td>400</td></tr>
<tr><td>Over 11</td><td>600</td></tr>
</table>
</td></tr>
<tr><td>Scale Hopper</td><td>Direct exhaust. Use taper</td><td>cfm = 1.25 x bushels/min.</td></tr>
<tr><td>Screw Conveyor</td><td>Direct exhaust. Use taper</td><td>200 cfm - ducts on 30 ft centers</td></tr>
<tr><td>Sifters</td><td>Enclosure</td><td>200 cfm/compartment</td></tr>
<tr><td>Track Sink</td><td>Direct exhaust from hopper.
Use taper.</td><td>100 cfm/ft² grate area</td></tr>
<tr><td>Tripper Car</td><td>Belt discharge. FS-304, 305, 306.
Spout ends - tapered connection.
Spillage - exhaust under head pulley.</td><td>See "Belt Discharge" above.
200 cfm/ft² spout cross-section
90 cfm/ft belt width</td></tr>
</table>

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TABLE 5-9-2

MISCELLANEOUS SPECIFIC OPERATION STANDARDS
(Not shown in VS-Prints)

Operation or Industry	Ventilation		Minimum Transport Velocity fpm	References and Remarks
	Type of Hood	Air Flow or Capture Velocity		
Abrasive Wheel Manufacture				(33)
Grading screen	Enclosure--booth	50 fpm at face	3000	----
Barrels	Close canopy	400 fpm at face	3000	Bbls. receive dust from cyclone
Grinding wheel dressing	Enclosure--booth	400 fpm at face	3000	----
Aluminum Furnaces	Enclosure	150-200 fpm through opening	2000	(14) ----
Asbestos				
Fiber Preparation	Enclosure	100-150 fpm through openings	3000	(9, 10, 32) Use pneumatic conveying
Carding	Enclosure	1600 cfm/card	3000	----
Spool Winding	Local hoods	50 cfm/spool	3000	----
Spinning and Twisting	Partial enclosure	50 cfm/spool	3000	Hinged front panels and skirt
Weaving	Canopy with baffles	50 fpm through openings	3000	Wet weaving preferred
Auto Parking Garage	2 Level	500 cfm/Parking Space		(80)
Ceramic	Enclosure	200 fpm through all openings	3500	(24, 31, 39) ----
Dry pan				
Dry press	Local at die	500 cfm	3500	Automatic feed
	Local at die	500 cfm	3500	Manual feed
	At supply bin	500 cfm	3500	Manual feed
Aerographing	Booth	100 fpm (face)	----	----
Spraying (lead glaze)	Booth	400 fpm (face)	2000	----
Coating pans (pharmaceutical)	Air flow into opening of pan	100-150 fpm through opening	3000	(24, 7) If heated air supplied to pan, add volume of heated air to exhaust
Cooling tunnels (foundry)	Enclosure	75-100 cfm per running foot of enclosure.	----	(22, 25) ----
Core knockout (Manual)	Large side-draft or semi-booth--exhaust near floor	200-250 cfm/sq ft dust producing working area	3500	(13, 22, 25)
Core sanding (on lathe)	Downdraft under work	100 fpm at source	3500	(34) ----
Crushers and grinders	Enclosure	200 fpm through openings	3500	(30)

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Miscellaneous Specific Operation Standards (Continued)

Operation or Industry	Ventilation		Minimum Transport Velocity fpm	References and Remarks
	Type of Hood	Air Flow or Capture Velocity		
Drilling (rocks)	Special trap (see references)	60 cfm--vertical (downward) work 200 cfm--horizontal work		(9, 17, 18) May vary with size and speed of drill
Forge (hand)	Booth--enclosure	200 fpm at face	1500	(14) ----
Packaging Machines	Booth Downdraft Complete Enclosure	50-100 fpm at face 95-150 fpm down 100-400 fpm opening	3000 to 4000	----
Paper Machine	Canopy	200-300 fpm at face	1500	(14) ----
Quartz fusing	Booth on bench	150-200 fpm at face	----	(35, 36) ----
Silver Soldering	Free Hanging	100 fpm at source	2000	----
Steam Kettles	Canopy	150 fpm at face	2000	----
Varnish kettles	Canopy	200-250 fpm at face	1500	---- (14, 39)
Wire Impregnating	Covered tanks	200 cfm/sq ft of opening	----	(46) Chlorinated naphthalenes & diphenyls

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MT-PWHD-004650

Section 6

DESIGN PROCEDURE

Calculations discussed below are essential to determine the duct sizes and the exhaust system pressure loss. This figure, coupled with the exhaust volume, will determine size and type of exhauster as well as its speed and motor horsepower required.

Preliminary Steps

The designer should have the following data available:

1. A layout of the operations, workroom, etc., (and building if necessary).
2. A line sketch including elevations of the ductwork layout, fan location, collector location, etc.
3. A rough design or sketch of the desired hood for each operation with direction and elevation of outlet for duct connection.
4. Information as to the details of the operations, toxicity of materials, etc. Number, letter or otherwise identify each branch and section of main on the line sketch for convenience.

Design Procedure

Determine the type of system and select the calculation method to be used.

1. Transport systems exhaust particulate matter and minimum transport velocities must be maintained in the ducts to prevent settling. (A variation is the Plenum Type system discussed later.)
2. Non-transport or vapor systems exhaust vapors, gases and non-condensing fumes. Duct velocities are not critical and may be lowered to permit operating economy.
3. Calculation methods are based on Equivalent Feet of duct or on Velocity Pressure loss. Either method may be used. The following procedure is common to both methods.

Select or design the hood and determine exhaust volumes and required conveying volocities from data in preceding sections. When cfm is determined, calculate branch size to maintain minimum recommended carrying velocity. The usual sheet metal fabricator will have patterns for pipes in 1/2 inch steps through 5 1/2 inch diameter; 1 inch steps 6 inches through 20 inches and 2 inch steps 22 inches and larger diameters.

In the illustrations, the following items should be noted:

1. There are two basic variations in the method of pressure loss calculations. One method is based on using the hood entrance loss only in computing the pressure loss. The method illustrated on this discussion uses the hood suction (entrance loss plus velocity pressure in the connecting branch) as the initial pressure loss in the system. It has a number of advantages including (See Figure 6-1):
   A. Branch velocities are often higher than the velocity at the exhauster inlet. The inclusion of the higher velocity pressure counterbalances small acceleration and deceleration losses in the system and produces a result on the safe side.
   B. By starting with the hood suction, pressures in the system can be immediately checked with a manometer against the calculated values in the system design.
2. With the small variation in velocities in any exhaust system, acceleration and deceleration losses have been neglected because such losses will be of too small magnitude to introduce measurable variation in exhaust volume. Actual static pressure losses for contraction and static pressure regain for enlargements are shown on Figure 6-7. An actual example of static pressure regain calculation is shown in Example Problem 1, Figure 6-1, and Examples 2 and 3, Figure 6-6.

Calculations, Equivalent Feet

All exhaust systems, whether simple or complex have in common the use of hoods, ductwork and special fittings leading to an exhaust fan. In fact, a complex system is merely an arrangement of several simple exhaust systems connected to a common duct. In designing an exhaust system, start at the most logical place—the hood—and proceed downstream to the fan and to the atmosphere.

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1113 JM - 83

MT-PWHD-004651

1. Select or design the exhaust hood to suit the operation to be controlled (See Sections 4 and 5).
2. Determine the desired air volume and minimum duct velocity; from this information arrive at the proper branch duct size.
3. Determine the actual length of the ductwork required, together with the types and equivalent length of the special fittings and elbows needed. Actual length is the centerline distance along the duct, neglecting the radius of elbows, etc. The equivalent length of fittings is added to the actual length as provided on the calculation sheets.
4. Using the calculation sheet, as illustrated in Figures 6-1, 6-3 and 6-4, compute the pressure losses due to the components of the system. These pressure losses are the Static Pressure of the exhaust system. In common practice, exhaust fan tables are rated in Fan Static Pressure which will be discussed later.

Problem 1

To illustrate the steps involved in calculating these pressure losses, Problem 1, Figure 6-1, is included. Note that the calculation of these losses is a straight-forward procedure using the calculation sheet provided. With the drawing of the system there is also a pressure profile of the system showing the magnitude and relationships of Total, Static and Velocity Pressures on both the "suction" and "pressure" sides of the system. It should be noted that Velocity Pressure is always positive with respect to atmospheric pressure. Also, while Total and Static pressures may be either negative or positive with respect to atmosphere, all pressures are positive on the absolute pressure scale and Total Pressure is always greater than Static Pressure (TP = SP + VP).

Details of Operation

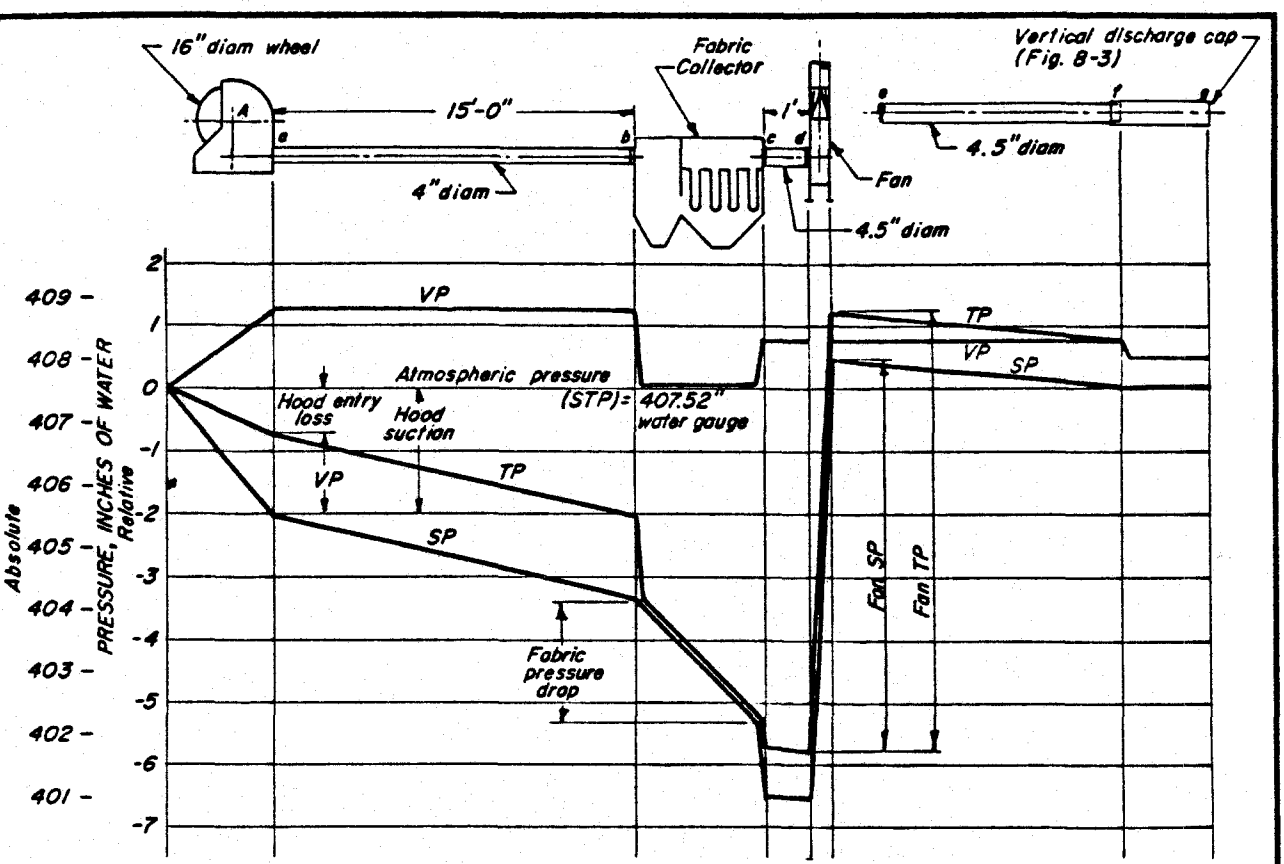
NO.		HOOD NO.	VS-PRINT	REQUIRED AIR-FLOW, cfm
1	16" Diameter Grinding Wheel, 2" wide	A	411	390

Dimensions

No. OF BRANCH OR MAIN	STRAIGHT RUN, FT.	CFM REQUIRED	ELBOWS	ENTRIES
ab	15	390	--	--
bc	Collector	390	--	--
cd	1	390	--	--
ef	10	390	--	--
fg	Stack head	390	--	--

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MT-PWHD-004652



Equivalent Foot Method
Calculation Sheet

Committee on Industrial Ventilation
P.O. Box 453
Lansing, Michigan 48902

Plant name PROBLEM 1
Location
Department
Refer to
Elevation
Temperature
Factor
Remarks

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
					From Section 5			From Fig 6-11	Col 7 plus Col 9	From Fig 6-15	Col 10 x Col 11 / 100	From Col 6 & Fig 6-16	From Fig 6-10	100 plus Col 14	Col 13 times Col 15	Col 12 plus Col 16	At junction	
			Air volume CFM			Length of duct in feet				Resistance in inches water gauge					Resistance in inches of water			
No of br or main	Dia duct in in	Area duct sq ft	in branch	in main	Vel in FPM	straight runs	Number of elbows entries	equiv length	total length	per 100	of run	one VP	entry loss(VP)	hood suct(VP)	hood suct	static press.	gov. SP	corrected CFM
A	4	.087	390		4470							1.25	.65	1.65	2.06			
a-b	4				4470	15			15	8.5	1.28	1.25				3.34		
Collector							SP drop across fabric				2.00					5.34		
c	3 1/2	.111			3510							.77	.49	1.49	1.15	6.49		
c-d	3 1/2				3510	1			1	4.5	.05					6.54		
Fan																		
e-f	3 1/2				3510	10			10	4.5	.45							

Fan SP = SPout - SPin - VPin
= 0.45 - (-6.54) - 0.77
Fan SP = 6.22"

Calculated fan characteristics for standard conditions
Capacity( ) CFM
Fan TP in WG
Fan SP
Fan, type and size
RPM

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PROBLEM 1

DATE 1-72 | Fig. 6-1

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Distribution of Air Flow

As discussed earlier, a complex exhaust system is actually a group of simple exhaust systems connected to a common main duct. Therefore, in designing a system of multiple hoods and branches, the same rules apply as before. In a multiple branch system, however, it is necessary to provide a means of distributing air flow between the branches either by balanced design or by the use of blast gates.

The reason for this is that air will always take the path of least resistance. If the design does not provide for proper distribution, a natural balance of the air will occur; that is, the exhaust volume will distribute itself automatically according to the resistance of the available flow paths. To provide distribution that will result in the design air flow at each hood, the designer must make sure that all flow paths (ducts) entering a junction will have equal static pressure resistance at design flow.

To accomplish this, the designer has a choice of two methods. The object of both methods is the same: to obtain the desired quantity of air flow at each hood of the system, at the same time maintaining the desired conveying velocity in each branch and main.

The two methods, labeled Method A and Method B, can be outlined as follows.

Method A: (See Figure 6-3) (Air Balance without Blast Gate Adjustment) provides a procedure for achieving the desired air flow (a "balanced" system) without the use of dampers or blast gates. This method is often called the "static pressure balance method". In this type of design, the calculation begins at the branch of greatest resistance and proceeds, branch to main, and section of main to section of main, on up to the fan. At each point of junction of two air streams, the static pressure necessary to achieve desired flow in one stream must match the static pressure in the joining air stream. (This condition actually will prevail in any operating system; but if the system is not in "balance", the desired air flow may not be achieved in each stream.) The static pressures are balanced at the desired rate of flow by suitable choice of pipe sizes, elbow radii, etc., and are more fully detailed below.

Method B: (See Figure 6-4) (Air Balance by Blast Gate Adjustment) depends on the use of blast gates which may be adjusted after installation in order to achieve the desired air flow at each hood. This design calculation also begins at the "branch of greatest resistance" and pressure drops are calculated through the branch and through the various sections of the main on up to the fan. At each section of main where another branch or submain joins, the desired volume of that added flow is added to the cfm in the main. No attempt is made to balance the static pressure in the joining air stream. The joining branches are merely sized to give the desired minimum duct velocity at the desired cfm. It will be apparent that care must be exercised in choosing the "branch of greatest resistance"; if the choice is incorrect, any branch having a higher resistance than that chosen will fail to draw the desired volume even though its blast gate is wide open. In case of doubt, check all branches possible of giving the greatest resistance.

Choice of Methods

Method A will normally be selected where highly toxic materials are controlled to safeguard against tampering with blast gates and consequently subjecting personnel excessive exposure. This method is mandatory where explosives, magnesium and radioactive dusts are exhausted as the possibilities of accumulations in the branch duct caused by a blast gate obstruction is eliminated.

The ability to distribute the exhaust air and the flexibility of Method B suggests that it can be used except where highly toxic materials are controlled or where linty material and explosive dusts would accumulate due to blast gate obstruction to the air stream flow.

It should be noted that in systems where branch velocities are appreciably higher than main velocities and where branch diameters are small and reasonably uniform, the branch ducts become load limiting orifices that tend to balance the system without the use of blast gates, even when air volumes and pressure losses are calculated as illustrated in Method B.

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Advantages and shortcomings of these two methods are further outlined as follows.

Relative Advantages of Method A and Method B

Method A (Balance Without Blast Gates)	Method B (Balance With Blast Gates)
1. Air volumes cannot easily be changed by workmen or at the whim of the operator.	1. Air volumes may be changed relatively easily even though precautions are taken. Such changes are desirable where pickup of unnecessary quantities of material may affect process.
2. Small degree of flexibility for future equipment changes or additions; the ductwork is "tailor-made" for the job.	2. Greater degree of flexibility for future changes or additions.
3. Choice of exhaust volumes for a new unknown operation may be incorrect; in such cases some ductwork revision is necessary.	3. Correction of improperly estimated exhaust volumes is easy, with certain ranges.
4. No unusual erosion or accumulation problems.	4. Partially closed blast gates may cause erosion to slides, thereby changing degree of restriction or may cause accumulations particularly of linty material.
5. Ductwork will not plug if velocities are chosen wisely.	5. Ductwork may plug if the blast gate adjustment has been tampered with by unauthorized persons.
6. Design calculation is more time-consuming than Method B.	6. Design calculations relatively brief.
7. Total air volumes slightly greater than design air volume due to added air handled to achieve balance.	7. Balance may be achieved with design air volume.
8. Poor choice of "branch of greatest resistance" will show up in design calculations.	8. Poor choice of "branch of greatest resistance" may remain undiscovered. In such case the branch or branches of greater resistance will be "starved."
9. Layout of system must be in complete detail with all obstruction cleared and length of runs accurately determined. Installations must exactly follow layout.	9. Leeway is allowed for moderate variation in duct location to miss obstructions or interferences not known at time of layout.

Balancing Procedures

Method A

Resistance of each branch is calculated, based on design data, and totaled for the length running from exhaust hood to junction of the next branch. At each junction the SP for each parallel path of air flow must be the same. Where difference in SP is pronounced (over 20%), the branch with lower pressure loss should be redesigned to increase its pressure drop. Usual method is to decrease pipe size so the increased pipe velocity will increase all losses in that run. Where pressure losses of parallel paths are within 20% of the governing static pressure, balance can be obtained by increasing the air flow through the run with the lower resistance. This increase in cfm is quickly calculated as pressure losses increase as the square of the exhaust volume; so:

$$\text{Corrected cfm} = \text{Design cfm} \sqrt{\frac{\text{SP run with larger SP loss}}{\text{SP run with lower SP loss}}}$$

Where balance is within 5% it is usual to ignore the small error and treat it as if paths were in complete balance.

Method B

Same data and type of calculations are involved as noted in Method A. Use care in selection of run of greatest resistance and where any question occurs, calculate pressure loss of each run in question and use run with greater loss.

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Problem 2

Typical worksheets illustrate an orderly and concise arrangement of data and calculation (See Figure 6-2, 6-3 and 6-4). A discussion of the calculations for either method can best be done by a typical example, using the exhaust system shown in Figure 6-2.

The problem considered in Figures 6-2, 6-3 and 6-4, is a foundry sand handling and shakeout system. A minimum conveying velocity of 3500 fpm is used throughout the problem. The operations, hood designations on diagram, VS-print references and required air flows are as follows.

Details of Operation

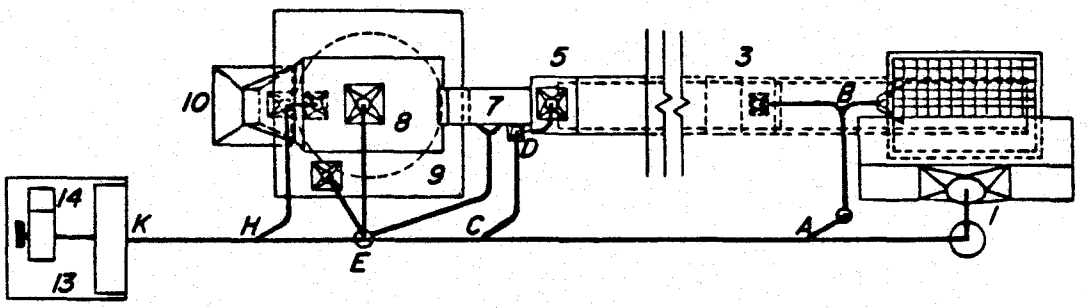
No.	Hood No.	VS Print	Minimum Exhaust, cfm
1. Vibrating shakeout 4' x 6' grate	1	110, 112	9600
2. Shakeout hopper	2	112	960
3. Vibrating pan feeder 24"	3	112, 306	700
4. Incline sand belt 24" x 28'			
5. Magnetic pulley	5	306	700
6. Tramp iron box			
7. Bucket elevator 24" x 30" casing, 34' high	7a (lower)	305	500
	7b (upper)		500
8. Vibrating screen 4' x 6' deck	8	307	1200
9. Sand bin 600 ft^3 capacity, 18" x 20" opening	9	304	500
10. Waste sand box 44" x 54", clearance 6"	10	903 V = 150 fpm	1225
11. Sand weigh hopper	11	108	
12. Sand muller 6' dia.	12		900
13. Wet dust collector			

DIMENSIONS

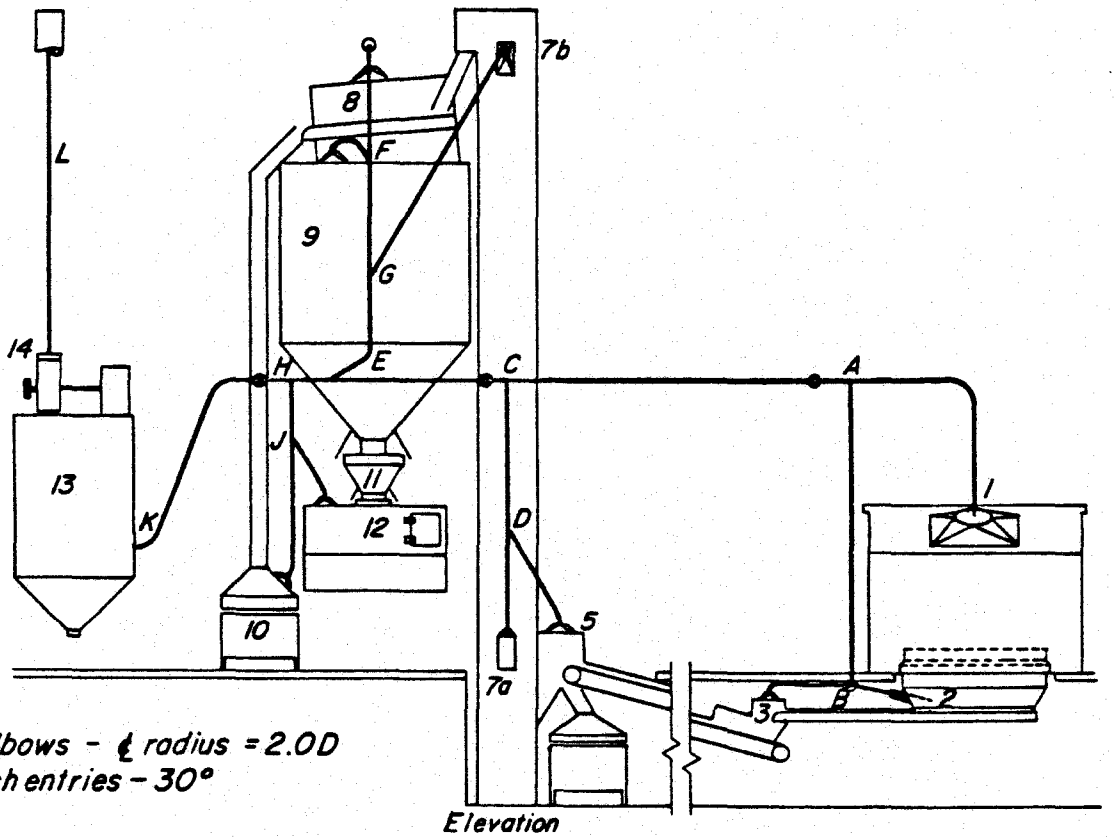
No. of Branch or Main	CFM Required, Minimum	Straight Run, Ft	Elbows	Entries
1-A	9,600	13	1-90°	
2-B	960	3	1-60°	1-30°
3-B	700	4	1-90° + 1-60°	1-30°
B-A	1,660	18	2-90°	1-30°
A-C	11,260	34		
5-D	700	7	1-30° + 1-60°	1-30°
7a-D	500	5		
D-C	1,200	14	1-90° + 1-60°	1-30°
C-E	12,460	6.5		
8-F	1,200	11	2-90°	
9-F	500	4	1-90° + 1-60°	1-30°
F-G	1,700	5		
7b-G	500	15	1-60°	1-30°
G-E	2,200	6	1-60°	1-30°
E-H	14,660	3.5		
10-J	1,225	6	1-45°	
12-J	900	2.5	1-30°	1-30°
J-H	2,125	8	1-90° + 1-60°	1-30°
H-K	16,785	9	2-45°	
13	16,785			
14-L	16,785	20		

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Plan view



All elbows - ℄ radius = 2.0D
Branch entries - 30°

Elevation

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PROBLEM 2

DATE 1-72 | Fig. 6-2

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Figure 6-3
Balanced System Design
Method A

Equivalent Foot Method
Calculation Sheet

Committee on Industrial Ventilation
P O Box 453
Lansing, Michigan 48902

Plant name Problem 2 | Refer to Figure 6-2 | Elevation | Factor | Remarks
Location | | Temperature | | |
Department FOUNDRY

1	2	3	4	5	6	7	8		9	10	11	12	13	14	15	16	17	18	19
					From Section 5				From Fig. 6-11	Col. 7 plus Col. 9	From Fig. 6-15	Col. 10 x Col. 11 / 100	From Col. 6 & Fig. 6-16	From Fig. 6-10	100 plus Col. 14	Col. 13 times Col. 15	Col. 12 plus Col. 16	At junction	
No. of br. or main	Dia. duct in in.	Area duct sq. ft	Air volume CFM in branch	Air volume CFM in main	Vel. in FPM	Length of duct in feet: straight runs	Number of: elbows	entries	equiv. length	total length	Resistance in inches water gauge: per 100	of run	one VP	entry loss (VP)	hood suct. (VP)	Resistance in inches of water: hood suct.	static press.	gov. SP	corrected CFM
1-A	Slots	10.0	9600		960								.06	1.78	--	.11			
	22	2.64			3635	13	90°		36	49	.70	.34	.82	.25	1.25	1.02	1.47		
2-B	7	.267	960		3590	3	60°	30°	12	15	2.8	.42	.80	.25	1.25	1.00	1.42	1.65	1030
3-B	6	.196	700		3570	4	90+60°	30°	16	20	3.3	.66	.79	.25	1.25	.99	1.65		
Branches 2 and 3 are within 15% of balance at "B". Air volume in 2 will increase: Q = 960 $\sqrt{1.65/1.42}$ = 1030 cfm																			
B-A	9	.442	1730		3920	18	2-90°	30°	32	50	2.5	1.25+.09	.96				2.99	3.22	1790
Velocity pressure in B-A is higher than Branch 2 or 3. See text. $VP_{2-3} = \frac{(Q_2+Q_3)^2}{[4005(A_2+A_3)]^2} = \frac{(1030+700)^2}{[4005(.267x.196)]^2} = 0.87$ Increase = .96 - .87 = .09"																			
At jct A, branch B-A requires 2.99" SP; branch 1-A requires 1.47". Refigure 1-A.																			
1-A	Slots	10.0	9600		960								.06	1.78	--	.11			
	18	1.77			5420	13	90°		28	41	2.0	.82	1.83	.25	1.25	2.29	3.22		
Branches 1-A and B-A are within 8% of balance at "A". Air volume in B-A will increase: Q = 1730 $\sqrt{3.22/2.99}$ = 1790 cfm																			
A-C	24	3.14		11390	3625	34				34	.62	.21					3.43		
7a-D	5	.136	500		3670	5				5	4.5	.23	.84	1.8	2.0	1.68	1.91		
5-D	6	.196	700		3570	7	90°	30°	12	19	3.3	.63	.79	.25	1.25	.99	1.62	1.91	760
Branches 5 and 7a are within 18% of balance at "D". Air volume in 5 will increase: Q = 700 $\sqrt{1.91/1.62}$ = 760 cfm																			
D-C	8	.349	1260		3610	14	90+60°	30°	24	38	2.5	.95					2.86	3.43	1380
Branches D-C and A-C are within 20% of balance at jct "C". Air volume in D-C will increase: Q = 1260 $\sqrt{3.43/2.86}$ = 1380 cfm																			
C-E	26	3.69		12770	3460	6.5				6.5	.60	.04					3.47		
8-F	8	.349	1200		3440	11	2-90°		20	31	2.2	.68	.74	.50	1.50	1.11	1.79	1.86	OK*
9-F	5	.136	500		3670	4	90+60°	30°	14	18	4.5	.81	.84	.25	1.25	1.05	1.86		
* Actually Q will increase slightly and duct velocity in branch 8 will be: 1225 / .349 = 3500 fpm																			
F-G	9	.442	1725		3900	5				5	2.4	.12 + .16	.95			2.14			
Velocity pressure in F-G is higher than branch 8 or 9. See text. $VP_{8-9} = \frac{(Q_8+Q_9)^2}{[4005(A_8+A_9)]^2} = \frac{(1725)^2}{(4005x.485)^2} = .79"$ Increase = .95 - .79 = .16"																			
7b-G	5	.136	500		3670	15	60°	30°	8	23	4.5	1.04	.84	1.0	2.0	1.68	2.72	2.82	OK
At jct G, branch F-G requires 2.15" SP, branch 7b-G requires 2.72" SP. Refigure F-G.																			
F-G	8	.349	1725		4940	5				5	4.5	.23 + .73	1.52				2.82		
Velocity pressure in F-G is higher than branch 8 or 9. Increase = 1.52" - VP_{8-9} = 1.52 - .79 = .73																			
G-E	10	.545	2225		4090	6	60°	30°	19	25	2.3	.58	1.04				3.40	3.47	OK
E-H	28	4.28		14995	3500	3.5				3.5	.50	.02					3.49		
10-J	8	.349	1225		3500	6	45°		5	11	2.3	.25	.76	.25	1.25	.95	1.20		
12-J	6	.196	900		4590	2.5	30°	30°	7	9.5	5.5	.52	1.31	.25	1.25	1.64	2.16		
At jct "J" branch 12-J requires 2.16" SP, branch 10-J requires 1.20". Refigure 10-J.																			
10-J	7	.267	1225		4590	6	45°		4.5	10.5	4.4	.46	1.26	.25	1.25	1.58	2.04	2.16	1260
Branches 10 and 12 are within 6% of balance. Air volume in branch 10 will increase: Q = 1225 $\sqrt{2.16/2.04}$ = 1260 cfm																			
J-H	10	.545	2160		3960	8	90+60°	30°	32	40	2.1	.84	.98				3.00	3.49	2320
At jct "H" branch J-H and main E-H are within 17% of balance. Air volume in J-H will increase: Q = 2160 $\sqrt{3.49/3.00}$ = 2330 cfm																			
H-K	30	4.91		17325	3530	9	2-45°			51	60	.45	.27				3.76		
13	Collector resistance, including fan inlet.											4.5					8.26		
14	Backward curved fan. Inlet = 35½ I.D. Outlet = 5.15 ft².																		
Inlet	35½	6.87		17325	2520								.40						
L	32	5.59		17325	3100	20				20	.33	.07					8.33		
Fan SP = SPout - SPin - VPin = 0.07" - (-8.26") - 0.40" = 8.33" - 0.40" = 7.93"																			

Calculated fan characteristics for standard conditions		Corrected for temperature and elevation	
Capacity( ) 17325 CFM	Fan, type and size	RPM CFM	Motor
Fan TP in WG		BHP TP	V Belt
Fan SP 8"	RPM BHP	SP	

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Figure 6-4
Blast Gate Design
Method 8

Equivalent Foot Method
Calculation Sheet

Committee on Industrial Ventilation
P O Box 453
Lansing, Michigan 48902

Plant name PROBLEM 2 | Refer to Figure 6-2 | Elevation | Factor | Remarks
Location | | Temperature
Department FOUNDRY

1	2	3	4	5	6	7	8		9	10	11	12	13	14	15	16	17	18	19
					From Section 5				From Fig. 6-11	Col. 7 plus Col. 9	From Fig. 6-15	Col. 10 × Col. 11 / 100	From Col. 6 & Fig. 6-16	From Fig. 6-10	100 plus Col. 14	Col. 13 times Col. 15	Col. 12 plus Col. 16	At junction	
			Air volume CFM			Length of duct in feet					Resistance in inches water gauge					Resistance in inches of water			
No. of br. or main	Dia. duct in in.	Area duct sq. ft.	in branch	in main	Vel. in FPM	straight runs	Number of elbows	entries	equiv. length	total length	per 100	of run	one VP	entry loss (VP)	hood suct (VP)	hood suct	static press.	gov. SP	corrected CFM
1-A	Slots	10.0	9600		960								.06	1.78	--	.11			
	22	2.64			3635	13	90°		36	49	.70	.34	.82	.25	1.25	1.02	1.47	2.75	Gate
2-B	7	.267	960		3590	3	60°	30°	12	15	2.8	.42	.80	.25	1.25	1.00	1.42	1.65	Gate
3-B	6	.196	700		3570	4	90+60°	30°	16	20	3.3	.66	.79	.25	1.25	.99	1.65		Gate
B-A	9	.442	1660		3750	18	2-90°	30°	32	50	2.2	1.10	.88				2.75		
A-C	24	3.14		11260	3580	34				34	.61	.21					2.96		
7a-D	5	.136	500		3670	5				5	4.5	.23	.84	1.0	2.0	1.68	1.91		Gate
5-D	6	.196	700		3570	7	90°	30°	12	19	3.3	.63	.79	.25	1.25	.99	1.62	1.91	Gate
D-C	8	.349	1200		3440														
Increase air volume in 5-D to give minimum transport velocity in D-C.																			
D-C	8	.349	1225		3500	14	90+60°	30°	24	38	2.3	.87					2.78	2.96	
C-E	24	3.14		12485	3980	6.5				6.5	.75	.05 + .20	.99				3.21	3.30	
Velocity pressure in C-E is higher than Branch A-C or D-C. See text. $VP_{A-C} = \frac{(Q_A+Q_C)^2}{[4005(A_A+A_C)]^2} = \frac{(11260+1200)^2}{(4005\times3.489)^2} = .79$ Increase = .99 - .79 = .20"																			
8-F	8	.349	1200		3440														
Increase Q to 1225 to maintain minimum transport velocity.																			
8-F	8	.349	1225		3500	11	2-90°		20	31	2.3	.71	.76	.50	1.50	1.14	1.85	1.86	Gate
9-F	5	.136	500		3670	4	90+60°	30°	14	18	4.5	.81	.84	.25	1.25	1.05	1.86		Gate
F-G	9	.442	1725		3900	5				5	2.4	.12 + .16	.95				2.14	2.72	
Velocity pressure in F-G is higher than branch 8 and 9. See text. $VP_{8-9} = \frac{(Q_8+Q_9)^2}{[4005(A_8+A_9)]^2} = \frac{(1725)^2}{(4005\times.485)^2} = .79"$ Increase = .95 - .79 = .16"																			
7b-G	5	.136	500		3670	15	60°	30°	8	23	4.5	1.04	.84	1.0	2.0	1.68	2.72		Gate
G-E	10	.545	2225		4090	6	60°	30°	19	25	2.3	.58	1.04				3.30		
E-H	26	3.69		14710	3990	3.5				3.5	.69	.02	.99				3.32		
10-J	8	.349	1225		3500	6	45°		5	11	2.3	.25	.76	.25	1.25	.95	1.20	2.16	Gate
12-J	6	.196	900		4590	2.5	30°	30°	7	9.5	5.5	.52	1.31	.25	1.25	1.64	2.16		Gate
J-H	10	.545	2125		3900	8	90+60°	30°	32	40	2.0	.80					2.96	3.32	
H-K	30	4.91		16835	3430														
Increase air volume at selected hoods to maintain minimum transport velocity.																			
H-K	30	4.91		17200	3500	9	2-45°		51	60	.45	.27					3.59		
13	Collector resistance, including fan inlet.											4.5					8.09		
14	Backward curved fan, inlet = 35½" I.D., outlet = 5.15 ft²																		
Inlet	35½	6.87		17200	2500								.39						
L	32	5.59		17200	3080	20				20	.33	.07					8.16		
All blast gates to be locked in place after system is balanced.																			
Fan SP = SPout - SPin - VPin = 0.07" - (-8.09") - 0.39" = 8.16" - 0.39" = 7.77"																			

Calculated fan characteristics for standard conditions		Corrected for temperature and elevation	
Capacity( ) 17,200 CFM	Fan, type and size	RPM CFM	Motor
Fan TP in WG		BHP TP	V Belt
Fan SP 7-3/4"	RPM BHP	SP	

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Corrections for Velocity Changes

Variations in duct velocity occur at many locations in exhaust systems because of the necessary limitations of available standard duct sizes (areas) or due to duct selections based on balanced system design. As noted earlier, small accelerations and decelerations are usually compensated automatically in the system where good design practices and proper fittings are used. There are times, however, when special circumstances require the designer to have a knowledge of the energy losses and regains which occur since these may work to his advantage or disadvantage in the final performance of the system.

Branch Entries to Main Ducts: Sometimes the final main duct velocity exceeds the higher of the two velocities in the branches entering the main. If the difference is great, additional SP is needed to produce the increased velocity. A difference of 0.10" or greater between the main VP and the resultant VP from the two branches should be corrected.

Correction is made by first computing the resultant velocity pressure (VP_r), corresponding to a pseudo velocity of the two volumes of air entering the junction. This is accomplished by applying the basic velocity pressure equation, $VP = \left(\frac{V}{4005}\right)^2$, using the total of the two air flows and the total of the two duct areas:

$$\text{Equation \#1} \quad VP_r = \left[\frac{Q_1 + Q_2}{4005(A_1 + A_2)}\right]^2$$

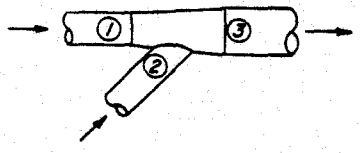
Where VP_r = resultant velocity pressure at the combined branch air volumes
Q_1 = cfm in branch #1
Q_2 = cfm in branch #2
A_1 = area of branch duct #1
A_2 = area of branch duct #2

It is assumed that branches #1 and #2 are balanced at the junction so that $SP_1 = SP_2$. If VP_3 is greater than VP_r, the difference between VP_3 and VP_r is the necessary SP required to produce the increase in kinetic energy between VP_3 and VP_r. The correction is made as follows:

$$\text{Equation \#2} \quad SP_3 = SP_1 + (VP_3 - VP_r) \text{ (algebraic values of SP are negative)}$$

Where SP_3 = SP in main #3
SP_1 = SP at branch #1 = SP at branch #2
VP_3 = Velocity pressure in main.

Example 1



Duct No.	Dia.	Area	Q	V	VP	SP
(1)	10	0.545	1935	3550	0.79	-2.11
(2)	4	0.087	340	3890	0.94	-2.11
Main (3)	10	0.545	2275	4170	1.08	—

$$VP_r = \frac{(Q_1 + Q_2)^2}{\left[4005\,(A_1 + A_2)\right]^2} = \frac{(1935 + 340)^2}{\left[4005\,(0.545 + 0.087)\right]^2}$$

$$= \frac{(2275)^2}{(4005 \times 0.632)^2} = 0.81"$$

$$SP_3 = SP_1 + (VP_r - VP_3) = -2.11 + (0.81 - 1.08) = -2.11 - 0.27$$

SP_1 = -2.38" (corrected SP to provide for increased velocity)

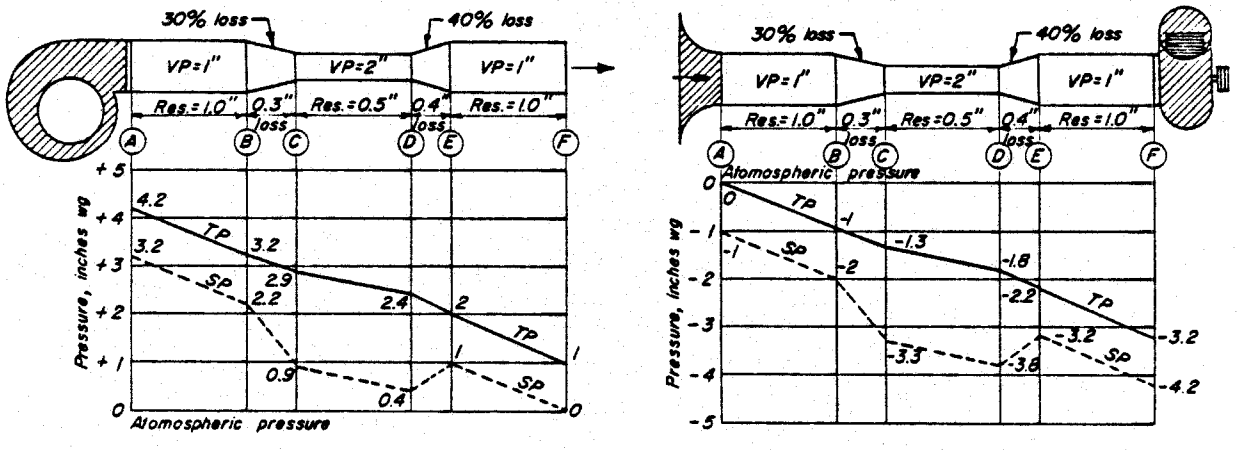
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Duct Contractions and Enlargements: Duct contractions are used where it is necessary to reduce the size of the pipe to fit into tight places, to fit equipment or to provide a high discharge velocity at the end of the stack. Duct enlargements are used to fit a particular piece of equipment or to reduce the energy consumed in the system by reducing velocity and friction. Enlargements are not desirable in transport systems since the duct velocity may become less than the minimum transport velocity and material may settle in the ducts.

Regain of pressure in a duct system is possible because static pressure and velocity pressure are mutually convertible. This conversion is accompanied by some energy loss, the amount of this loss being a function of the geometry of the transition piece (the more abrupt the change in velocity, the greater the loss) and depends on whether air is accelerated or decelerated. Loss is expressed as a percentage of difference between velocity pressure in the entrance and the exit of the transition piece. One minus the loss, expressed as a decimal fraction, is the efficiency of the energy conversion or regain.

A perfect contraction or enlargement (no loss) would cause no change in the Total Pressure in the duct. There would be an increase (decrease) in Static Pressure corresponding exactly to the decrease (increase) in Velocity Pressure of the air. In practice, the enlargement or contraction will not be perfect and there will be a change in Total Pressure. See Examples 2 and 3. In each example, total pressure and static pressure are plotted in order to show their relationship at various points in each system.



Example 2—Ductwork located on discharge side of fan. Velocity changes as indicated.

Example 3—Ductwork located on suction side of fan. Velocity changes as indicated.

Fig. 6-5

From the sketch, the ductwork is located all on the discharge side of the fan. Total pressure at the fan discharge (point A) is equal to the velocity pressure at the discharge end of the duct (point F) plus the accumulated resistances. These add up to 1.0 + 1.0 + 0.4 + 0.5 + 0.3 + 1.0 = 4.2.

Static pressure regain between D and E follows the regain formulae (Fig. 6-6). If there were no energy loss in the transition piece, static pressure at D would be 0 because the difference in VP of 1 would show up as static pressure regain. However, the transition is only 60% efficient which means a loss of 0.4, so SP at point D = 0 + 0.4 = 0.4.

Conversion of static pressure into velocity pressure between B and C follows contraction formulae (Fig. 6-6). There must be sufficient static pressure at B to furnish the additional velocity pressure required at C. In addition, transformation of energy between these two points is accompanied by a loss of 0.3. Since SP at C equals 0.9, SP at B = 0.9 + 0.3 + 1.0 = 2.2. Since there is no ductwork on the suction side of the fan, total pressure against which the fan is operating is 4.2".

Since all the ductwork is on the suction side of the fan, SP at the fan inlet (point F) is equal to VP at the fan inlet plus the total duct resistance up to that point. This equals -4.2 SP since static pressure on the suction side of the fan is always negative. The duct system is the same as was used in Example 2 and therefore has the same overall resistance of 3.2. If it is again assumed that the inlet and discharge of the fan are of equal areas, the total pressure across the fan will be the same as in Example 1 and in each case the fan will deliver the same air horsepower when handling equal volumes of air.

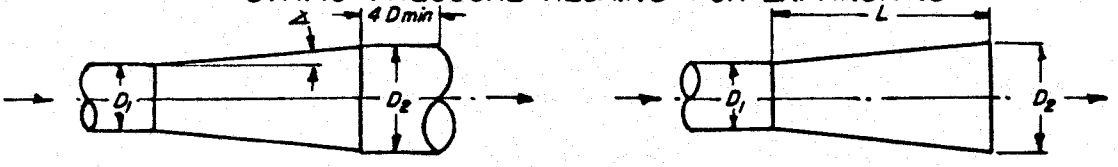
Static pressure conversion between B and C follows contraction formulae (Fig. 6-6). There must be sufficient SP at B to furnish the additional VP required at C. In addition, the energy transfer between these two points is accompanied by a loss of 0.3. Since SP at B = -2, SP at C = -2.0 + (-1.0) + (-0.3) = -3.3.

Static pressure regain between D and E follows the regain formulae (Fig. 6-6). If there were no loss in the transition piece, the difference of 1 in velocity pressure would all be regained as static pressure at E and SP at that point would be -2.8. However, the transition is only 60% efficient (0.4 loss) so the SP at E = -2.8 + (-0.4) = -3.2.

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STATIC PRESSURE REGAINS FOR EXPANSIONS



Within duct

Regain (R), fraction of VP difference					
Taper angle degrees	Diameter ratios D_2/D_1 1.25:1	1.5:1	1.75:1	2:1	2.5:1
3 1/2	0.92	0.88	0.84	0.81	0.75
5	0.88	0.84	0.80	0.76	0.68
10	0.85	0.76	0.70	0.63	0.53
15	0.83	0.70	0.62	0.55	0.43
20	0.81	0.67	0.57	0.48	0.43
25	0.80	0.65	0.53	0.44	0.28
30	0.79	0.63	0.51	0.41	0.25
Abrupt 90	0.77	0.62	0.50	0.40	0.25
Where: $SP_2 = SP_1 + R(VP_1 - VP_2)$					

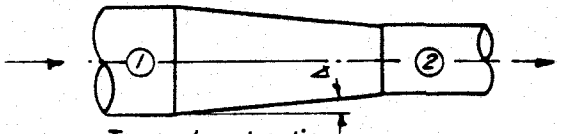
At end of duct

Regain (R), fraction of inlet VP						
Taper length to inlet diam L/D	Diameter ratios D_2/D_1 1.2:1	1.3:1	1.4:1	1.5:1	1.6:1	1.7:1
1.0:1	0.37	0.39	0.38	0.35	0.31	0.27
1.5:1	0.39	0.46	0.47	0.46	0.44	0.41
2.0:1	0.42	0.49	0.52	0.52	0.51	0.49
3.0:1	0.44	0.52	0.57	0.59	0.60	0.59
4.0:1	0.45	0.55	0.60	0.63	0.63	0.64
5.0:1	0.47	0.56	0.62	0.65	0.66	0.68
7.5:1	0.48	0.58	0.64	0.68	0.70	0.72
Where: $SP_1 = SP_2 - R(VP_1)$*						

*When SP_2=0 (atmosphere) SP_1 will be (-)

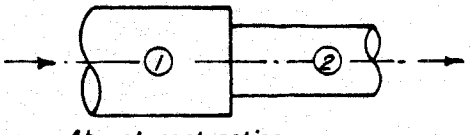
The regain (R) will only be 70% of value shown above when expansion follows a disturbance or elbow (including a fan) by less than 5 duct diameters.

STATIC PRESSURE LOSSES FOR CONTRACTIONS



Tapered contraction
$SP_2 = SP_1 - (VP_2 - VP_1) - L(VP_2 - VP_1)$

Taper angle degrees	L(loss)
5	0.05
10	0.06
15	0.08
20	0.10
25	0.11
30	0.13
45	0.20
60	0.30
over 60	Abrupt contraction



Abrupt contraction
$SP_2 = SP_1 - (VP_2 - VP_1) - K(VP_2)$

Ratio A_2/A_1	K
0.1	0.48
0.2	0.46
0.3	0.42
0.4	0.37
0.5	0.32
0.6	0.26
0.7	0.20

A = duct area, sq ft

Note:
In calculating SP for expansion or contraction use algebraic signs:
VP is (+)
and usually
SP is (+) in discharge duct from fan
SP is (-) in inlet duct to fan

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DUCTWORK DESIGN DATA

DATE 1-72 | Fig. 6-6

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Corrections for Different Duct Materials

The friction loss charts, Figures 6-15A, 6-15B and 6-17, provide average values for clean, round galvanized metal ducts having approximately 40 joints per 100 feet based on the flow of standard air of 0.075 pounds per cubic foot density. The values obtained may be used with no significant error for the majority of designs; occasionally, however, more precise calculations of duct friction are required.

Figure 6-14 presents correction factors depending on duct smoothness, size and velocity. These are applied directly to the values obtained from Figures 6-15A, 6-15B and 6-17.

Example 4: 4" diameter duct; 4500 fpm; 390 cfm. "Average" friction (Fig. 6-15A) = 8.5"/100'. Special construction: 10' duct lengths, welded and polished longitudinal seam. From Fig. 6-14, consider as medium smooth, 5" duct is closest. Factor = 0.85. Actual friction = 0.85 × 8.5"/100' = 7.2"/100'.

In addition to Figure 6-14, various manufacturers have developed data for special duct materials including transite, non-metallic flexible ducts and metallic flexible ducts. These values should be obtained from the manufacturer when precise calculations are required.

Friction Loss in Non-Circular Ducts

Round ducts are preferred for industrial exhaust systems because of a more uniform air velocity to resist settling of material and an ability to withstand higher static pressure. At times, however, the designer must use other duct shapes.

Rectangular duct friction can be calculated by using the friction charts, Figures 6-15A, 6-15B and 6-17, in conjunction with Figure 6-24 to obtain rectangular equivalents for circular ducts on the basis of equal friction loss per 100 feet. It should be noted that on this basis, the area of the rectangular duct will be larger than the equivalent round duct; consequently, the actual air velocity in the duct will be reduced. Therefore, it is necessary to use care to maintain minimum transport velocities.

Occasionally the designer will find it necessary to estimate the air-handling ability of odd-shaped ducts. The following procedure will be helpful in determining the frictional resistance and actual velocity of air flow. To illustrate the method, an example and table have been developed for triangular ducts of equilateral cross-section; tables of data for other duct shapes can be developed easily. (Reference 85)

Procedure

1. Find duct cross-sectional area, ft^2 . . . . . A
2. Find wetted perimeter, ft . . . . . P
3. Calculate hydraulic radius, ft . . . . . $R(R = \frac{A}{P})$
4. Convert R to inches . . . . . r(r = 12R)
5. Calculate equivalent diameter, in . . . . . D(D = 4r)
6. Use standard friction chart, Figure 6-15

Example 5

Duct shape: Equilateral triangle; Q = 1,000 cfm STP
Allowable friction = 0.1"/100'
Find: Duct size
Actual velocity

a. From friction chart, find round pipe size = 14" equivalent diameter for 0.1" friction loss.
b. Hydraulic radius, $r = \frac{D}{4} = 3.5"$
c. From Table 6-1, select 24" equilateral triangle
d. Actual velocity = Q ÷ A = 1,000 ÷ 1.731 = 578 fpm

TABLE 6-1 Equilateral Triangle A△C (B)

Side of Triangle (A,B,C) inches	Area, ft^2 A, ft^2	Perimeter, P, Feet	Hydraulic Radius		Equivalent Diameter D, inches
			Feet	Inches	
6	0.108	1.5	0.0722	0.87	3.45
8	0.193	2.0	0.0965	1.16	4.6
10	0.301	2.5	0.122	1.44	5.75
12	0.433	3.0	0.144	1.73	6.9
14	0.0589	3.5	0.168	2.0	8.0
16	0.770	4.0	0.192	2.3	9.2
18	0.973	4.5	0.216	2.6	10.4
20	1.201	5.0	0.240	2.87	11.45
22	1.455	5.5	0.264	3.17	12.68
24	1.731	6.0	0.289	3.45	13.88

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Corrections for Temperature, Moisture and Elevations

Fan tables, exhaust volume requirements and resistance charts assume standard atmospheric conditions. These assumptions fix the air density at 0.075 pounds per cubic foot. Where appreciable variation occurs the change in air density must be considered. Factors for increased temperatures and increased elevations are listed in the Density Correction Factor Table on Figure 6-14. As noted, correction for temperatures between 40 F and 100 F and/or elevations between -1000 feet and +1000 feet are seldom required with the permissible variations in usual exhaust system design. It is helpful to remember that a centrifugal exhauster connected to a given system will exhaust the same VOLUME regardless of air density. The pounds of air moved, however, will be a function of the density, as will the pressure developed and horsepower consumed.

Variable Temperature and/or Different Elevation—Normal Moisture: Assume an exhauster connected to a given system and capable of moving 10,000 cfm of standard air through that system. If the standard air entering the exhaust hoods was subsequently heated to 600 F before entering the exhauster, the volume would be 10,000 cfm at 600 F. The volume at this temperature would contract to 5,000 cfm at 70 F, reducing the inflow of air to the hoods to 50 per cent of the original volume.

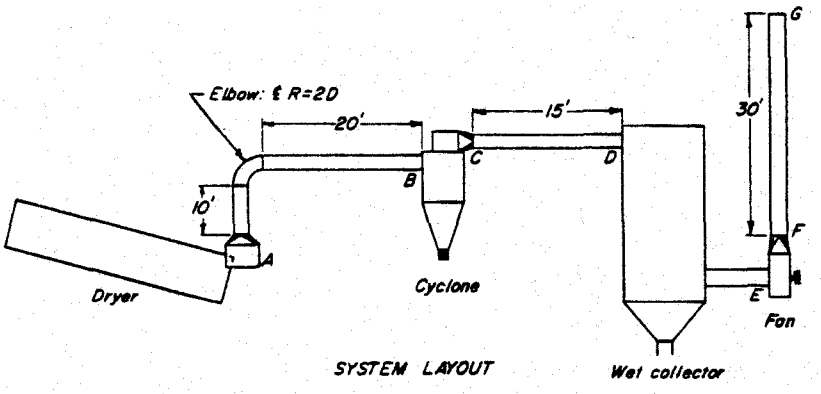
In like manner, move the exhaust system handling standard air from sea level to an elevation of 5,500 feet above sea level. The exhauster would still handle 10,000 cfm but the pounds of air would be reduced to 81 per cent of the weight of standard air.

Where high temperatures or elevations are encountered, corrections from standard air data can be made as follows:

Increase exhaust volumes by reciprocal of density factor to keep the same pounds of air as those for standard conditions moving into the hood to prevent dust escaping. Size branch and main ducts, calculate pressure losses and select fan as if corrected volumes were for standard air. This procedure will arrive at the correct size of fan and RPM. Horsepower and pressure losses throughout the system will decrease directly as the density factor.

—Elevated Moisture: When air temperature is under 100 F, no correction for humidity is necessary. When air temperature exceeds 100 F and moisture content is greater than 0.02# H_2O per pound of dry air, correction is required to determine fan operating RPM and horsepower. Correction factors may be read from the psychrometric charts, Section 13. The following example illustrates the effect of elevated moisture and temperature and the method of calculation:

Example 6:



Given: The exit volume from a 60" x 24' dryer is 16,000 scfm plus removed moisture. Exhaust air temperature is 500 F. The dryer delivers 60 tons/hr of dried material with capacity to remove 5% moisture. Required suction at the dryer hood is -2.0" wg; minimum conveying velocity must be 4000 fpm.

It has been determined that the air pollution control system should include a cyclone for dry product recovery and a high energy wet collector. These devices have the following operating characteristics:

Cyclone: Pressure drop is 4.5" wg at rated volume of 35,000 scfm. As with all cyclones, pressure drop across cyclone varies directly with density and as the square of volume handled.

High Energy Wet Scrubber: The manufacturer has determined that a pressure drop of 20" wg is required in order to meet existing air pollution regulations and has sized the collector accordingly. The humidifying efficiency of the wet collector is 90%.

Fan: A size #34 "XYZ" fan with the following performance rating has been recommended.

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Fan size Nº 34					*Inlet diameter = 34"*														*Max. safe rpm = 1700*			
CFM VOLUME	20" SP		22" SP		24" SP		26" SP		28" SP		30" SP		32" SP		34" SP		36" SP		38" SP		40" SP	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
14688	1171	73.3	1225	81.4	1277	89.8	1326	98.3	1374	107	1421	116	1466	125	1510	134	1552	143	1594	153	1634	162
16524	1181	81.8	1234	90.2	1286	98.8	1335	107	1382	116	1428	126	1472	135	1516	145	1557	155	1600	165	1639	175
18360	1191	90.2	1244	99.5	1294	108	1344	118	1391	127	1437	137	1481	146	1524	157	1565	167	1606	178	1645	188
20196	1204	99.9	1256	109	1306	119	1354	129	1400	139	1446	149	1490	160	1532	170	1574	181	1615	191	1654	202
22032	1217	110	1268	120	1318	130	1366	141	1412	151	1456	162	1499	173	1542	184	1584	196	1624	207	1663	218
23868	1230	120	1282	131	1331	142	1378	154	1424	165	1468	176	1511	187	1553	199	1594	211	1633	223	1672	235
25704	1245	131	1296	143	1345	155	1391	167	1437	179	1481	191	1524	203	1565	215	1606	227	1645	239	1683	252
27540	1261	143	1311	156	1359	168	1406	181	1450	193	1494	206	1537	219	1578	232	1618	245	1658	258	1695	271
29376	1277	156	1327	169	1374	182	1421	196	1465	209	1508	222	1550	236	1591	249	1631	263	1670	277		
31212	1295	170	1344	184	1391	197	1436	211	1480	225	1523	239	1564	253	1605	268	1644	282	1683	297		
33048	1313	184	1361	198	1407	213	1453	228	1496	242	1538	257	1580	272	1620	287	1659	302	1697	317		
34864	1331	198	1379	214	1425	229	1469	245	1513	260	1555	276	1595	291	1635	307	1674	323				

Required: Size the ductwork and select fan RPM and motor size.

Solution:

Step 1. Find the actual gas volume that must be exhausted from the dryer. This volume must include both the air used for drying and the water, as vapor, which has been removed from the product. Since it is actual volume, it must be corrected to represent temperature and pressure which exist in the duct.

Step 1A. Find the amount (weight) of water vapor exhausted.

Dryer Discharge = 60 tons/hr of dried material (given)
Since the dryer has capacity to remove 5% moisture

Dryer Discharge = (0.95) (dryer feed)

60 tons/hr dried material = (0.95) (dryer feed)

$$\text{dryer feed} = \frac{60 \text{ tons/hr}}{0.95} = 63.2 \text{ tons/hr}$$

Moisture removed = (feed rate) - (discharge rate)
= 63.2 tons/hr - 60 tons/hr
= 6400 lbs/hr or 106.6 lbs/min

Step 1B. Find the amount (weight) of dry air exhausted.

Dry air exhausted = 16,000 scfm 70 F and 29.92" Hg (given)
Dry air at 70 F and 29.92" Hg weighs 0.075 lbs/cu ft (page XI)

Exhaust rate, lbs/min = (16,000 scfm) (0.075 lbs/cu ft)
= 1200 lbs/min dry air

Step 1C. Knowing the water to dry air ratio and the temperature of the mixture, it is possible to determine other qualities of the air to water mixture. This can be accomplished by the use of the Psychrometric Chart (see Appendix) which is a most useful tool when working with humid air.

$$\frac{\text{lbs of water}}{\text{lbs of dry air}} = \frac{106.6 \text{ lbs } H_2O/\text{min}}{1200 \text{ lbs dry air/min}} = 0.089 \text{ lbs } H_2O/\text{lbs dry air}$$

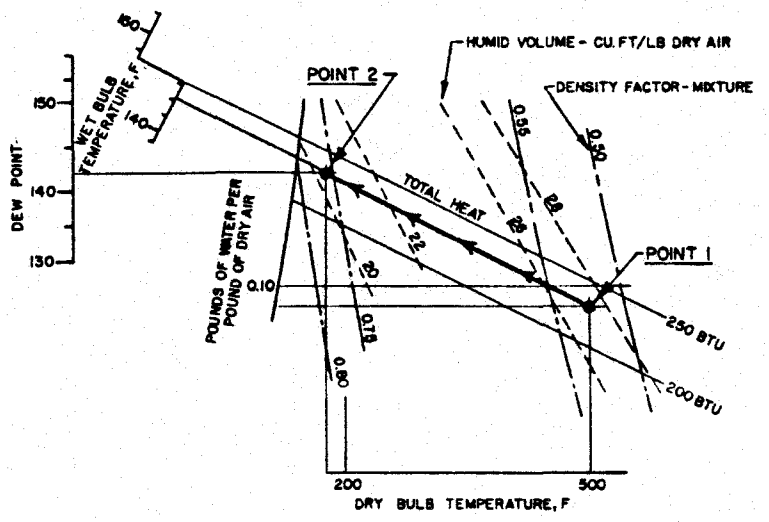
Dry bulb temperature = 500 F (given)

The intersection of the 500 F dry bulb temperature line and the 0.089 lbs H_2O/lb dry air line can be located on the Psychrometric Chart. This point, Point #1, completely defines the quality of the air and water mixture. Other data relative to this specific mixture can be read as follows:

Dew Point, F	122 F
Wet Bulb Temperature	145 F
Humid volume, cu ft/lb of dry air	27.5 cu ft/lb dry air
Enthalpy, BTU/lb of dry air	235 BTU/lb dry air
Density factor, d	0.53

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PSYCHROMETRIC CHART FOR HUMID AIR
(See Appendix, page 13-16)

Step 1D. Find actual gas volume, acfm

Exhaust Volume, acfm = (humid volume) (weight of dry air/min)
Humid volume, hv, was found in Step 1C as 27.5 cu ft/lb
Weight of dry air/min was found in Step 1B as 1200 lb/min

Exhaust volume, acfm = (27.5 cu ft/lb) (1200 lb/min) = 33,000 acfm

Step 2. The first line of the calculation sheet can now be completed. Minimum conveying velocity of 4000 fpm was given. Suction at the dryer of -2.0" wg corresponds to hood suction.

Step 3. Calculate resistance from A to B and determine static pressure at Point B (see second line of calculation sheet).

It is noted on Figures 6-15 and 6-16B that the loss is based on standard air with a density factor of one (1.0). Pressure loss varies directly with the density and must, therefore, be corrected to represent actual pressure loss at actual air density. Density factor was determined in Step 1C.

Step 4. The pressure loss of the cyclone is calculated on the third line of the calculation sheet. As advised by the cyclone manufacturer, the cyclone pressure loss is 4.5" at rated flow of 35,000 scfm. The pressure loss through cyclone, as with ductwork, varies as the square of the volume and directly with density.

Step 5. The calculation from Point C to D is the same as from A to B in Step 3.

Step 6. An important characteristic of wet collectors is their ability to humidify a gas stream. The humidification process is generally assumed to be adiabatic or without gain or loss of heat to the surroundings. Therefore, water vapor is added to the mixture but the enthalpy, BTU/lb dry air, remains unchanged. During the humidification process the point on the Psychrometric Chart that describes the mixture moves to the left, along a line of constant enthalpy, toward saturation where no more water vapor can be added.

All wet collectors do not have the same ability to humidify. If a collector is capable of taking an air stream to complete adiabatic saturation, it is said to have a humidifying efficiency of 100%. The efficiency of a given device to humidify may be expressed by either of the following equations:

$$\text{Humidifying Efficiency, \%} = \frac{(t_i - t_o) \times 100}{(t_i - t_s)}$$

where t_i = dry bulb temperature at collector inlet

t_o = dry bulb temperature at collector outlet

t_s = adiabatic saturation temperature

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or

$$\text{Humidifying Efficiency, \%} = \frac{W_i - W_o}{W_i - W_s}$$

where W_i = weight of H_2O, in H_2O/lb dry air at inlet

W_o = weight of H_2O, in H_2O/lb dry air at outlet

W_s = weight of H_2O, in H_2O/lb dry air at adiabatic saturation condition

Step 6A. Find the quality of the air to water mixture at Point 2, the collector outlet.

Humidifying Efficiency = 90% (given)
Dry Bulb Temperature at Collector Inlet = 500 F (given)

Adiabatic saturation temperature = 145 F from inspection of Psychrometric Chart

$$90 = \frac{(500 - t_o)}{(500 - 145)} \times 100$$

$$t_o = 180 \text{ F}$$

Then the air leaving the collector will have a dry bulb temperature of 180 F and an enthalpy of 235 BTU/lb of dry air as the humidifying process does not change the total heat or enthalpy.

The intersection, on the Psychrometric Chart, of 180 F dry bulb and 235 BTU/lb dry air defines the quality of the air leaving the collector and allows other data to be read from the chart as follows:

Dew Point Temperature, F	143 F
Wet Bulb Temperature, F	145 F
Humid Volume, cu ft/lb dry air	20.5 cu ft/lb dry air
Enthalpy, BTU/lb dry air	235 BTU/lb dry air
Density Factor, d	0.76

Step 7. What is exhaust volume, acfm, and density factor, d, at collector outlet?

Step 7A. Exhaust Volume, acfm = (humid volume) (weight of dry air/min)
Humid Volume from Step 6 is 20.5 cu ft/lb dry air
Weight of dry air/min from Step 1B is 1200 lbs/min
Volume = (20.5 cu ft/lb) (1200 lbs/min)
= 24,6000 acfm

Line DE can now be completed on the calculation sheet.

Step 7B. On low pressure exhaust systems, where the negative pressure at the fan inlet is less than 20" wg, the effect of the negative pressure is usually ignored. However, as pressures decrease, or the magnitude of negative pressures increase, it is understood that gases expand to occupy a larger volume. Unless this larger volume is anticipated and the fan sized to handle the larger volume, it will have the effect of reducing the amount of air that is pulled into the hood at the beginning of the system. From characteristic equation PQ = WRT, the pressure volume relationship of $P_1 Q_1 = P_2 Q_2$ or $\frac{P_1}{P_2} = \frac{Q_2}{Q_1}$ has been derived.

Up to this point the air has been considered to be at standard atmospheric pressure which is 14.7 PSI, 29.92" Hg or 407" wg. The pressure within the duct at Point E is -24.4" wg and minus or negative only in relation to the pressure outside the duct which is 407" wg. Therefore, the absolute pressure within the duct is 407" wg - 24.4" wg = 382.6" wg.

$$\frac{407\text{" wg}}{382.6\text{" wg}} = \frac{Q_2}{24{,}600 \text{ acfm}}$$

$$Q_2 = 26{,}200 \text{ acfm}$$

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Step 7C. Pressure also affects the density of the air. From PQ = WRT the relationship $\frac{P_1}{P_2} = \frac{W_1}{W_2}$ can be derived. W, if expressed as density, lb/cu ft is directly proportional to the density factor and the equation can be re-written $\frac{P_1}{P_2} = \frac{d_1}{d_2}$.

$$\text{Substitute } \frac{407}{382.6} = \frac{0.76}{d} \quad \text{(d was determined to be 0.76 in Step 6)}$$

$$d = 0.71$$

Step 8. Calculate the resistance from fan discharge F to stack discharge G (see calculation sheet). Again, the resistance must be corrected to represent the actual duct density. Since the air is now on the fan discharge, the pressure is very near atmospheric and both volume and density factor are what they were before the correction for negative pressure.

Step 9. Determine actual fan static pressure.

Step 10. Determine equivalent fan static pressure in order to enter fan rating table. Equivalent fan static pressure is determined by dividing actual fan static pressure by the density factor corresponding to density at fan inlet. This is necessary since fan rating tables are based on standard air.

Step 11. Select fan from rating table.

Step 12. Horsepower read from table corresponds to the requirement if density at fan inlet were 0.075 lbs/cu ft. Since actual density is less, operating horsepower is determined by multiplying by density factor. If a damper is installed in the ductwork to prevent overloading of the motor at cold start the motor need only be a 200 HP.

NOTE: Steps 6 and 7 which involve calculation of changes in volume, density, etc., across the wet collector should be provided by the equipment manufacturer.

Equivalent Foot Method
Calculation Sheet

Committee on Industrial Ventilation
P.O. Box 453
Lansing, Michigan 48902

Plant name Dryer Problem
Location
Department

Refer to Elevation
Temperature

Factor

Remarks

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
					From Section 5			From Fig 6-11	Col 7 plus Col 9	From Fig 6-15	Col 10 x Col 11 / 100	From Col 6 & Fig 6-16	From Fig 6-10	100 plus Col 14	Col 13 times Col 15	Col 12 plus Col 16	At junction	
No of br or main	Dia duct in in	Area duct sq ft	Air volume CFM in branch	Air volume CFM in main	Vel in FPM	Length of duct in feet: straight runs	Number of elbows/entries	equiv length	total length	Resistance in inches water gauge: per 100	of run	d	one VP	entry loss (VP)	hood suct (VP)	Resistance in inches of water: hood suct	static press	gov SP	corrected CFM
A	38	7.88		33000	4200								1.10			2.0	2.0	Step #2, #2	
AB	38	7.88		33000	4200	30	1-90°	68	98	0.46	0.47	0.53						Step #3	
			Resistance corrected for density = (0.47) (0.53) = 0.25														2.25		
			VP corrected for density = (1.10) (0.53) =										0.58						
BC		Cyclone		33000							2.12						4.37	Step #4	
CD	38	7.88		33000		15			15	0.48	0.07							Step #5	
			Resistance corrected for density = (0.07) (0.53) =								0.04						4.41		
DE		Wet Collector		24600							20"	0.76					24.41	Step #6, #7a	
		Correct Volume for Negative Pressure, Q_2 = 24,600 $\left(\frac{407}{382.6}\right)$ = 26,200 cfm																Step #7b	
		Correct Density Factor for Negative Pressure = (0.76) $\left(\frac{382.6}{407}\right)$ =										0.71						Step #7c	
Fan	34	6.3		26200	4160		(VP) (d) = (1.09) (0.71)						0.77						
FG	36	7.07		24600	3490				30	0.35	0.11							Step #8	
		Resistance corrected for density = (0.11) (0.76)									0.08	0.76					0.08		
		= 0.08																	
		Actual Fan SP = SPout - SPin - VPin = 0.08" - (-24.41") - 0.77" = 24.49" - 0.77" = 23.72																Step #9	
		Equivalent Fan SP = Actual FSP = 23.7 = 33.4" (d = 0.71)																Step #10	
		Select fan for 26200 cfm (volume at fan inlet) and EFSP of 33.5"																Step #11	
		Interpolation of Rating table yields RPM = 1559, BHP = 217																	
		Operating horsepower = (hp from fan table) (d) = (217 BHP) (0.71) = 154 BHP (hot)																Step #12	

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Air Cleaning Equipment

Dusts, fumes and toxic or corrosive gases should not be discharged to the atmosphere. Each exhaust system handling such materials should be provided with an adequate air cleaner as outlined in Section 11. The exhaust fan should be located on the clean air side of such equipment. An exception is in the use of cyclone cleaners where the hopper discharge is not tightly sealed and better performance is obtained by putting the fan ahead of the collector.

Fan Static Pressure

Exhaust system calculations made on the calculation sheet are based on static pressure; that is, all hood static pressures and balancing or governing pressures at the duct junctions are given as static pressures which can be measured directly as described in Section 9. Most industrial exhauster rating tables are based on Fan Static Pressure which cannot be read directly from the calculation sheet. A simple additional calculation is required to determine Fan Static Pressure before selecting the exhaust fan.

Fan total pressure is the increase in total pressure through or across the fan and can be expressed by the equation:

$$\text{Fan TP} = TP_{\text{outlet}} - TP_{\text{inlet}}$$

The Air Moving and Conditioning Association Test Code (28) defines the Fan Static Pressure as follows: the static pressure of the fan is the total pressure diminished by the fan velocity pressure. The fan velocity pressure is defined as the pressure corresponding to the air velocity at the fan outlet. Fan Static Pressure can be expressed therefore by the equation:

$$\text{Fan SP} = \text{Fan TP} - VP_{\text{Fan Outlet}}$$

$$\text{or} \qquad TP_{\text{outlet}} - TP_{\text{inlet}} - VP_{\text{outlet}}$$

Since TP = SP + VP, the equation can be re-written:

$$\text{Fan SP} = (SP_{\text{outlet}} + VP_{\text{outlet}}) - (SP_{\text{inlet}} + VP_{\text{inlet}}) - VP_{\text{outlet}}$$

Combining terms leads to a final equation:

$$\text{Fan SP} = SP_{\text{outlet}} - SP_{\text{inlet}} - VP_{\text{inlet}}$$

A few fan manufacturers base catalog ratings on total pressure. To select a fan on this basis the Fan Total Pressure is calculated as follows:

$$\text{Fan TP} = TP_{\text{outlet}} - TP_{\text{inlet}}$$

$$= (SP_{\text{outlet}} + VP_{\text{outlet}}) - (SP_{\text{inlet}} + VP_{\text{inlet}})$$

In selecting a fan from catalog ratings, the rating tables should be examined to determine whether they are based on Fan Static Pressure or Fan Total Pressure. The proper pressure can then be calculated bearing in mind the proper signs; i.e., VP is always positive (+), SP inlet is usually negative (-) and SP outlet is usually positive (+).

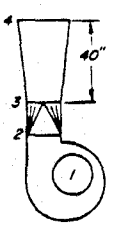
Evasé Discharge: An evasé discharge is a gradual enlargement at the outlet of the exhaust system (see Figure 10-9). The purpose of the evase is to reduce the air discharge velocity efficiently; thus, the available velocity pressure can be regained and credited to the exhaust system instead of being wasted. Practical considerations usually limit the construction of an evasé to approximately a 10° angle (5° side angle) and a discharge velocity of about 2000 fpm (0.25" velocity pressure) for normal exhaust systems. Further streamlining or lengthening the evasé gives diminishing returns.

It should be noted, however, that for optimum vertical dispersion of contaminated air many designers feel that the discharge velocity from the stack should not be less than 3000-3500 fpm. When these considerations prevail, the use of an evasé is questionable.

Example 7 indicates the application of the evasé fitting. It is not necessary to locate the evasé directly after the outlet of the fan. It should be noted that, depending upon the evasé location, the static pressure at the fan discharge may be below atmospheric, i.e., negative (-), as shown in this example.

Example 7:

Duct No.	Dia.	Q	V	VP	SP
1 Fan Inlet	20	8300	3800	0.90"	7.27"
2 Fan Discharge = 16-1/2 X 19-1/2			3765	0.88"	
3 Round Duct Connection	20		3800	0.90"	
4 Evasé Outlet	28		1940	0.23"	0"



To calculate the effect of the evasé, see Figure 6-6.

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Where: the Diameter Ratio, $\frac{D_4}{D_3} = \frac{28"}{20"} = 1.4$ and Taper length $\frac{L}{D} = \frac{40"}{20"} = 2.$

R = 0.52 (Fig. 6-6) x 70% (Since the evasé is within 5 diameters of the fan outlet)
SP_4 = 0 (Since the end of the duct is at atmospheric pressure)
VP_3 = 0.5 as given

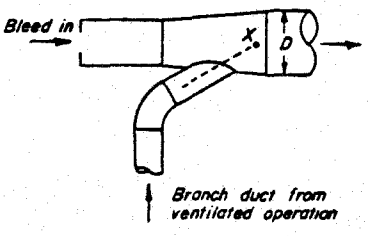
$SP_4 = SP_3 - R(VP_3)$
$0 = SP_3 - 0.52 \times 0.70\ (0.90")$
$SP_3 = -0.33"$

Exhaust Stack Outlets

The type and location of exhaust stacks are important to permit good dispersion of contaminated air from exhaust systems, even when an efficient air cleaner is used. Poor discharge conditions result in low-level contamination which can re-enter the building due to wind effect (building turbulence), negative pressure, or the action of mechanical air supply systems. Figures 6-22 and 8-3 illustrate the principles of good stack design; Figure 6-23 shows the influence of building turbulence and stack height. Whenever there is doubt about the proper height and location of outlets, simple observations and tests with smoke candles will be helpful in determining air flow pattern across the building roof.

Air Bleed-ins: Bleed-ins are used at the ends of branch ducts to provide additional air volumes to transport heavy material loads as in woodworking at saws and jointers or at the ends of a main duct to maintain minimum transport velocity when the system has been oversized deliberately to provide for future extension. Some designers use bleed-ins also to introduce additional air to an exhaust system to reduce air temperature or dew point and to assist in balancing the system.

Calculation of bleed-in size:



End cap bleed in

End cap bleed-in. Consider as an orifice, Fig. 6-10; $h_e = 1.78$ VP

1. Calculate SP for branch duct to junction (X).
2. Determine air volume in main duct according to design or future capacity or determine Q bleed-in directly from temperature or moisture considerations.
3. Q bleed-in = (Q main duct) - (Q branch).
4. SP bleed-in = SP branch as calculated.
5. VP, bleed-in = $\frac{\text{SP bleed-in}}{h_e + VP} = \frac{SP}{1.78 + 1.0} = \frac{SP}{2.78}$
6. Velocity, bleed-in from VP and Fig. 6-16.
7. Area bleed-in = $\frac{\text{Q Bleed-in}}{\text{V Bleed-in}}$

Plenum Type Exhaust Systems

Plenum type systems differ from the designs illustrated earlier in methods A and B. Minimum transport velocities are maintained only in the branch ducts to prevent settling of particulate matter; the main duct is oversized and velocities are allowed to decrease far below normal values. The function of the main duct is to provide a low resistance path for air flow from the various branches to the air cleaner on the fan. This helps to maintain balanced exhaust in all of the branches and often provides a minimum operating horsepower.

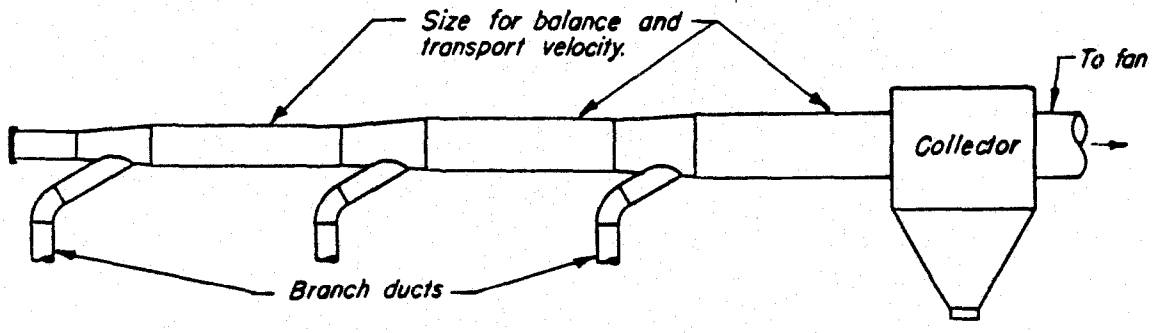
Advantages of the plenum type exhaust system include:

1. Branch ducts can be added, removed or relocated at any convenient point along the main duct.
2. Branch ducts can be closed off and the air volume in the entire system reduced so long as minimum transport velocities are maintained in the remaining branches.
3. The main duct can act as a primary separator (settling chamber) for large particulate matter and refuse material which might be undesirable in the air cleaner or fan.

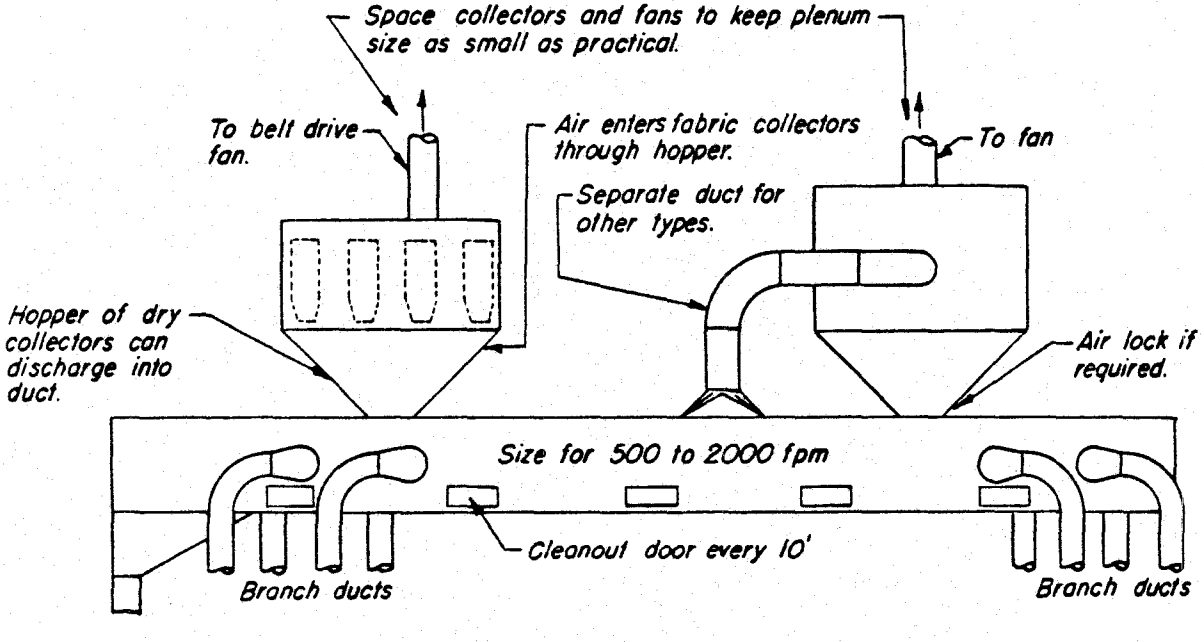
Limitations of this design include:

1. Sticky, linty materials such as buffing dust are difficult to handle and tend to clog the main duct. It may be expected that greatest difficulty will be encountered with the drag chain type of cleaning but the other types will be susceptible to build-up also.

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TAPER DUCT SYSTEM
Maintains transport velocity



EXTENDED PLENUM SYSTEM
Self cleaning type

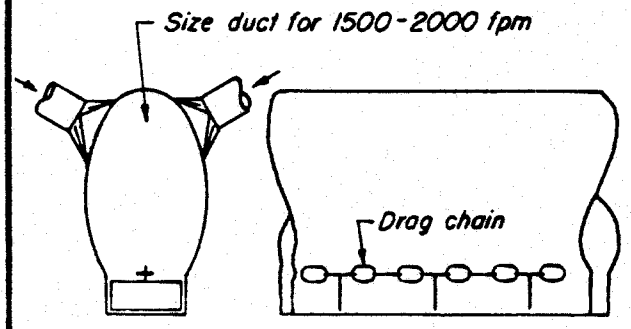
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PLENUM vs CONVENTIONAL SYSTEM

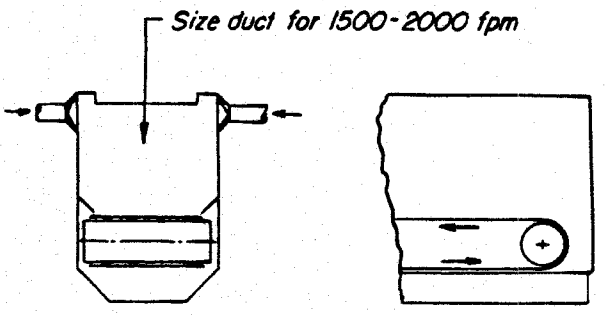
DATE 1-70 | Fig. 6-7

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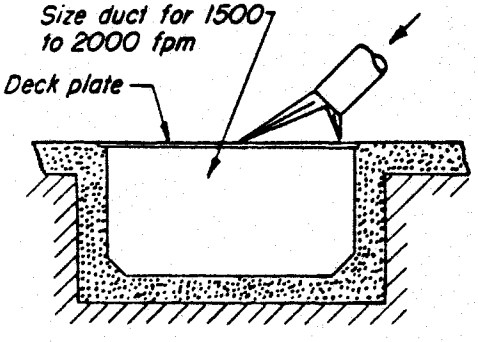
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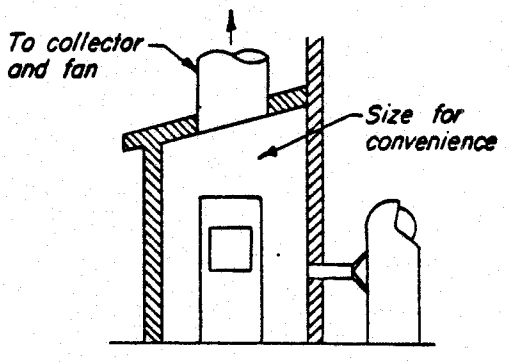
1. Self cleaning main – drag chain



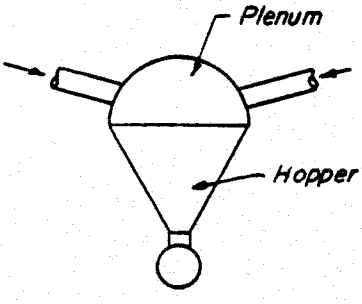
2. Self cleaning main – belt conveying

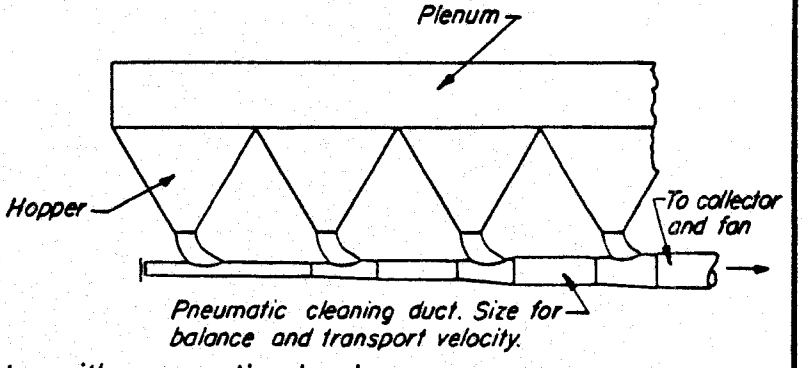


3. Under floor – manual cleaning



4. Large plenum – manual cleaning





5. Hopper duct – with pneumatic cleaning

Reference 89

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TYPES OF PLENUMS	
DATE 1-70	Fig. 6-8

PRODUCED 1134 JM - 83

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2. Materials which are subject to direct or spontaneous combusion must be handled with care. Wood dust has been handled successfully in systems of this type; buffing dust and lint are subject to this limitation and are not recommended. Explosive dusts such as magnesium and titanium as well as grain dusts should not be handled in systems of this type.

3. The cost of these systems is somewhat higher than conventional designs, ranging approximately 25¢ - 50¢ per cfm additional.

Choice of Systems: Various types of plenum exhaust systems are used in industry, including both self-cleaning and manual-cleaning designs. Self-cleaning types include pear-shaped designs which incorporate a drag chain conveyor in the bottom of the duct to convey the dust to a chute, tote box, or enclosure for disposal. Another self-cleaning design uses a rectangular main with a belt conveyor. In these types, the conveyors may be run continuously or on periodic cycles to empty the main duct before considerable build-up and clogging occurs. A third type (Reference 89) of self-cleaning design utilizes a standard conveying main duct system to remove the collected material from a hopper type of main duct above. Such a system is usually run continuously to avoid clogging of the pneumatic air circuit. Manual cleaning designs may be built into the floor as shown in Figure 6-9 or may be large enclosures behind the equipment to be ventilated. Experience indicates that these should be generously oversized, particularly the underfloor designs, to permit added future exhaust capacity, if needed, as well as convenient housekeeping intervals.

Design: Control air volumes, hoods and duct sizes for all branches are calculated in the same manner as with methods A and B. The branch run of greatest resistance will govern the static pressure required in the main duct. Other branches will be designed to operate at this static pressure or locking dampers can be used to adjust their resistance to the same static pressure as the governing branch. Where the main duct is relatively short or where the air cleaners or fans can be spaced along the duct, static pressure losses due to air flow in the main duct can be ignored. For extremely long ducts, it is necessary to calculate the static pressure drop along the main in a manner similar to that used in methods A and B. Approximate results only will be obtained, however. Duct connections to air cleaners, fans and discharge to outside are handled in the normal manner.

Optimum Economic Velocity

In systems which are intended to carry dust, a minimum conveying velocity is necessary to insure that the dust will not settle in the duct. Also, when a system is installed in a quiet area it may be necessary to keep velocities below some maximum to avoid excessive duct noise. When axial flow fans are used, duct velocities of 1000 to 1500 fpm are preferred. In a gas or vapor exhaust system installed in a typical factory environment where none of these restrictions apply, the velocity may be selected to yield the lowest annual cost.

To determine the optimum economic velocity, the system must first be designed at any assumed velocity and the total initial costs of duct material, fabrication and installation estimated. (97)

This optimum economic velocity may range from under 2000 fpm to over 4000 fpm. Long expected service periods and system operating times tend to lower the optimum while high interest rates and ductwork costs tend to raise the optimum. In general a velocity of 2500-3000 fpm will not result in equivalent total annual costs much in excess of the true optimum.

Computer Design of Exhaust Systems

A computer program has been written to design balanced industrial exhaust systems. The input consists of data obtained from the system layout plan and from the VS diagrams (Section 5). The program sizes all ducts, calculates losses and balances junctions either duct resizing or flow adjustment. The printed output gives the values for each duct in a format similar to that of the velocity pressure method. All values are recalculated to represent actual finished system conditions rather than interim design values.

This program can be adapted to any computer using a FORTRAN type language, having a 4K or larger memory and some peripheral memory such as tape, disc or drum. For further information write the Committee on Industrial Ventilation, P. O. Box 453, Lansing, Michigan, 48902.

Velocity Pressure Method of Calculation

The Velocity Pressure Method is an alternate method of duct design. This method has several advantages over the Equivalent Length Method illustrated in the first examples. It is generally more rapid and offers the advantage of quick recalculation of branch duct sizes for balanced exhaust system design.

The method is based on the fact that all frictional and dynamic losses in exhaust ducts and hoods are directly proportional to the Velocity Pressure. Loss factors for hoods, straight ducts, elbows, branch entries, weather caps and many other fittings are well known and are established in terms of the velocity pressure. Thus it is necessary to establish only one value for elbows and fittings in starting the design. As a convenience, losses for elbows and entries are presented on the calculation form.

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For use with this method a new "friction chart" based on Velocity Pressure loss per 100 feet of straight duct has been prepared. From this chart it is possible to obtain friction loss in VP/100 ft, velocity and duct diameter for the design air volume. (See Figure 6-17.)

The velocity pressure method follows the general procedure outlined on page 6-1 except that the Velocity Pressure calculation sheet, Figure 6-9, is used. Since the method is based on the same principles of air flow and the same established data, there will be no significant difference in the results obtained by either this method or the equivalent length method.

Velocity Pressure Method
Calculation Sheet

Plant name Example Problems 1&2 Elevation ____ Date ____ Calculated 17450 cfm Remarks ____
Location ____ Temperature ____ Refer to drawing Fig.6-1,6-2 (Std conditions) 7-7/8 SP"
Department Foundry Factor ____ Designer JCB TP"

				Example Problem 1 Fig 6-1			Example Problem 2 Fig 6-2				1-A'	A-C	7a-D
1	Branch or Main duct number						A	B	C	D			
2	Air volume		cfm	390			9600	960	700	1740	9600	11420	500
3	For Slot & Plenum hoods only: Slot area		sq. ft				10				10		
4	Slot velocity		fpm				960				960		
5	Slot VP	Fig. 6-16	in H_2O				0.06				0.06		
6	Slot entry loss factor	Fig. 6-10					1.78				1.78		
7	Acceleration factor	100 VP					②				②		
8	Plenum loss factor	Item 6+7					1.78				1.78		
9	Plenum SP	Item 5x8	in H_2O				0.11				0.11		
10	Branch duct dia		inches	4	4 1/2		22	7	6	9	18	24	5
11	Branch duct area		sq. ft	.0873	0.111		2.64	.267	.196	.442	1.77	3.14	.136
12	Branch duct velocity		fpm	4470	3510		3630	3590	3570	3940	5425	3640	3670
13	Branch duct VP	Fig. 6-16	in H_2O	1.25	0.77		0.82	0.80	0.79	.97 ④	1.83	.82	.84
14	Straight duct length		ft	10	20		13	3	4	18	13	34	5
15	Straight duct friction	Fig. 6-17	VP/100'	6.9	6.2		0.85	3.5	4.2	2.6	1.05	.75	5.3
16	Straight duct loss factor	Item 14x15		0.69	1.24		0.11	0.11	0.17	0.47	.14	.26	.27
17	Hood entry loss factor	Section 5 & Fig. 6-10		.65			0.25	0.25	.25		.25		1.0
18	Acceleration factor	1.00 VP		1.00			1.00	1.00	1.00 ③		1.00		1.0
19	Elbow loss factor No. x factor	Fig. 6-12					0.27	.18	.45 ③	.54	.27		
20	Entry loss factor	Fig. 6-13		10°				.18	.18	.18			
21	Special fittings			Expansion Fig 6-7 ①									
22	Duct loss factor	Total of 16 to 21		2.34	1.24		1.63	1.72	2.05	1.19	1.66	.26	2.27
23	Duct SP loss	Item 13x 22	in H_2O	2.92	0.96		1.34	1.38	1.62	1.15 ④	3.04	.21	1.91
24	Other losses		in H_2O							.09 ⑤			
25	Branch or Main SP loss	Item 9+23x 24	in H_2O	2.65	0.96		1.45	1.38	1.62	2.86 ⑤	3.15	3.36	1.91
26	Governing SP at junction		in H_2O		3.61			1.62			3.15		
27	Corrected air volume*		cfm					1040		1820			
28	Hood static pressure**	Items [9+13x(17+18)]		2.06				1.06	0.99		2.29		1.68

* $Q_{corr} = Q_{duct} \sqrt{\frac{SP_{gov}}{SP_{duct}}}$

Fan SP = SPout - SPin - VPin
=
Fan SP = 0.07 - (-8.16) - .40
= 7.83"

① $SP_C = SP_b + R(VP_B - VP_C)$
$= (-)2.92 + .56(1.25 - .77)$
$= (-)2.92 + .27$
$= (-)2.65$ enter as item 25

② Due to plenum design, Slot VP is not lost. Take acceleration at branch VP (Item 18)

③.

④.

⑤ VP is higher than in connecting branches
Increase = 1.48 - .77 = .71"

⑥ Resize 10-J

** This value useful for testing See Section 9

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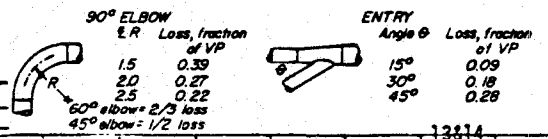
Figure 6-9

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When some specialized exhaust hoods are used (slot hoods and hoods having a double entry loss), it is necessary to make a separate calculation of the slot loss since this may occur at a different velocity than that established in the branch duct. For these hoods, a special section of the calculation sheet is used; for simple exhaust hoods, this step is not necessary.

To gain familiarity with this method of calculation, the designer is urged to compare the example problems worked out both in the Equivalent Length Method (Figures 6-1, 6-2, 6-3 and 6-4) and in the Velocity Pressure Method (Figure 6-9).



5-D	D-C	C-E	8-F	9-F	F-G	7b-G	F'-G'	G-E	E-H	10-J	12-J	10'-J	J-H	H-K	13&14 inlet	L
			1200	500	1700	500	1700	2200	15090	1225	900	1225	2125	17400	17400	17400
6	8	26	8	5	9	5	8	10	28	8	6	7	10	30	35 1/2	32
.196	.349	3.69	.349	.136	.442	.136	.349	.545	4.28	.349	.196	.267	.545	4.91	6.87	5.59
3570	3640	3470	3440	3670	3850	3670	4870	4030	3530	3500	4590	4590	3900	3540	2530	3120
0.79	.82	.75	.74	.84	.92 ⑥	.84	1.48 ⑧	1.01	.78	.76	1.31	1.31	.95	.78	.40	.61
7	14	6.5	11	4	5	15	5	6	3.5	6	2.5	6	8	9		20
4.2	2.9	.69	3.0	5.3	2.6	5.3	2.8	2.2	.68	2.9	4.1	3.4	2.2	.58		.55
.29	.41	.04	.33	.21	.13	.80	.14	.13	.02	.17	.10	.20	.18	.05		.11
.25			.50	.25		1.00				.25	.25	.25				
1.0			1.00	1.00		1.00				1.00	1.00	1.00				
.27	.45		.54	.45		.18		.18		.14	.09	.14	.45	.27		
.18	.18			.18		.18		.18			.18		.18			
1.99	1.04	.04	2.37	2.09	.13	3.16	.14	.49	.02	1.56	1.62	1.59	.81	.32		.11
1.57	.85	.03	1.75	1.75	.12	2.66	.21 ⑧	.50	.02	1.19	2.12	2.08	.77	.25		.07
					.19 ⑥		.71								4.5	
1.57	2.76	3.39	1.75	1.76	2.03	2.66 ⑦	2.68	3.18	3.41	1.19 ⑨	2.12	2.08	2.89	3.66	8.16	8.23
1.91	3.36		1.76			2.68		3.39		2.12		2.12	3.41			
770	1400		OK			OK		2270				OK	2310			

Typical:
1-90° elbow = .27
1-60° elbow = .18
.45 VP

VP is higher than in connecting branches. See text.

$$VP_{2-3} = \frac{(Q_2+Q_3)^2}{[4005(A_2+A_3)]^2} = .88"$$

Increase = .97" - .88" = .09"

⑤ Branch 1-A requires 1.45"SP at jct A
Branch B-A requires 2.90"SP at jct A
Resize 1-A
Trial VP = Gov. SP / Branch Loss Factor = 2.90 / 1.63 = 1.78
Trial velocity = 5343 fpm
Trial duct area = Q / V = 9600 / 5343 = 1.8 ft²
Closest std. duct size = 18"ϕ

⑥ VP is higher than in connecting branches. See text.

$$VP_{8-9} = \frac{(Q_8+Q_9)^2}{[4005(A_8+A_9)]^2} = .77"$$

Increase = .92 - .77 = .15"

⑦ Branch F-G requires 2.03" SP at jct G
Branch 7b-G requires 2.66"SP at jct G
Resize branch F-G

0.99			1.11	1.05							1.64	1.64				

113 REPRODUCED JM - 83

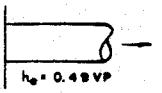
MT-PWHD-004675



$h_e = 0.93\,VP$

PLAIN DUCT END

$C_e = 0.72$



$h_e = 0.49\,VP$

FLANGED DUCT END

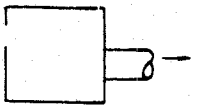
$C_e = 0.82$



$h_e = 1.78\,VP$ ORIFICE

SHARP-EDGED ORIFICE

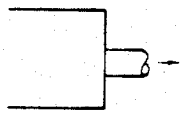
$C_e = 0.60$



$h_e = 2.3\,VP$ DUCT, (WHEN DUCT VELOCITY = SLOT VELOCITY)
BETTER: $1.78\,VP$ ORIFICE + $0.49\,VP$ DUCT

ORIFICE PLUS FLANGED DUCT
(MANY SLOT TYPES)

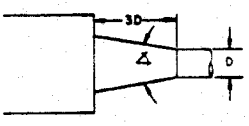
$C_e = 0.55$ (WHEN DUCT VELOCITY = SLOT VELOCITY)



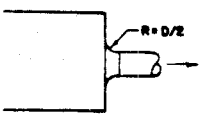
$h_e = 0.50\,VP$

DIRECT BRANCH - BOOTH

$C_e = 0.82$



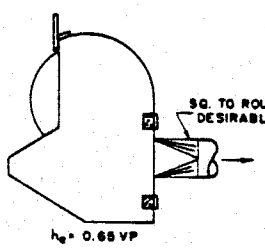
∠	ENTRY LOSS		ENTRY COEFFICIENT	
	ROUND	RECTANGULAR	ROUND	RECTANGULAR
15°	0.15 VP	0.25 VP	0.93	0.89
30°	0.00 VP	0.16 VP	0.96	0.93
45°	0.06 VP	0.15 VP	0.97	0.93
60°	0.08 VP	0.17 VP	0.96	0.92
90°	0.15 VP	0.26 VP	0.93	0.89
120°	0.26 VP	0.35 VP	0.09	0.86
150°	0.40 VP	0.48 VP	0.84	0.82



$h_e = 0.06\,VP$ TO $0.10\,VP$

BOOTH PLUS ROUNDED ENTRANCE

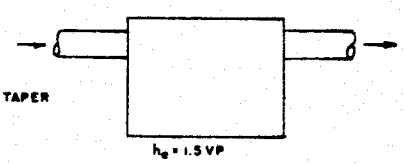
$C_e = 0.97$



$h_e = 0.65\,VP$

STANDARD GRINDER HOOD

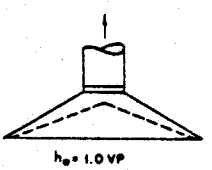
$C_e = 0.79$



$h_e = 1.5\,VP$

TRAP OR SETTLING CHAMBER

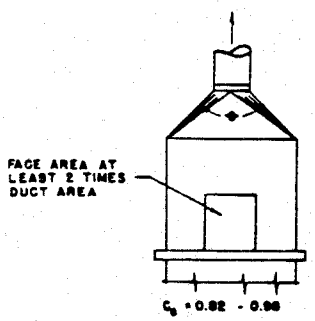
$C_e = 0.63$ (approx.)



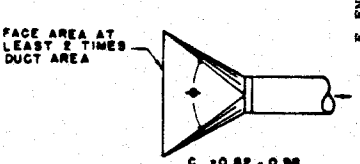
$h_e = 1.0\,VP$

DOUBLE (INNER CONE) HOOD

$C_e = 0.70$ (approx.)



$C_e = 0.82 - 0.98$

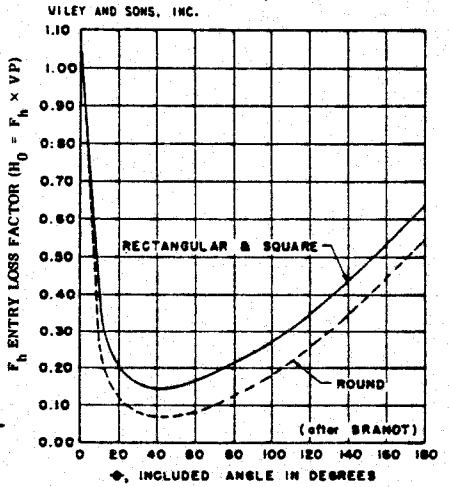


$C_e = 0.82 - 0.98$

TAPERED HOODS

FLANGED OR UNFLANGED; ROUND, SQUARE OR RECTANGULAR.
θ IS THE MAJOR ANGLE ON RECTANGULAR HOODS.

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$$h_e = \frac{1-C_e^2}{C_e^2} \times VP$$

$$F_h = \frac{1-C_e^2}{C_e^2}$$

$$h_e = F_h \times VP$$

$$Q = 4005\,A C_e \sqrt{SP}$$

F_h = ENTRY LOSS FACTOR
VP = VELOCITY PRESSURE IN DUCT
SP = STATIC PRESSURE AT THROAT, INCHES WATER GAGE
h_e = ENTRY LOSS, INCHES WATER GAGE
Q = AIR VOLUME, CFM
A = CROSS SECTION AT THROAT, SQUARE FEET
C_e = COEFFICIENT OF ENTRY

ENTRY LOSS FOR COMPLICATED HOOD SHAPES:
1. BREAK HOOD INTO SIMPLE COMPONENTS
2. CALCULATE h_e FOR EACH COMPONENT
3. ADD VALUES OF h_e

MISCELLANEOUS VALUES

HOOD	ENTRY LOSS, F_h
ABRASIVE BLAST CHAMBER	1.0
ABRASIVE BLAST ELEVATOR	2.3
ABRASIVE SEPARATOR	2.3
ELEVATORS (ENCLOSURES)	0.69
FLANGED PIPE PLUS CLOSED ELBOW	0.8
PLAIN PIPE PLUS CLOSE ELBOW	1.60
TUMBLING MILLS (VARIES WITH DESIGN OF MILL)	AV. 2.0

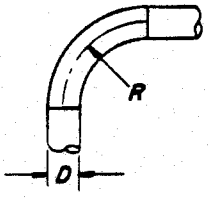
HOOD ENTRY LOSS

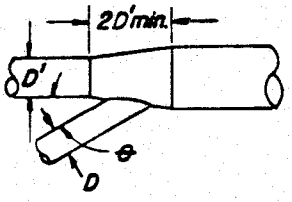
Fig. 6-10

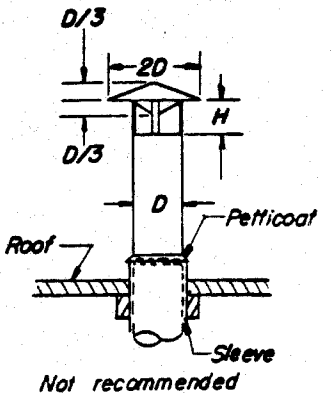
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EQUIVALENT RESISTANCE IN FEET OF STRAIGHT PIPE







Not recommended

Pipe D	90° Elbow * Centerline Radius			Angle of Entry		H, No of Diameters		
	1.5 D	2.0 D	2.5 D	30°	45°	1. D	.75 D	.5 D
3"	5	3	3	2	3	2	2	9
4"	6	4	4	3	5	2	3	12
5"	9	6	5	4	6	2	4	16
6"	12	7	6	5	7	3	5	20
7"	13	9	7	6	9	3	6	23
8"	15	10	8	7	11	4	7	26
10"	20	14	11	9	14	5	9	36
12"	25	17	14	11	17	6	11	44
14"	30	21	17	13	21	7	13	53
16"	36	24	20	16	25	9	15	62
18"	41	28	23	18	28	10	18	71
20"	46	32	26	20	32	11	20	80
24"	57	40	32			13	24	92
30"	74	51	41			17	31	126
36"	93	64	52			22	39	159
40"	105	72	59					
48"	130	89	73					

* For 60° elbows — 0.67 x loss for 90°
45° elbows — 0.5 x loss for 90°
30° elbows — 0.33 x loss for 90°

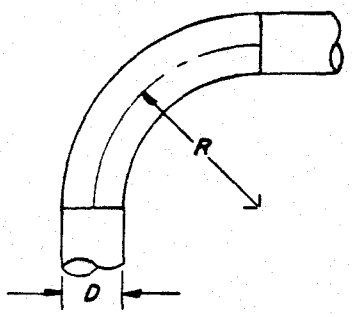
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

DUCT DESIGN DATA

DATE 1-72 | Fig. 6-11

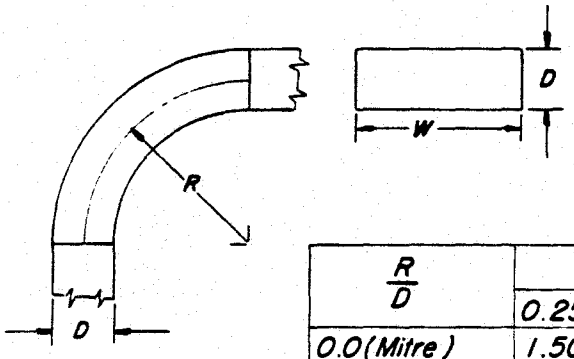
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MT-PWHD-004677



R, No. of Diameters	Loss Fraction of VP
2.75 D	0.26
2.50 D	0.22
2.25 D	0.26
2.00 D	0.27
1.75 D	0.32
1.50 D	0.39
1.25 D	0.55

ROUND ELBOWS



Loss, Fraction of VP

R/D	Aspect Ratio, W/D					
	0.25	0.5	1.0	2.0	3.0	4.0
0.0(Mitre)	1.50	1.32	1.15	1.04	0.92	0.86
0.5	1.36	1.21	1.05	0.95	0.84	0.79
1.0	0.45	0.28	0.21	0.21	0.20	0.19
1.5	0.28	0.18	0.13	0.13	0.12	0.12
2.0	0.24	0.15	0.11	0.11	0.10	0.10
3.0	0.24	0.15	0.11	0.11	0.10	0.10

SQUARE & RECTANGULAR ELBOWS

ELBOW LOSSES

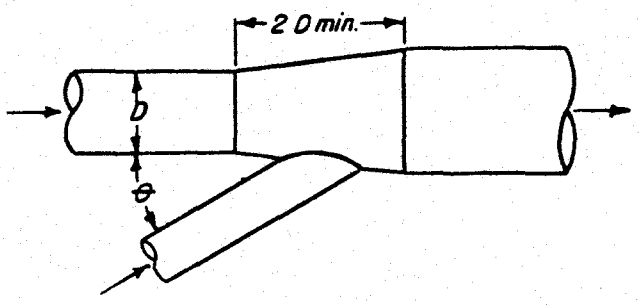
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DUCTWORK DESIGN DATA

DATE 1-66 | Fig. 6-12

PRODUCED 1140 JM - 83

MT-PWHD-004678

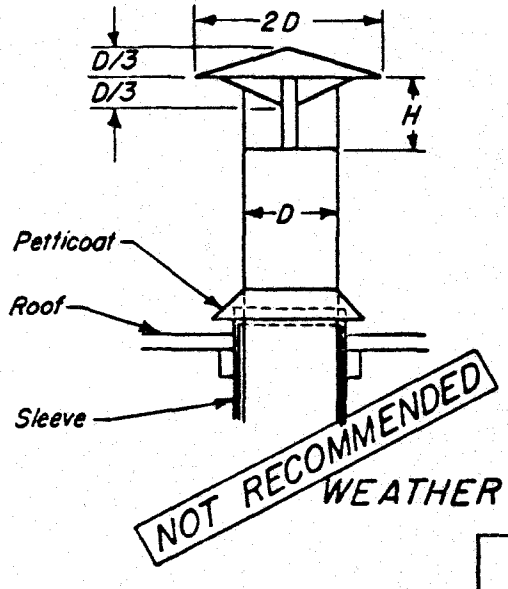


Angle θ Degrees	Loss Fraction of VP in Branch
10	0.06
15	0.09
20	0.12
25	0.15
30	0.18
35	0.21
40	0.25
45	0.28
50	0.32
60	0.44
90	1.00

Note: Bronch entry loss assumed to occur in branch and is so calculated.

Do not include an enlargement regain calculation for branch entry enlargements.

BRANCH ENTRY LOSSES



H, No. of Diameters	Loss Fraction of VP
1.0 D	0.10
0.75 D	0.18
0.70 D	0.22
0.65 D	0.30
0.60 D	0.41
0.55 D	0.56
0.50 D	0.73
0.45 D	1.0

WEATHER CAP LOSSES

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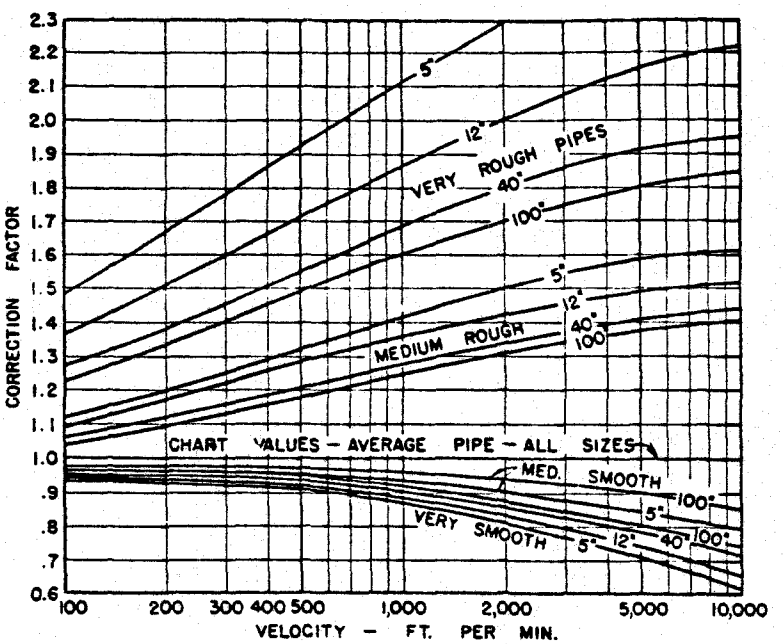
DUCTWORK DESIGN DATA

DATE 1-72 | Fig. 6-13

PRODUCED IM 483

MT-PWHD-004679

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MADISON AND ELLIOTT(26)

AIR DENSITY CORRECTION FACTOR, d

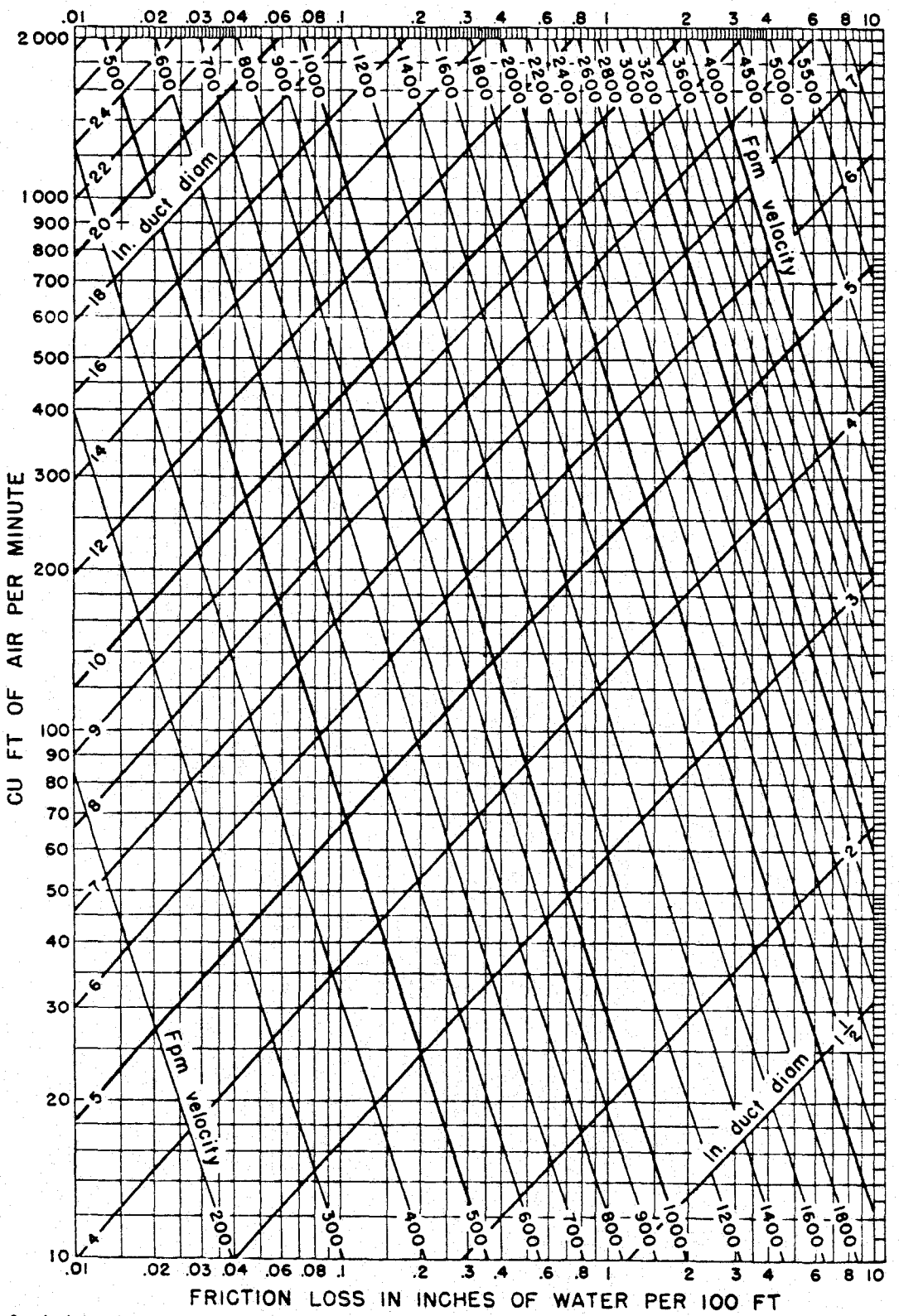
Altitude, ft.		– 1000	Sea Level	1000	2000	3000	4000	5000	6000	7000	8000	9000	10,000
Barometer	"Hg	31.02	29.92	28.86	27.82	26.82	25.84	24.90	23.98	23.09	22.22	21.39	20.58
	"Wg	422.2	407.5	392.8	378.6	365.0	351.7	338.9	326.4	314.3	302.1	291.1	280.1
Air Temp. F	–40	1.31	1.26	1.22	1.17	1.13	1.09	1.05	1.01	0.97	0.93	0.90	0.87
	0	1.19	1.15	1.11	1.07	1.03	0.99	0.95	0.91	0.89	0.85	0.82	0.79
	40	1.10	1.06	1.02	0.99	0.95	0.92	0.88	0.85	0.82	0.79	0.76	0.73
	70	1.04	1.00	0.96	0.93	0.89	0.86	0.83	0.80	0.77	0.74	0.71	0.69
	100	.98	0.95	0.92	0.88	0.85	0.81	0.78	0.75	0.73	0.70	0.68	0.65
	150	.90	0.87	0.84	0.81	0.78	0.75	0.72	0.69	0.67	0.65	0.62	0.60
	200	.83	0.80	0.77	0.74	0.71	0.69	0.66	0.64	0.62	0.60	0.57	0.55
	250	.77	0.75	0.72	0.70	0.67	0.64	0.62	0.60	0.58	0.56	0.58	0.51
	300	.72	0.70	0.67	0.65	0.62	0.60	0.58	0.56	0.54	0.52	0.50	0.48
	350	.68	0.65	0.62	0.60	0.58	0.56	0.54	0.52	0.51	0.49	0.47	0.45
	400	.64	0.62	0.60	0.57	0.55	0.53	0.51	0.49	0.48	0.46	0.44	0.42
	450	.60	0.58	0.56	0.54	0.52	0.50	0.48	0.46	0.45	0.43	0.42	0.40
	500	.57	0.55	0.53	0.51	0.49	0.47	0.45	0.44	0.43	0.41	0.39	0.38
	550	.54	0.53	0.51	0.49	0.47	0.45	0.44	0.42	0.41	0.39	0.38	0.36
	600	.52	0.50	0.48	0.46	0.45	0.43	0.41	0.40	0.39	0.37	0.35	0.34
	700	.47	0.46	0.44	0.43	0.41	0.39	0.38	0.37	0.35	0.34	0.33	0.32
	800	.44	0.42	0.40	0.39	0.37	0.36	0.35	0.33	0.32	0.31	0.30	0.29
	900	.40	0.39	0.37	0.36	0.35	0.33	0.32	0.31	0.30	0.29	0.28	0.27
	1000	.37	0.36	0.35	0.33	0.32	0.31	0.30	0.29	0.28	0.27	0.26	0.25

Standard Air Density, Sea Level, 70 F = 0.075#/ft³

Fig. 6-14

1142 PRODUCED JM - 83

MT-PWHD-004680

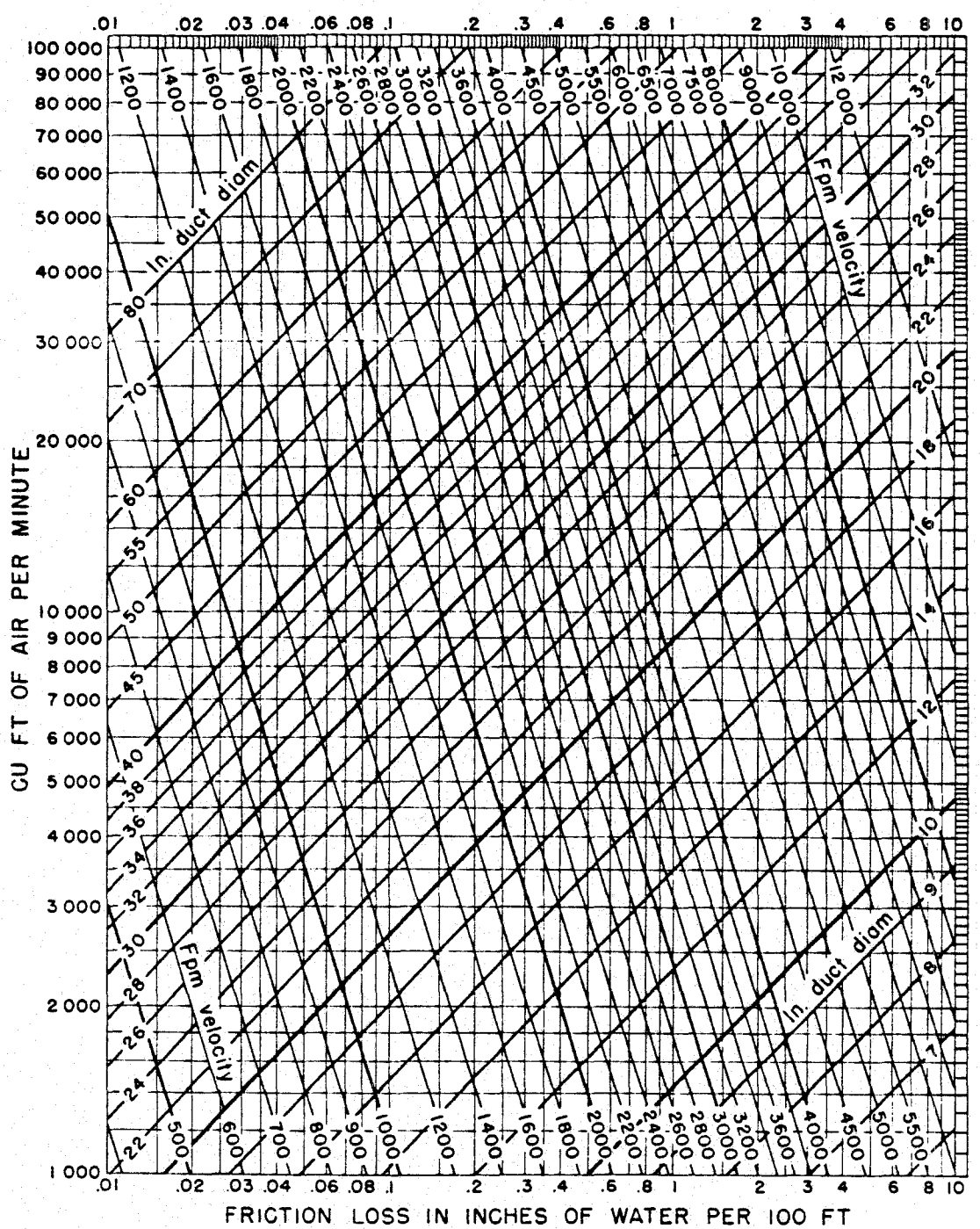


(Based on Standard Air of 0.075 lb per cu ft density flowing through average, clean, round, galvanized metal ducts having approximately 40 joints per 100 ft.) Caution: Do not extrapolate below chart.

Friction of Air in Straight Ducts for Volumes of 10 to 2000 Cfm

Fig. 6-15A

1143
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JM - 83
MT-PWHD-004681



(Based on Standard Air of 0.075 lb per cu ft density flowing through average, clean, round, galvanized metal ducts having approximately 40 joints per 100 ft.)

Friction of Air in Straight Ducts for Volumes of 1000 to 100,000 Cfm

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Fig. 6-15B

PRODUCED 1144 JM - 83

MT-PWHD-004682

VELOCITY PRESSURES FOR DIFFERENT VELOCITIES – STANDARD AIR

FROM: $V = 4005\sqrt{VP}$

V = VELOCITY FPM
VP = VELOCITY PRESSURE, INCHES OF WATER

VP	V	VP	V	VP	V	VP	V	VP	V	VP	V
0.01	400	0.52	2888	1.03	4064	1.54	4970	2.05	5734	3.10	7051
0.02	566	0.53	2916	1.04	4084	1.55	4986	2.06	5748	3.20	7164
0.03	694	0.54	2943	1.05	4103	1.56	5002	2.07	5762	3.30	7275
0.04	801	0.55	2970	1.06	4123	1.57	5018	2.08	5776	3.40	7385
0.05	896	0.56	2997	1.07	4142	1.58	5034	2.09	5790	3.50	7492
0.06	981	0.57	3024	1.08	4162	1.59	5050	2.10	5804	3.60	7599
0.07	1060	0.58	3050	1.09	4181	1.60	5066	2.11	5817	3.70	7704
0.08	1133	0.59	3076	1.10	4200	1.61	5082	2.12	5831	3.80	7807
0.09	1201	0.60	3102	1.11	4219	1.62	5098	2.13	5845	3.90	7909
0.10	1266	0.61	3127	1.12	4238	1.63	5114	2.14	5859	4.00	8010
0.11	1328	0.62	3153	1.13	4257	1.64	5129	2.15	5872	4.10	8109
0.12	1387	0.63	3179	1.14	4276	1.65	5144	2.16	5886	4.20	8208
0.13	1444	0.64	3204	1.15	4295	1.66	5160	2.17	5899	4.30	8305
0.14	1498	0.65	3229	1.16	4314	1.67	5175	2.18	5913	4.40	8401
0.15	1551	0.66	3254	1.17	4332	1.68	5191	2.19	5927	4.50	8496
0.16	1602	0.67	3279	1.18	4350	1.69	5206	2.20	5940	4.60	8590
0.17	1651	0.68	3303	1.19	4368	1.70	5222	2.21	5954	4.70	8683
0.18	1699	0.69	3327	1.20	4386	1.71	5237	2.22	5967	4.80	8774
0.19	1746	0.70	3351	1.21	4405	1.72	5253	2.23	5981	4.90	8865
0.20	1791	0.71	3375	1.22	4423	1.73	5268	2.24	5994	5.00	8955
0.21	1835	0.72	3398	1.23	4442	1.74	5283	2.25	6008	5.10	9044
0.22	1879	0.73	3422	1.24	4460	1.75	5298	2.26	6021	5.20	9133
0.23	1921	0.74	3445	1.25	4478	1.76	5313	2.27	6034	5.30	9220
0.24	1962	0.75	3468	1.26	4495	1.77	5328	2.28	6047	5.40	9307
0.25	2003	0.76	3491	1.27	4513	1.78	5343	2.29	6061	5.50	9392
0.26	2042	0.77	3514	1.28	4531	1.79	5359	2.30	6074	5.60	9477
0.27	2081	0.78	3537	1.29	4549	1.80	5374	2.31	6087	5.70	9562
0.28	2119	0.79	3560	1.30	4566	1.81	5388	2.32	6100	5.80	9645
0.29	2157	0.80	3582	1.31	4583	1.82	5403	2.33	6113	5.90	9728
0.30	2193	0.81	3604	1.32	4601	1.83	5418	2.34	6128	6.00	9810
0.31	2230	0.82	3625	1.33	4619	1.84	5433	2.35	6140	6.10	9891
0.32	2260	0.83	3657	1.34	4636	1.85	5447	2.36	6153	6.20	9972
0.33	2301	0.84	3669	1.35	4653	1.86	5462	2.37	6166	6.30	10052
0.34	2335	0.85	3690	1.36	4671	1.87	5477	2.38	6179	6.40	10132
0.35	2369	0.86	3709	1.37	4688	1.88	5491	2.39	6192	6.50	10210
0.36	2403	0.87	3729	1.38	4705	1.89	5506	2.40	6205	6.60	10289
0.37	2436	0.88	3758	1.39	4722	1.90	5521	2.41	6217	6.70	10366
0.38	2469	0.89	3779	1.40	4739	1.91	5535	2.42	6230	6.80	10444
0.39	2501	0.90	3800	1.41	4756	1.92	5550	2.43	6243	6.90	10520
0.40	2533	0.91	3821	1.42	4773	1.93	5564	2.44	6256	7.00	10596
0.41	2563	0.92	3842	1.43	4790	1.94	5579	2.45	6269	7.50	10968
0.42	2595	0.93	3863	1.44	4806	1.95	5593	2.46	6282	8.00	11328
0.43	2626	0.94	3884	1.45	4823	1.96	5608	2.47	6294	8.50	11676
0.44	2656	0.95	3904	1.46	4840	1.97	5623	2.48	6307	9.00	12015
0.45	2687	0.96	3924	1.47	4856	1.98	5637	2.49	6320	9.50	12344
0.46	2716	0.97	3945	1.48	4873	1.99	5651	2.50	6332	10.00	12665
0.47	2746	0.98	3965	1.49	4889	2.00	5664	2.60	6458	11.00	13283
0.48	2775	0.99	3985	1.50	4905	2.01	5678	2.70	6581	12.00	13874
0.49	2804	1.00	4005	1.51	4921	2.02	5692	2.80	6702	13.00	14440
0.50	2832	1.01	4025	1.52	4938	2.03	5706	2.90	6820	13.61	14775
0.51	2860	1.02	4045	1.53	4954	2.04	5720	3.00	6937	14.00	14986

Fig. 6-16

PRODUCED JM 1145-83

MT-PWHD-004683

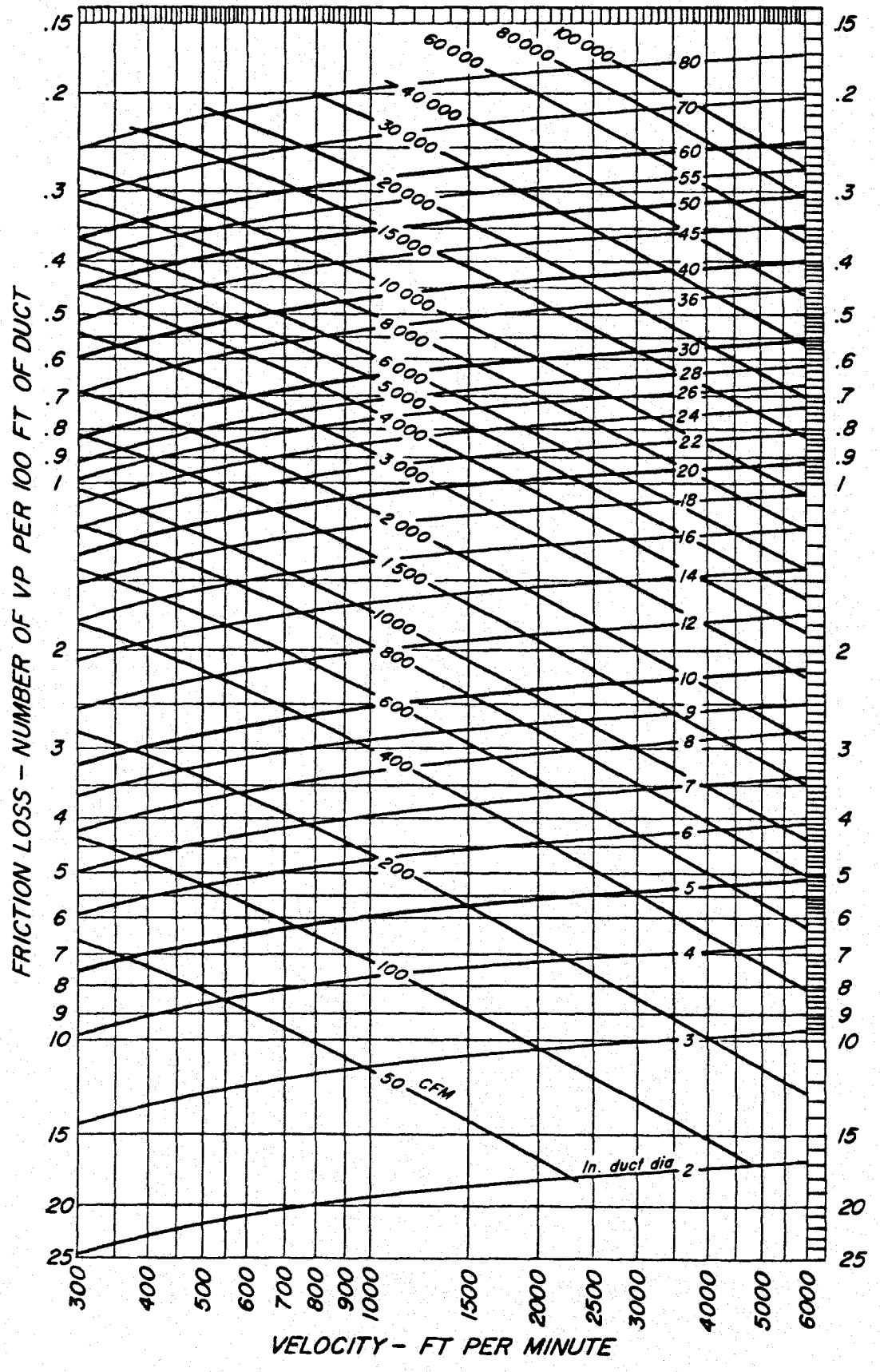


Fig. 6-17

PRODUCED JM - 83
1146

MT-PWHD-004684

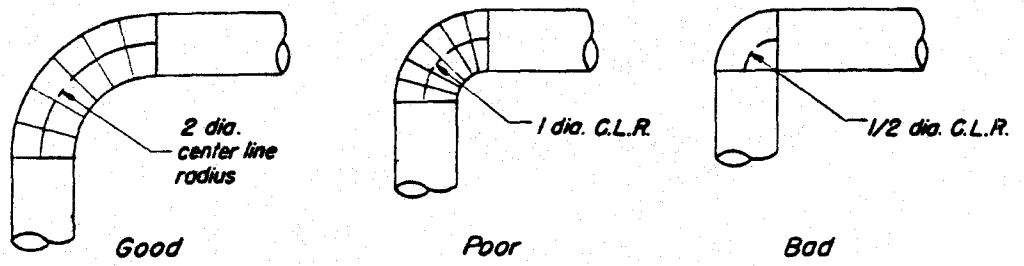
AREA AND CIRCUMFERENCE OF CIRCLES

Diam. in Inches	AREA		CIRCUMFERENCE		Diam. in Inches	AREA		CIRCUMFERENCE	
	Square Inches	Square Feet	Inches	Feet		Square Inches	Square Feet	Inches	Feet
1	.7854	.0054	3.1416	.2618	30	706.8	4.909	94.25	7.854
1½	1.767	.0123	4.712	.3927	31	754.7	5.241	97.39	8.116
2	3.14	.0218	6.28	.5236	32	804.2	5.585	100.5	8.376
2½	4.910	.0341	7.854	.6544	33	855.3	5.940	103.7	8.639
3	7.07	.0491	9.42	.7854	34	907.9	6.305	106.8	8.901
3½	9.620	.0668	11.00	.9164	35	962.1	6.611	109.9	9.163
4	12.57	.0873	12.57	1.047	36	1017.8	7.069	113.1	9.425
4½	15.90	.1105	14.14	1.178	37	1075.2	7.467	116.2	9.686
5	19.63	.1364	15.71	1.309	38	1134.1	7.876	119.4	9.948
5½	23.76	.1650	17.28	1.439	39	1194.5	8.296	122.5	10.21
6	28.27	.1964	18.85	1.571	40	1256.6	8.727	125.7	10.47
6½	33.18	.2305	20.42	1.702	41	1320.2	9.168	128.8	10.73
7	38.48	.2673	21.99	1.833	42	1385.4	9.621	131.9	10.99
7½	44.18	.3068	23.56	1.964	43	1452.2	10.08	135.1	11.26
8	50.27	.3491	25.13	2.094	44	1520.5	10.56	138.2	11.52
8½	56.75	.3940	26.70	2.225	45	1590.4	11.04	141.4	11.78
9	63.62	.4418	28.27	2.356	46	1661.9	11.54	144.5	12.04
9½	70.88	.4923	29.85	2.487	47	1734.9	12.05	147.6	12.30
10	78.54	.5454	31.42	2.618	48	1809.5	12.57	150.8	12.57
11	95.03	.6600	34.56	2.880	49	1885.7	13.10	153.9	12.83
12	113.1	.7854	37.70	3.142	50	1963.5	13.64	157.1	13.09
13	132.7	.9218	40.84	3.403	51	2042	14.19	160.2	13.35
14	153.9	1.069	43.98	3.665	52	2124	14.75	163.4	13.61
15	176.7	1.227	47.12	3.927	53	2206	15.32	166.5	13.88
16	201.0	1.396	50.26	4.189	54	2290	15.90	169.6	14.14
17	226.9	1.576	53.41	4.451	56	2463	17.10	175.9	14.66
18	254.4	1.767	56.55	4.712	58	2642	18.35	182.2	15.18
19	283.5	1.969	59.69	4.974	60	2827	19.63	188.5	15.71
20	314.1	2.182	62.83	5.236	62	3019	20.97	194.8	16.33
21	346.3	2.405	65.97	5.498	64	3217	22.34	201.1	16.76
22	380.1	2.640	69.11	5.760	66	3421	23.76	207.3	17.28
23	415.4	2.885	72.26	6.021	68	3632	25.22	213.6	17.80
24	452.3	3.142	75.40	6.283	70	3848	26.73	219.9	18.33
25	490.8	3.409	78.54	6.545	72	4072	28.27	226.2	18.85
26	530.9	3.687	81.68	6.807	74	4301	29.87	232.5	19.37
27	572.5	3.976	84.82	7.069	76	4536	31.50	238.8	19.90
28	615.7	4.276	87.96	7.330	78	4778	33.18	245.0	20.42
29	660.5	4.587	91.11	7.592	80	5027	34.91	251.3	20.94

Fig. 6-18

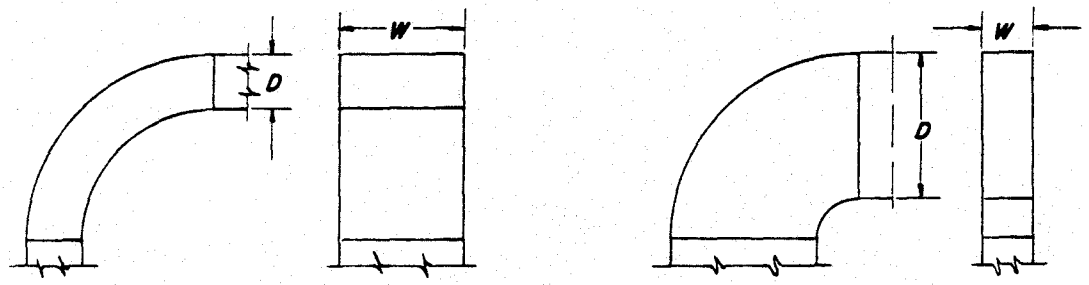
1147
PRODUCED
JM - 83

MT-PWHD-004685



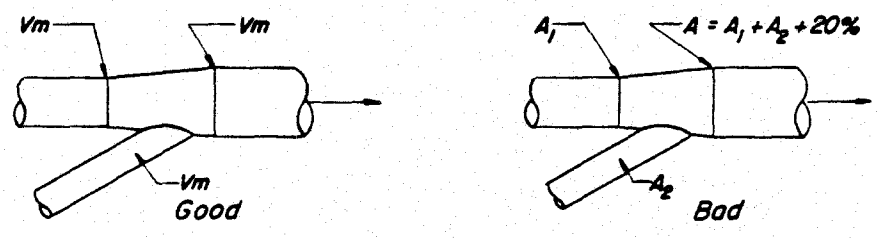
ELBOW RADIUS

Elbows should be 2 or 2 1/2 diameters centerline radius except where space does not permit.



ASPECT RATIO

Keep AR($\frac{W}{D}$) high in using rectangular duct



Vm = Minimum transport velocity.
A = Cross section area.

PROPER DUCT SIZE

Size the duct to hold the selected transport velocity or higher.

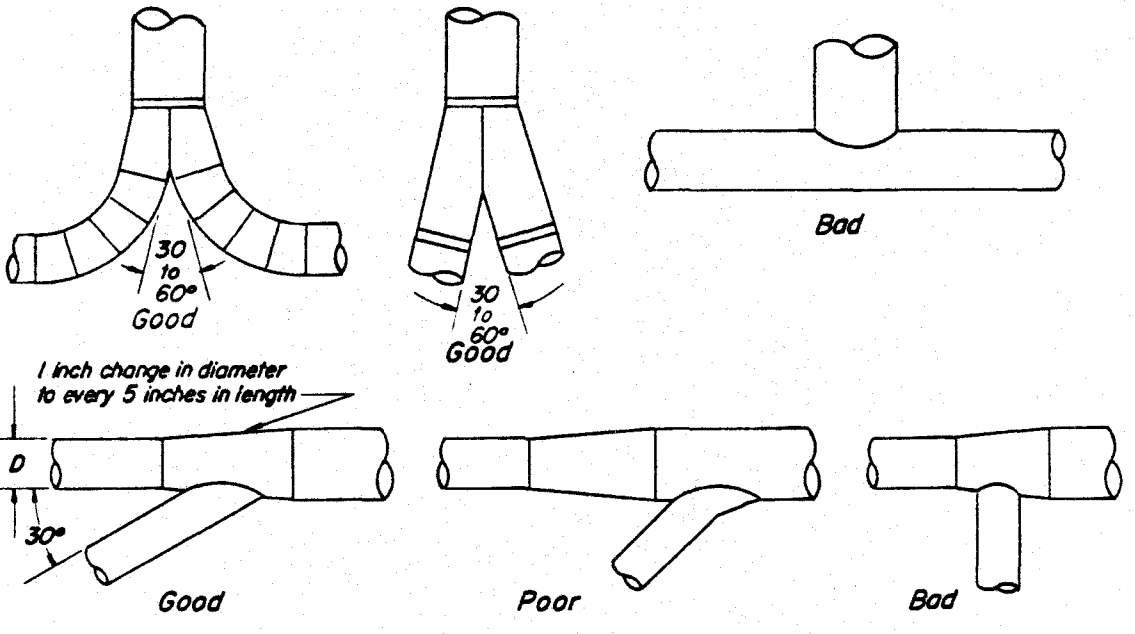
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

PRINCIPLES OF DUCT DESIGN

DATE 1-66 | Fig. 6-19

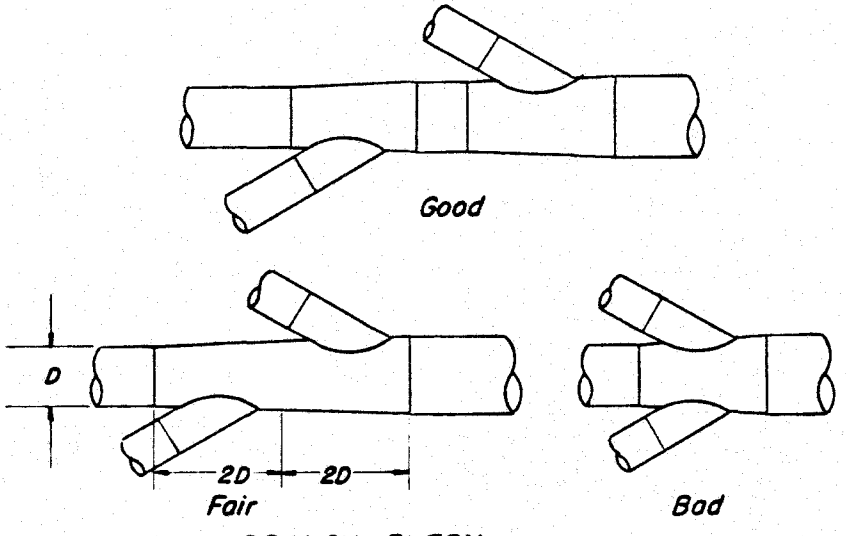
1148 PRODUCED JM - 83

MT-PWHD-004686



BRANCH ENTRY

Branches should enter at gradual expansions and at an angle of 30° or less (preferred) to 45° if necessary.



BRANCH ENTRY

Branches should not enter directly opposite each other.

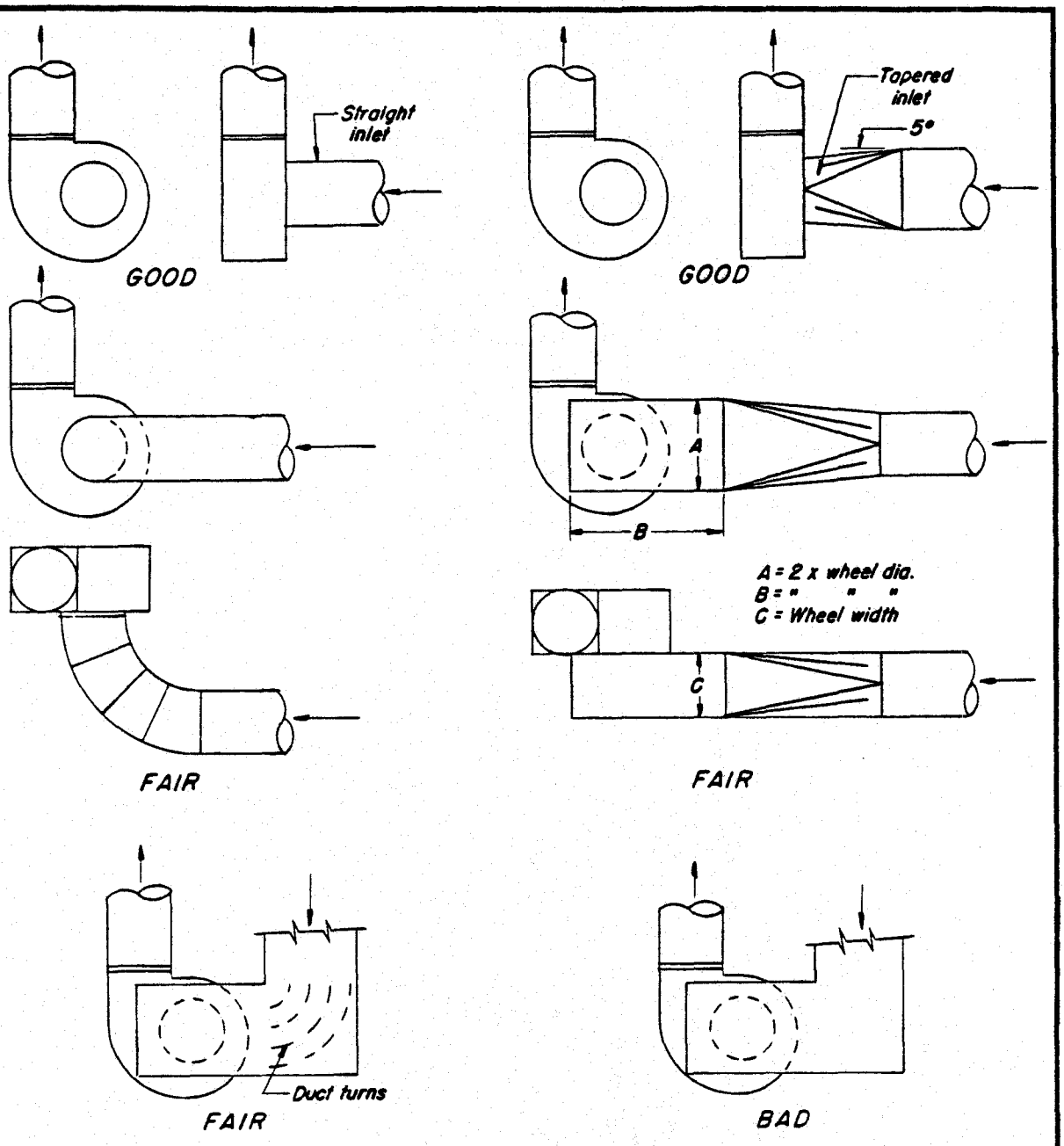
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

PRINCIPLES OF DUCT DESIGN

DATE 1-66 | Fig. 6-20

PRODUCED JM - 83
1149

MT-PWHD-004687



FAN INLET

A straight inlet is best: if an elbow inlet is necessary, provide an inlet box and duct turn vanes to eliminate air spin or uneven loading of the fan wheel. Inlet boxes should not be used for dust-laden air.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

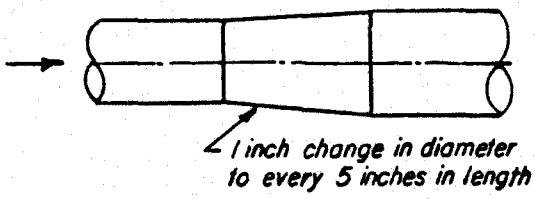
PRINCIPLES OF DUCT DESIGN

DATE 1-66 | Fig. 6-21

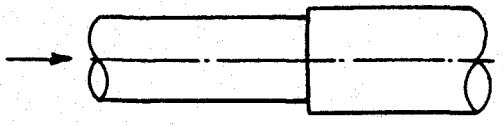
1150 PRODUCED JM - 83

MT-PWHD-004688

DUCT ENLARGEMENT

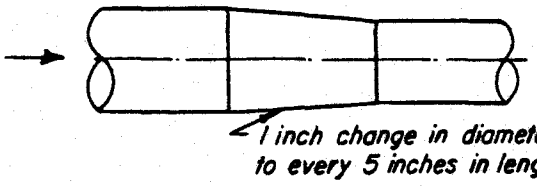


GOOD

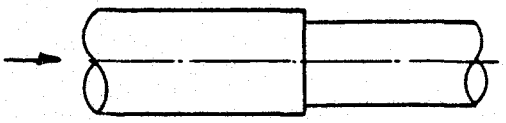


BAD

DUCT CONTRACTION

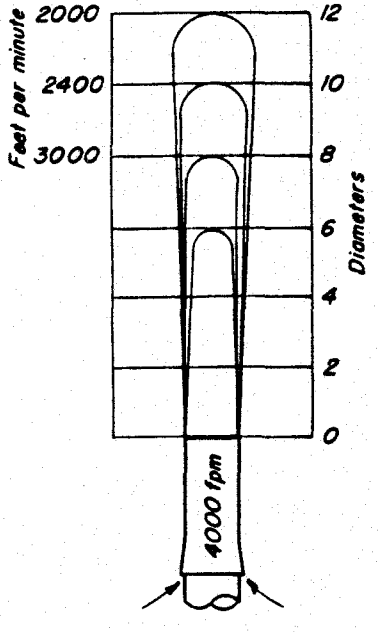


GOOD



BAD

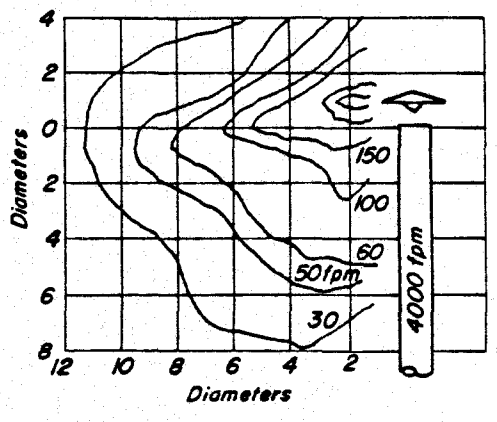
STACKHEAD



RIGHT

Vertical discharge cap throws upward where dilution will take place.

WEATHER CAP



WRONG

Deflecting weather cap discharges downward.

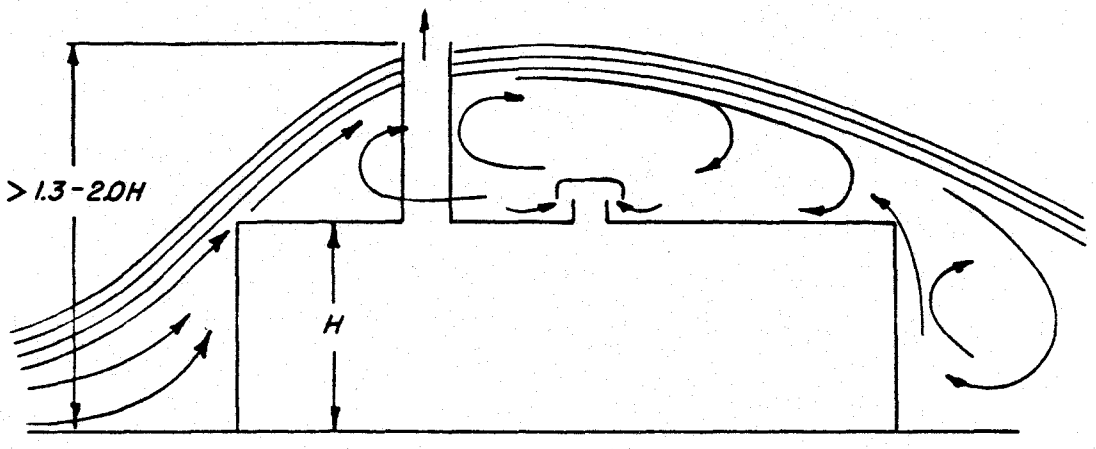
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

PRINCIPLES OF DUCT DESIGN

DATE 9-66 | Fig. 6-22

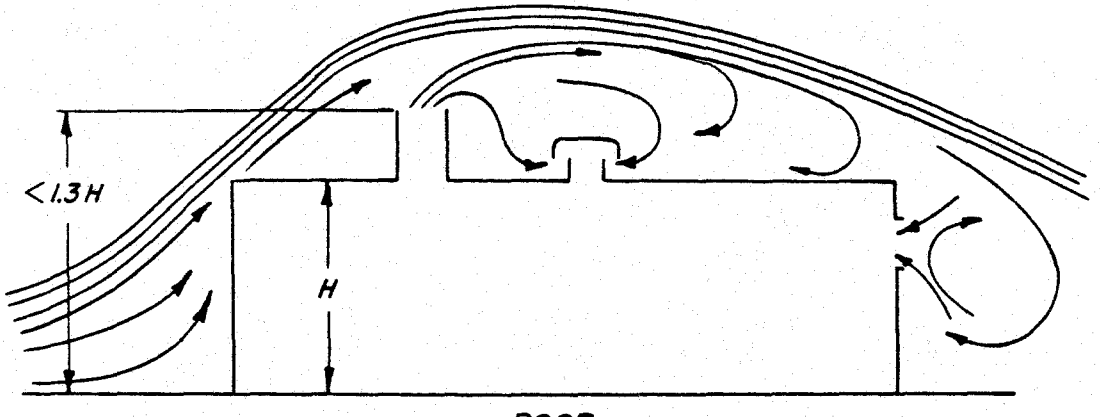
PRODUCED IN - 82
1151

MT-PWHD-004689



GOOD

High discharge stack relative to building height, air inlet on roof.



POOR

Low discharge stack relative to building height, air inlet on roof and wall.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
BUILDING AIR INLETS AND OUTLETS	
DATE 1-66	Fig. 6-23

(Ref. 87)

1152 PRODUCED JM - 83

MT-PWHD-004690

Circular Equivalents of Rectangular Ducts for Equal Friction and Capacity

Side Rectangular Duct	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16
3.0	3.9	4.0	4.2	4.4	4.6	4.8	4.9	5.1	5.2	5.4	5.5	5.6	5.7	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0
3.5	4.1	4.3	4.6	4.8	5.0	5.2	5.3	5.5	5.7	5.8	6.0	6.1	6.3	6.4	6.5	6.7	6.5	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6
4.0	4.4	4.6	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.4	6.6	6.8	6.9	7.1	7.2	7.3	7.5	7.5	7.7	7.9	7.9	8.1	8.2	8.3
4.5	4.6	4.9	5.2	5.4	5.5	5.9	6.1	6.3	6.5	6.7	6.9	7.0	7.2	7.4	7.5	7.7	7.5	8.0	8.1	8.2	8.4	8.5	8.6	8.7	8.9
5.0	4.9	5.2	5.5	5.7	6.0	6.2	6.4	6.7	6.9	7.1	7.3	7.4	7.6	7.8	8.0	8.1	8.3	8.4	8.6	8.7	8.9	9.0	9.1	9.3	9.4
5.5	5.1	5.4	5.7	6.0	6.3	6.5	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2	8.4	8.6	8.7	8.8	9.0	9.2	9.4	9.5	9.6	9.8	9.8

Side Rectangular Duct	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	56	60	64	68	72	76	80	84	88	Side Rectangular Duct
6	6.6																																								6
7	7.1	7.7																																								7
8	7.5	8.2	8.8																																						8
9	8.0	8.6	9.3	9.9																																						9
10	8.4	9.1	9.8	10.4	10.9																																				10
11	8.8	9.5	10.2	10.9	11.4	12.0																																			11
12	9.1	9.9	10.7	11.3	11.9	12.5	13.1																																		12
13	9.5	10.3	11.1	11.8	12.4	13.0	13.6	14.2																																	13
14	9.8	10.7	11.5	12.2	12.9	13.5	14.2	14.7	15.3																																14
15	10.1	11.0	11.8	12.6	13.3	14.0	14.6	15.3	15.8	16.4																															15
16	10.4	11.4	12.2	13.0	13.7	14.4	15.1	15.7	16.3	16.9	17.5																														16
17	10.7	11.7	12.5	13.4	14.1	14.9	15.5	16.1	16.8	17.4	18.0	18.6																													17
18	11.0	11.9	12.9	13.7	14.5	15.3	16.0	16.6	17.3	17.9	18.5	19.1	19.7																												18
19	11.2	12.2	13.2	14.1	14.9	15.6	16.4	17.1	17.8	18.4	19.0	19.6	20.2	20.8																											19
20	11.5	12.5	13.5	14.4	15.2	15.9	16.8	17.5	18.2	18.8	19.5	20.1	20.7	21.3	21.9																										20
22	12.0	13.1	14.1	15.0	15.9	16.7	17.6	18.3	19.1	19.7	20.4	21.0	21.7	22.3	22.9	24.1																									22
24	12.4	13.6	14.6	15.6	16.6	17.5	18.3	19.1	19.8	20.6	21.3	21.9	22.6	23.2	23.9	25.1	26.2																								24
26	12.8	14.1	15.2	16.2	17.2	18.1	19.0	19.8	20.6	21.4	22.1	22.8	23.5	24.1	24.8	26.1	27.2	28.4																							26
28	13.2	14.5	15.6	16.7	17.7	18.7	19.6	20.5	21.3	22.1	22.9	23.6	24.4	25.0	25.7	27.1	28.2	29.5	30.6																						28
30	13.6	14.9	16.1	17.2	18.3	19.3	20.2	21.1	22.0	22.9	23.7	24.4	25.2	25.9	26.7	28.0	29.3	30.5	31.6	32.8																					30
32	14.0	15.3	16.5	17.7	18.8	19.8	20.8	21.8	22.7	23.6	24.4	25.2	26.0	26.7	27.5	28.9	30.1	31.4	32.6	33.8	35.0																				32
34	14.4	15.7	17.0	18.2	19.3	20.4	21.4	22.4	23.3	24.2	25.1	25.9	26.7	27.5	28.3	29.7	31.0	32.3	33.6	34.8	36.0	37.2																			34
36	14.7	16.1	17.4	18.6	19.8	20.9	21.9	23.0	23.9	24.8	25.8	26.6	27.4	28.3	29.0	30.5	32.0	33.0	34.6	35.8	37.0	38.2	39.4																		36
38	15.0	16.4	17.8	19.0	20.3	21.4	22.5	23.5	24.5	25.4	26.4	27.3	28.1	29.0	29.8	31.4	32.8	34.2	35.5	36.7	38.0	39.2	40.4	41.6																	38
40	15.3	16.8	18.2	19.4	20.7	21.9	23.0	24.0	25.1	26.0	27.0	27.9	28.8	29.7	30.5	32.1	33.6	35.1	36.4	37.6	39.0	40.2	41.4	42.6	43.8																40
42	15.6	17.1	18.5	19.8	21.1	22.3	23.4	24.5	25.6	26.6	27.6	28.5	29.4	30.4	31.2	32.8	34.4	35.9	37.3	38.6	39.9	41.1	42.4	43.6	44.8	45.9															42
44	15.9	17.5	18.9	20.2	21.5	22.7	23.9	25.0	26.1	27.2	28.2	29.1	30.0	31.0	31.9	33.5	35.2	36.7	38.1	39.5	40.8	42.0	43.4	44.6	45.8	46.9	48.1														44
46	16.2	17.8	19.2	20.6	21.9	23.2	24.3	25.5	26.7	27.7	28.7	29.7	30.6	31.6	32.5	34.2	35.9	37.4	38.9	40.3	41.7	43.0	44.3	45.6	46.8	47.9	49.1	50.3													46
48	16.5	18.2	19.6	20.9	22.3	23.6	24.8	26.0	27.2	28.2	29.2	30.2	31.2	32.2	33.1	34.9	36.6	38.2	39.7	41.2	42.6	43.9	45.2	46.5	47.8	48.9	50.2	51.3	52.6												48
50	16.8	18.4	19.9	21.3	22.7	24.0	25.2	26.4	27.6	28.7	29.8	30.8	31.8	32.8	33.7	35.5	37.3	38.9	40.4	42.0	43.5	44.8	46.1	47.4	48.7	49.8	51.2	52.3	53.6	54.7											50
52	17.0	18.7	20.2	21.6	23.1	24.4	25.6	26.8	28.1	29.2	30.3	31.4	32.4	33.4	34.3	36.2	38.0	39.6	41.2	42.8	44.3	45.7	47.1	48.3	49.7	50.8	52.2	53.3	54.6	55.8	56.9										52
54	17.3	19.0	20.5	22.0	23.4	24.8	26.1	27.3	28.5	29.7	30.8	31.9	32.9	33.9	34.9	36.8	38.7	40.3	42.0	43.6	45.0	46.5	48.0	49.3	50.6	51.8	53.2	54.3	55.6	56.8	57.9										54
56	17.6	19.3	20.9	22.4	23.8	25.2	26.5	27.7	28.9	30.1	31.2	32.4	33.4	34.5	35.5	37.4	39.3	41.0	42.7	44.3	45.8	47.3	48.8	50.1	51.5	52.7	54.1	55.3	56.5	57.8	58.9	61.3									56
58	17.8	19.5	21.1	22.7	24.2	25.5	26.9	28.2	29.3	30.5	31.7	32.9	33.9	35.0	36.0	38.0	39.8	41.7	43.4	45.0	46.6	48.1	49.6	51.0	52.4	53.7	55.0	56.2	57.5	58.8	60.0	62.3									58
60	18.1	19.8	21.4	23.0	24.5	25.8	27.3	28.7	29.8	31.0	32.2	33.4	34.5	35.5	36.5	38.6	40.4	42.3	44.0	45.8	47.3	48.9	50.4	51.8	53.3	54.6	55.9	57.1	58.5	59.8	61.0	63.3	65.7								60
62	18.3	20.1	21.7	23.3	24.8	26.2	27.6	29.0	30.2	31.4	32.6	33.8	35.0	36.0	37.1	39.2	41.0	42.9	44.7	46.5	48.0	49.7	51.2	52.6	54.2	55.5	56.8	58.0	59.4	60.7	62.0	64.3	66.7								62
64	18.6	20.3	22.0	23.6	25.2	26.5	27.9	29.3	30.6	31.8	33.1	34.2	35.5	36.5	37.6	39.7	41.6	43.5	45.4	47.2	48.7	50.4	52.0	53.4	55.0	56.4	57.7	59.0	60.3	61.6	62.9	65.3	67.7	70.0							64
66	18.8	20.6	22.3	23.9	25.5	26.9	28.3	29.7	31.0	32.2	33.5	34.7	35.9	37.0	38.1	40.2	42.2	44.1	46.0	47.8	49.5	51.1	52.8	54.2	55.8	57.2	58.6	59.9	61.2	62.5	63.9	66.3	68.7	71.1							66
68	19.0	20.8	22.5	24.2	25.8	27.3	28.7	30.1	31.4	32.6	33.9	35.1	36.3	37.5	38.6	40.7	42.8	44.7	46.6	48.4	50.2	51.8	53.5	55.0	56.6	58.0	59.5	60.8	62.1	63.4	64.8	67.3	69.7	72.1	74.4						68
70	19.2	21.1	22.8	24.5	26.1	27.6	29.1	30.4	31.8	33.1	34.3	35.6	36.8	37.9	39.1	41.3	43.3	45.3	47.2	49.0	50.9	52.5	54.2	55.8	57.3	58.8	60.3	61.7	63.0	64.3	65.7	68.3	70.7	73.1	75.4						70
72															39.6	41.8	43.8	45.9	47.8	49.7	51.5	53.2	54.9	56.5	58.0	59.6	61.1	62.6	63.9	65.2	66.6	69.2	71.7	74.1	76.4	78.8					72
74															40.0	42.3	44.4	46.4	48.4	50.3	52.1	53.9	55.6	57.2	58.8	60.4	61.9	63.3	64.8	66.1	67.5	70.1	72.7	75.1	77.4	79.7					74
76															40.5	42.8	44.9	47.0	49.0	50.8	52.7	54.6	56.3	57.9	59.5	61.2	62.7	64.1	65.6	67.0	68.4	71.0	73.6	76.1	78.4	80.9	83.2				76
78															40.9	43.3	45.5	47.5	49.5	51.5	53.3	55.2	57.0	58.6	60.3	62.0	63.4	64.9	66.4	67.9	69.3	71.8	74.5	77.1	79.4	81.8	84.2				78
80															41.3	43.8	46.0	48.0	50.1	52.0	53.9	55.8	57.6	59.3	61.0	62.7	64.3	65.7	67.2	68.7	70.1	72.7	75.4	78.1	80.4	82.8	85.2	87.5			80
82															41.8	44.2	46.4	48.6	50.6	52.6	54.5	56.4	58.2	60.0	61.7	63.4	64.9	66.5	68.0	69.5	71.0	73.6	76.3	79.0	81.4	83.8	86.2	88.6			82
84															42.2	44.6	46.9	49.2	51.1	53.2	55.1	57.0	58.9	60.7	62.4	64.1	65.7	67.3	68.8	70.3	71.8	74.5	77.2	79.9	82.4	84.8	87.2	89.6	91.9		84
86															42.6	45.0	47.4	49.6	51.6	53.7	55.7	57.6	59.5	61.3	63.0	64.8	66.4	68.0	69.5	71.1	72.6	75.4	78.1	80.8	83.3	85.8	88.2	90.6	92.9		86
88															43.0	45.4	47.9	50.1	52.2	54.3	56.3	58.2	60.1	62.0	63.7	65.4	67.0	68.7	70.3	71.8	73.4	76.3	79.0	81.6	84.2	86.8	89.2	91.6	93.9	96.3	88
90															43.4	45.9	48.3	50.6	52.8	54.8	56.9	58.8	60.7	62.6	64.4	66.0	67.8	69.4	71.1	72.6	74.2	77.1	79.9	82.5	85.1	87.8	90.2	92.6	94.9	97.3	90
92															43.8	46.3	48.7	51.1	53.4	55.4	57.4	59.4	61.3	63.2	65.0	66.8	68.5	70.1	71.8	73.3	74.9	77.8	80.8	83.4	86.0	88.7	91.2	93.6	95.9	98.3	92
94															44.2	46.7	49.1	51.6	53.9	55.9	57.9	60.0	61.9	63.8	65.6	67.5	69.2	70.8	72.5	74.1	75.6	78.6	81.7	84.3	86.9	89.6	92.1	94.6	96.9	99.3	94
96															44.6	47.2	49.5	52.0	54.4	56.5	58.4	60.5	62.4	64.4	66.2	68.2	69.8	71.5	73.2	74.8	76.3	79.4	82.6	85.2	87.8	90.5	93.0	95.6	97.9	100.3	96

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Fig. 6-24

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Section 7

MAKE-UP AND RECIRCULATED AIR

Principles of Make-Up Air

Make-up air is a ventilation term used to indicate the supply of outdoor air to a building to replace air removed by exhaust ventilation and combustion processes.

In some cases, an exhaust system will induce sufficient air flow into the building to replace the air being exhausted without producing adverse effects. However, when exhaust volumes are high relative to the size of the building and the free inlet area, difficulty is encountered and make-up air must be supplied. Make-up air not only replaces the volume of air exhausted but can also serve as supplemental, general ventilation for comfort. The volume of make-up air should be approximately the same as the total volume exhausted, although in some cases where a flow of air from clean areas to contaminated areas is desired, balance can be achieved by regulating the quantity of make-up air.

Natural Infiltration

The need for make-up air should not be based on "air change" figures since there is a great variation between new and old buildings, as well as differences in basic building types. A relatively old building with large sash areas is "open" and air leakage will be quite pronounced. On the other hand, a modern, windowless plant of masonry construction is practically air tight and the building will be truly "air starved" with appreciable exhaust ventilation. Between these two extremes it is difficult to apply engineering data to determine minimum volumes required. In general it is best to provide make-up to supply approximately the same volume of air as that exhausted.

Make-up air is important for the following reasons:

1. To insure that exhaust hoods operate properly--A lack of make-up air creates a "negative pressure" condition which increases static pressure which the exhaust fans must overcome. This causes a reduction in exhaust volume and is particularly serious with low-pressure fans such as wall fans and roof exhausters.
2. To insure the proper operation of natural stacks such as combustion flues and vents.
3. To eliminate high-velocity cross drafts through windows and shipping doors--These cross drafts not only interfere with proper operation of exhaust ventilation but may also disperse contaminated air from one section of the building into another. This is particularly important in the case of dusty operations where settled material may be dislodged from beams and ledges.
4. To eliminate cold drafts on workers--Drafts not only cause discomfort and reduced working efficiency but may also result in lower overall plant ambient temperatures from the existing heating equipment.
5. To eliminate differential pressure on doors.

It must be emphasized that make-up air will always enter the building; otherwise the exhaust fans cannot function. Further, this air will be heated eventually by inefficient mixing, while still producing all the disadvantages in air leakage and inefficient exhaust ventilation. It is more economical to introduce the air through make-up air heaters whereby its temperature and distribution can be controlled.

Application of Make-Up Air

1. The fresh air intake should be located remote from any contaminating sources such as exhaust stacks or furnace exhausts. It is advisable to filter the fresh air to protect the equipment and provide maximum heat exchange efficiency. In the case of finned-coil heating units, filtering is necessary to prevent plugging.

2. The air supply system must be provided with a fan. Otherwise the room will still be under a negative pressure since the exhaust fans must pull the air through the resistances of the filters, coils and ductwork.

3. Make-up air sources should be located to provide cross ventilation. In this way the air can be "used twice." First, it will provide general ventilation of nuisance producing areas and finally, make-up air for the exhaust systems. This does not apply for spot cooling applications where the air will be introduced directly at the work station and may vary significantly from room temperature. The air distribution pattern

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must be engineered carefully to provide effective area coverage without excessive cross drafts which will interfere with the workers or the existing systems. Preferably, there should be convenient "two-season" control to afford changes in the make-up air pattern for summer and winter without closing off the outlets.

4. Make-up air should be introduced into the "living zone" of the plant, that is, below the 8' - 10' level. In this manner the air is used first by the people and best results of general ventilation are obtained. This distribution also provides closer control of the ambient working temperature.

5. Make-up air temperatures are usually maintained at approximately the same as the desired room temperature. Since this air is being used for ventilation and replacement purposes and is not relied on for heating the building, the usual temperature range will be 65-80 F. However, in modern high-speed machining areas where equipment heat load is a factor, lower air temperatures can be used. Make-up air is also used for spot cooling applications at very high heat stress operations. In these cases the final air temperature and air motion depend on the workers' requirements.

Make-Up Air Equipment

There are three basic equipment types: (1) Heat exchangers using steam or hot water, (2) Direct-fired heat exchangers using oil or gas and (3) Open flame heaters.

1. Steam and hot water units should be provided with distributing-tube coils (non-freeze) and automatic controls to minimize the possibility of freezing the heating coils during sub-zero conditions. Controls will include modulating valves, thermostats and motor-operated outside louvers. Multiple coil units with preheat and reheat coils usually give closer control of discharge air temperature than single coil units. Condensate return piping must be sized for the large volumes of returned water and coils must be vented properly to assure proper flow at various positions of the main valve.

2. Direct-fired units must be vented to the outside and must be provided with adequate safety controls as specified by the American Gas Association and various underwriting firms. Attention must be given to proper location from the standpoint of air distribution and restrictions for hazardous locations.

3. Open-flame heaters are those units in which the fuel is burned directly in the make-up air stream with no outside venting. These units are usually gas-fired and the combustion safety controls must be of the approved type. Care must be taken in their location also, especially where hazardous materials are involved. Since these units present a potential danger of carbon monoxide gas, additional requirements must be met:

A. The make-up air volume must be sufficient to dilute any possible carbon monoxide to less than 10 ppm.

B. Controls must stop the supply fan and close the main gas valve in case of any flame failure.

C. Controls should be arranged to interlock the make-up air unit with the exhaust fans (or the main exhaust fan) to prevent the unit from being operated without sufficient exhaust ventilation.

Engineering data on conventional oil and gas fuels is included in Table 7-3. From these the engineer may calculate fuel and combustion air requirements for gas and oil-fired make-up air units.

Cost of Heating Make-Up Air

As noted above, all air that enters the building will be heated to some extent by mixing, thus the operating cost of makeup air units will not be necessarily additive to the overall plant heating cost; in fact, costs can actually drop when an efficient makeup air unit is used.

The following two equations may be used to estimate makeup air heating costs on an hourly and yearly basis. Since there is an allowance for the efficiency of the makeup air unit, these equations will tend to give a low result if air is allowed to enter by infiltration only.

$$\text{Hourly cost} = \frac{0.001\ QN}{q} \times c \qquad \text{Yearly cost} = \frac{0.154\ QD\ dg}{q} \times c$$

Where: Q = air volume, cfm
N = required heat, BTU/hr/1000 cfm (Figure 7-1 and Table 7-1)
D = operating time, hours/week
q = available heat per unit of fuel (Table 7-2)
dg = Annual Degree Days (Table 7-3)
c = cost of fuel, $/unit

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Example Problem 1

Find the hourly cost of tempering 10,000 cfm of makeup air to 70 F in St. Louis, Missouri, using oil at $0.08/gallon.

Average temperature = 35 F (Figure 7-1).

$$\text{Hourly cost} = \frac{0.001\ QN}{q} \times c = \frac{0.001 \times 10{,}000 \times 38{,}000}{106{,}500} \times 0.08 = \$0.235/\text{hour}$$

Example Problem 2

Find the annual cost for the same city.

Annual degree days, dg, = 6023 (Table 7-3)

Operating time, D, = 40 hours/week

$$\text{Yearly cost} = \frac{0.154 \times 10{,}000 \times 40 \times 6023}{106{,}500} \times 0.08 = \$279.00/\text{year}$$

Formula 2 is more representative of annual costs because both the length and the severity of the heating season are taken into account.

Average Outside Air Temperature, F	N, Required Heat BTU/hr/1000 cfm @ 70F
0	75,500
5	70,000
10	65,000
15	59,500
20	54,000
25	48,500
30	43,000
35	38,000
40	32,500
45	27,000
50	21,500
55	16,000
60	11,000
65	5,500

TABLE 7-1

Fuel	Btu Per Unit	Efficiency %	Available Btu Per Unit q
Coal	12,000 Btu/lb.	50	6,000
Oil	142,000 Btu/gal.	75	106,500
Gas	1,000 Btu/cu.ft.		
Heat Exchanger		80	800
Direct Fired		90	900

TABLE 7-2

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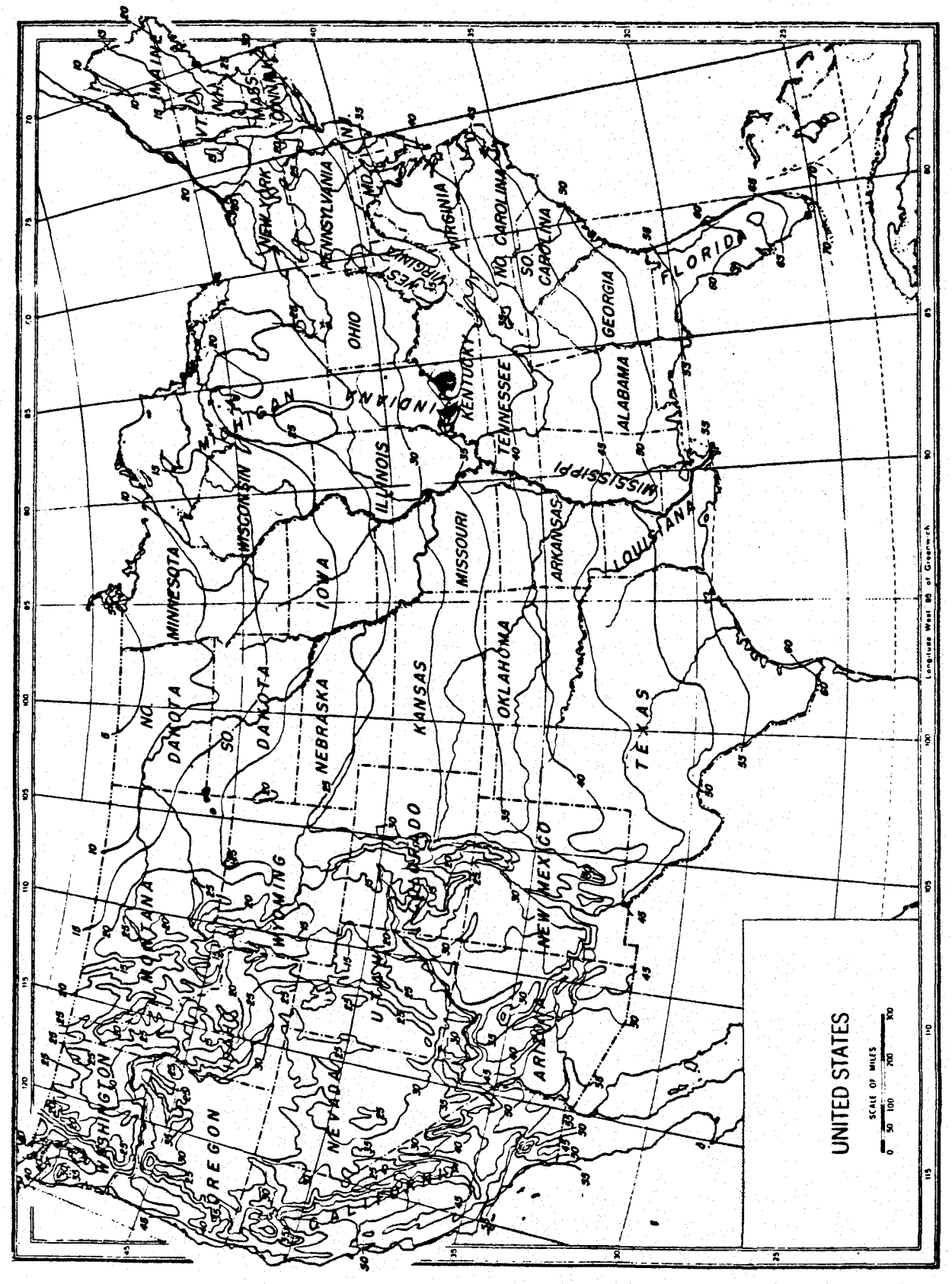


Fig. 7-1. Average Winter Temperatures December - February, Inclusively. (Courtesy U.S. Weather Bureau.)

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HEATING DEGREE-DAY NORMALS (79)

Air Discharge Temperature F (Base)	Albany	Boston	Chicago	Cleveland	Detroit	Minneapolis	N. Y.	Phila.	Pittsburgh	St. Louis	Wash., D. C.
					Annual Heating Degree-Day Normals						
80	11782	10409	10613	11343	10959	13176	9284	9652	10797	8943	8422
79	11425	10049	10277	10982	10605	12826	8937	9300	10436	8624	8089
78	11062	9690	9940	10621	10256	12478	8596	8954	10076	8310	7764
77	10709	9342	9610	10265	9914	12135	8265	8619	9723	8003	7446
76	10356	8994	9283	9915	9581	11797	7938	8285	9379	7702	7139
75	10009	8652	8972	9570	9247	11475	7620	7959	9036	7413	6835
74	9669	8317	8656	9229	8920	11142	7308	7641	8702	7121	6538
73	9333	7990	8349	8898	8599	10816	7004	7328	8373	6839	6250
72	9007	7668	8046	8567	8291	10496	6706	7028	8050	6560	5974
71	8682	7354	7750	8248	7981	10180	6421	6728	7740	6289	5703
70	8364	7046	7468	7928	7678	9870	6146	6438	7429	6023	5438
69	8056	6749	7183	7617	7383	9567	5871	6158	7127	5767	5179
68	7750	6458	6905	7313	7100	9269	5606	5886	6833	5523	4929
67	7452	6175	6635	7016	6816	8975	5349	5618	6546	5277	4690
66	7162	5903	6373	6722	6543	8687	5101	5360	6272	5053	4455
65	6881	5633	6122	6445	6278	8410	4858	5109	5997	4822	4229
64	6607	5370	5875	6165	6020	8131	4621	4864	5734	4595	4014
63	6340	5118	5638	5897	5772	7858	4394	4628	5483	4379	3798
62	6081	4873	5399	5636	5533	7590	4176	4397	5234	4168	3588
61	5829	4634	5164	5381	5290	7339	3957	4172	5006	3963	3383
60	5586	4399	4936	5140	5054	7086	3747	3952	4769	3761	3182

TABLE 7-3 (2)

Recirculation of Air From Industrial Exhaust Systems

It is apparent that if large amounts of air are exhausted from a room or building in order to remove obnoxious dusts, gases, fumes or vapors, an equivalent amount of fresh, tempered air should be supplied to the room. The supplied air must be heated in cold weather and heating costs may be large if sizeable amounts of air are handled. Attempts are sometimes made to eliminate such heating costs by appropriate cleaning of the exhausted air and subsequent recirculation of the air into the room. Acceptance of such recirculating systems will depend on the degree of health hazard associated with the particular contaminant being exhausted, as well as on other factors discussed below.

Recirculation Not Recommended: It is the general policy of all official industrial health agencies not to recommend the recirculation of exhaust air if the contaminant is a material which may have a definite effect on the health of the worker. The reasons are as follows:

1. Many types of air cleaners do not collect toxic contaminants efficiently enough to remove the health hazard.
2. Poor maintenance of the air cleaner would result in the deliberate return of highly contaminated air to the breathing zone of the workers. Not being production equipment, air cleaners are too often poorly maintained.
3. Improper operation of the air cleaner, through mechanical failure or through ignorance or neglect on the part of the operators would also result in the return of highly contaminated air.

Recirculation Accepted: Some types of air contaminants, particularly some dusts, are regarded as nuisances rather than true health hazard. For exhaust systems handling these materials, recirculation may be accepted. No blanket acceptances can be made. Acceptance should be made on the merits of each specific application on the basis that if any of the factors mentioned above should operate to cause the return of contaminated air, such contamination would not result in unduly disagreeable working conditions.

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If a recirculating system is proposed in the case of a nuisance contaminant, the following factors concerning design and operation are of importance.

1. All air that is recirculated must first pass through an air cleaning device. The engineering specifications and collection effectiveness of the device must be known. Knowledge of the contaminant concentration in the effluent air stream under given conditions of application and contaminant loading is more valuable than percentage efficiencies alone.
2. The amount of contaminant returned in the effluent of the air cleaner must be NO MORE THAN 20% OF THE TLV. In some few instances other factors of plant operation may be such that it is impractical or unnecessary to hold to such a maximum.
3. The manufacturer's recommendations as to the operation and maintenance of air cleaning devices should be strictly followed.
4. Air distribution from the recirculation ductwork should not cause high velocity drafts on the workers or in the zone of influence of local exhaust hoods.
5. Wherever practical, discharge from air cleaners should be arranged for discharge to outside of the building except during the heating season.

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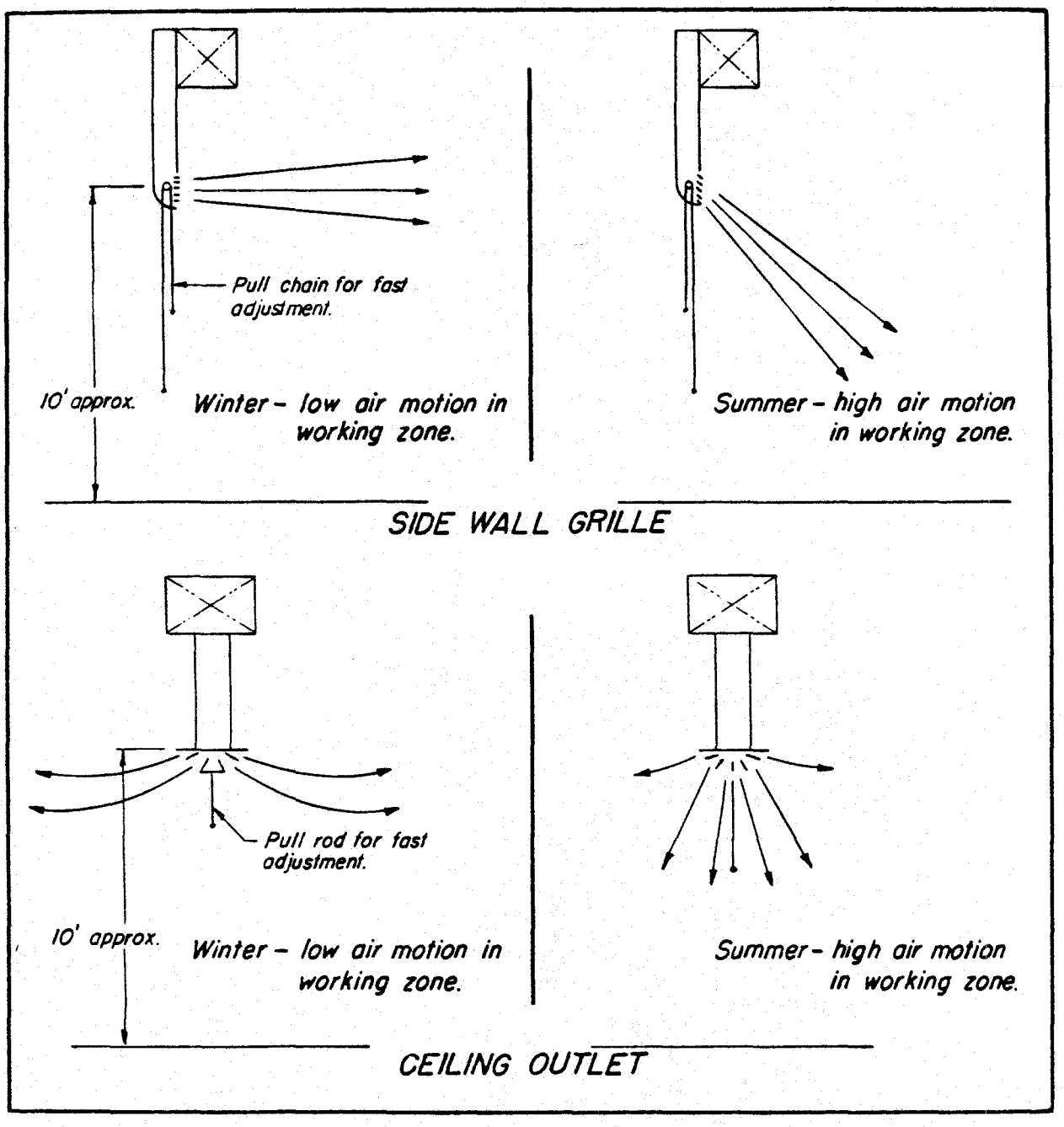


Fig. 7-2 Seasonal air control for comfort

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PROPERTIES OF TYPICAL OIL & GAS FUELS

	1	2	3	4	5	6	7	8	9	10	11
Gases	Fuel Unit	Heating Value, HV net BTU/ Fuel Unit	Air Required for Combustion, CR Ft³/ Fuel Unit	Ultimate % CO_2	Combustion Products						
					Ft³/ Fuel Unit				#/ Fuel Unit		Density
					CO_2	N_2	H_2O	Total PC	$CO_2 + N_2$(dry)	H_2O	#Ft³ **
Natural Gas (Pittsburgh)	Ft³	1021	10.58	12.1	1.15	8.37	2.22	11.73	0.739	0.1035	0.0718
Commercial Butane		2977	30.47	14.0	3.93	24.07	4.93	32.93	2.20	0.230	0.0738
Commercial Propane		2371	23.82	13.7	3.00	18.82	4.17	25.99	1.71	0.194	0.0733
Blast Furnace Gas		92	0.68	25.5	0.39	1.14	0.02	1.54	0.127	0.0009	0.0831
Corburetted Water Gas		508	4.60	17.2	0.76	3.66	0.87	5.29	0.352	0.0406	0.0742
Coke Oven Gas		514	4.99	11.2	0.51	4.02	1.25	5.78	0.350	0.0583	0.0706
Mixed Coke Oven & Corburetted Water Gas		495	4.71	13.9	0.62	3.85	1.04	5.51	0.350	0.0485	0.0723
Fuel Oils											
Kerosene – Distillate	Gal.	126,000	1230	13.3	177	984	169	1330	91.64	7.88	0.0748
#1 Fuel Oil *		127,300	1250								
#2 Fuel Oil *		131,500	1290	13.7	186	1005	164	1355	94.20	7.65	0.0752
#4 Fuel Oil *		140,600	1370								
Distillate or Residual											
#5 Fuel Oil – Residual PS – 300*		141,900	1380	13.9	204	1091	170	1465	102.5	7.93	0.0754
#6 Fuel Oil - PS – 400*		144,400	1410	14.6	219	1121	160	1500	106.4	7.46	0.0759

* Approximate Oil Classification

** Approximate density of combustion products at standard temperature and pressure, no excess air. #/ft³ of combustion products.

COMBUSTION CALCULATIONS

EA = Excess Air. Usually 0.20 (20%).

t_f = Flue gas temperature. Usually 300 - 500 F.

BTUh = BTU per hour
gph = gallons per hour
cfh = cubic feet per hour

	GAS	OIL
1. Fuel Consumption	$cfh = \frac{\text{Heating Requirement, BTUh}}{\text{HV BTU/ft (col. 2)}}$	$gph = \frac{\text{Heating Requirement, BTUh}}{\text{HV BTUh gal. (col. 2)}}$
2. Combustion air, scfm	$= \frac{\text{Gas, cfh} \times \text{CR, ft}^3/\text{ft}^3 \times (1.0 + \text{EA})}{60}$	$= \frac{\text{gph} \times \text{CR, ft}^3/\text{gal.} \times (1.0 + \text{EA})}{60}$
3. Flue gas volume, scfm	$= \frac{\text{Gas, cfh} \times (\text{Total PC} + (\text{CR} \times \text{EA}))}{60}$	$= \frac{\text{gph} \times (\text{Total PC} + (\text{CR} \times \text{EA}))}{60}$
4. Flue gas volume at stack temperature, acfm	GAS or OIL: Flue gas volume, scfm $\times \frac{460 + t_f}{530}$	

5. In certain processes combustion products are mixed with a ventilation air volume, Q,cfm. In order to enter the psychrometric chart the following approximation can be used:

HUMIDITY RATIO OF FLUE GAS – AIR MIXTURE, $\frac{\#H_2O}{\#\text{DRY AIR}} = \frac{\text{FUEL CONSUMPTION} \times \#H_2O \text{ (col. 10)}}{\text{FUEL CONSUMPTION} \times \#CO_2 + N_2 \text{ (col. 9)} + 4.5\,Q}$

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Section 8

CONSTRUCTION SPECIFICATIONS FOR LOCAL EXHAUST SYSTEMS

Correct design and competent installation of sheet steel ducts and hoods are necessary for the proper functioning of any exhaust system. The following minimum specifications are recommended.

General

All exhaust systems shall be constructed with the materials recommended herewith and shall be installed in a permanent and workmanlike manner. Interior of all ducts shall be smooth and free from obstructions with joints either welded or soldered air-tight.

Materials

1. Ducts shall be constructed of black iron welded or of galvanized sheet steel riveted and soldered unless the presence of corrosive gases, vapors and mists, or other conditions makes such material impractical. Galvanized construction is not recommended for temperatures exceeding 400 F. Welding of black iron lighter than 18 gauge is not recommended.
2. For average exhaust systems on non-corrosive applications, the following metal thickness shall be supplied:

Diameter of Straight Ducts	U. S. Standard Gauge for Steel Duct		
	Class I	Class II	Class III
to 8"	24	22	20
Over 8" to 18"	22	20	18
Over 18" to 30"	20	18	16
Over 30"	18	16	14

Class I. Includes non-abrasive applications such as paint spray, woodworking, pharmaceutical and food products; discharge ducts from dust collectors.

Class II. Includes non-abrasive material in high concentration (low pressure pneumatic conveying); moderately abrasive material; and highly abrasive materials in light concentrations. Typical examples are conveying of chemicals and wood dust; exhaust of foundry shakeouts and sand-handling systems, grain dusts; coal crushing and screening; and grinding, buffing and polishing.

Class III. Includes all highly abrasive materials in moderate to heavy concentrations and moderately abrasive materials in heavy concentrations such as low pressure conveying of tobacco; exhaust systems from sand and grit blasting, abrasive cleaning operation, rock and ore screening, crushing, dryers and kilns; fly ash from boiler stacks.

Brown and Sharpe gauge numbers have been used to indicate thickness of aluminum sheet as compared with U. S. Standard gauges for steel sheet. Where aluminum duct is indicated, the following equivalent B & S gauges should be used:

Steel - U. S. Standard Gauge	26	24	22	20	18	16	14
Aluminum - B & S Gauge	24	22	20	18	16	14	12

3. For exhaust systems on corrosive applications, consideration should be given to non-corrosive materials or coatings.
4. Elbows and angles shall be a minimum of two gauges heavier than straight lengths of equal diameter.
5. Hoods shall be a minimum of two gauges heavier than straight section of connecting branches.
6. Where flexible piping is necessary, a non-collapsible type of flexible piping shall be used and it shall be kept at a minimum.

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Construction

1. Longitudinal joints of ducts shall be lapped and riveted or spot welded on 3" centers maximum. Double-lock seams may be used on Class I application only.
2. Girth joints of duct shall be made with inner lap in direction of air flow, with 1" lap, diameters to 19", and 1-1/4" laps for diameters over 19".
3. Elbows and angles shall have a centerline radius of two pipe diameters whenever possible. Large radii are recommended for heavy concentrations of highly abrasive dusts. Construct elbows 6" or less in diameter of at least five sections, over 6" diameter of seven sections. Prefabricated elbows of smooth construction may be used. Angles pieced proportionately.
4. Hoods must be free of sharp edges or burrs and reinforced to provide necessary stiffness.
5. Use straight-through weather caps unless otherwise specified.

System Details

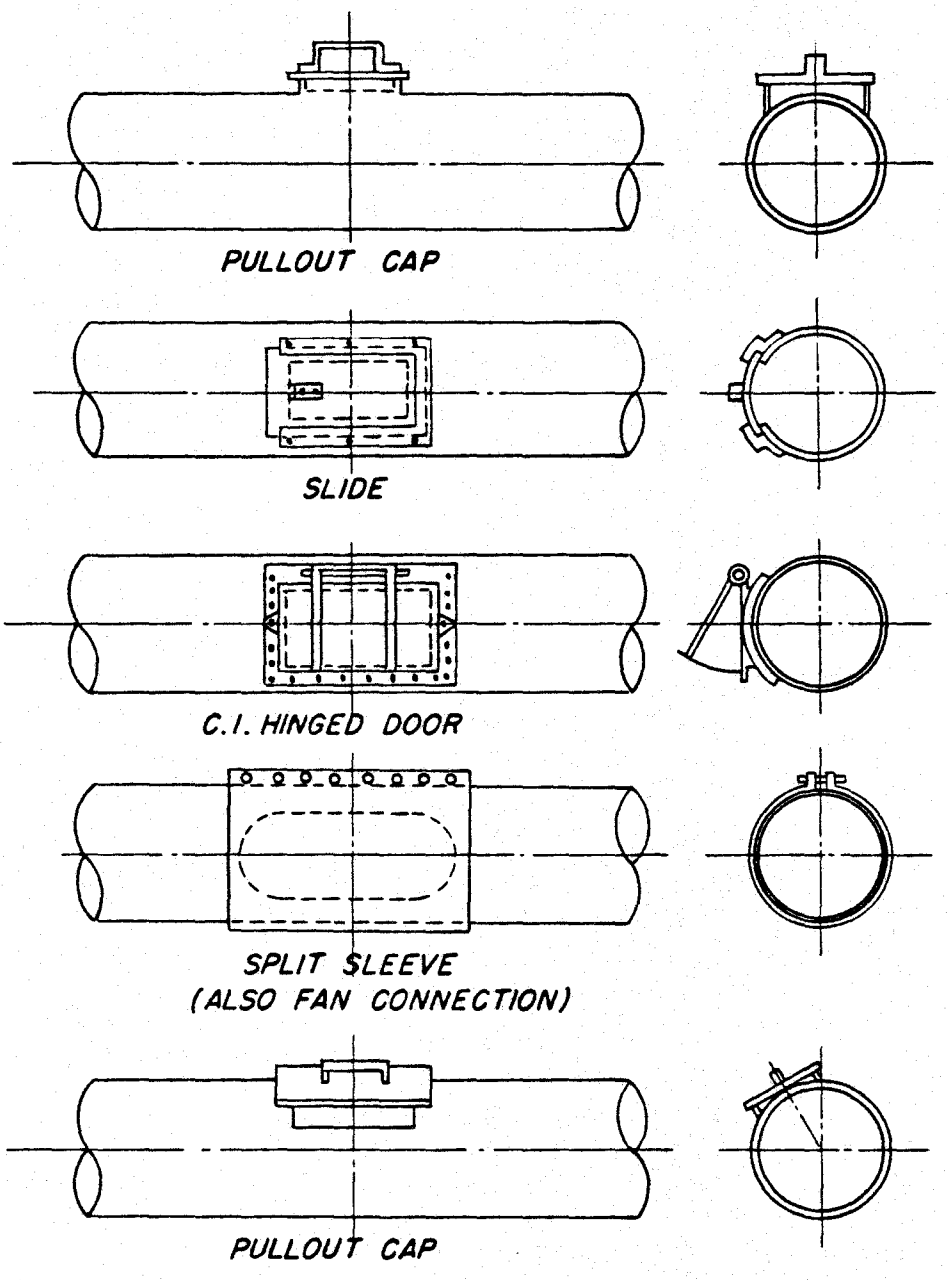
1. Connect duct to fan inlet with split sleeve drawband at least one pipe diameter long, but not less than 12".
2. Transitions in mains and sub-mains to be tapered; taper 5" long for each 1" change in diameter when possible.
3. All branches shall enter main at the large end of transition at an angle not to exceed 45^{o}; 30^{o} is preferred. Connect branches only to top or sides of main with no two branches entering diametrically opposite.
4. Provide dead-end caps within 6" from last branch of all mains and sub-mains.
5. Provide access openings or cleanouts every 10' and near each elbow, angle or duct junction in horizontal sections, except for non-corrosive gases and vapors containing no particulate matter.
6. Support ducts sufficiently to place no load on connecting equipment and to carry weight of system if plugged with material. Maximum supporting interval 12' for 8" or smaller ducts, 20' interval for larger ducts.
7. Provide 6" minimum clearance between ducts and ceiling, wall or floors.
8. Where blast gates are used for adjustment of system, place near connection of branch to main. Provide means of locking after adjustments have been made. Butterfly-type dampers shall not be permitted.
9. Fire dampers, explosion vents, etc., should be installed in accordance with National Fire Protection Association Codes or local fire ordinances.
10. Rectangular ducts can be used only when clearance prevents the use of round ducts. Rectangular ducts must be made as nearly square as possible. Weight of metal, lap and other construction details are to be equal to round duct construction whose diameter equals the longest side.
11. Support fans and motors on common vibration absorbing mounting.
12. Exhaust fans installed in a hazardous area shall be spark-resistant and shall have non-ferrous blade or wheel and a non-ferrous ring about the opening through which shaft passes. Provide electrical grounding for all fan parts.
13. Where state or local laws conflict with above specifications, the more stringent regulation shall be followed, Any other deviation must be approved before installation.

Testing

Measure the air flow in the system with a standard pitot tube to determine whether it is functioning in accordance with design specifications.

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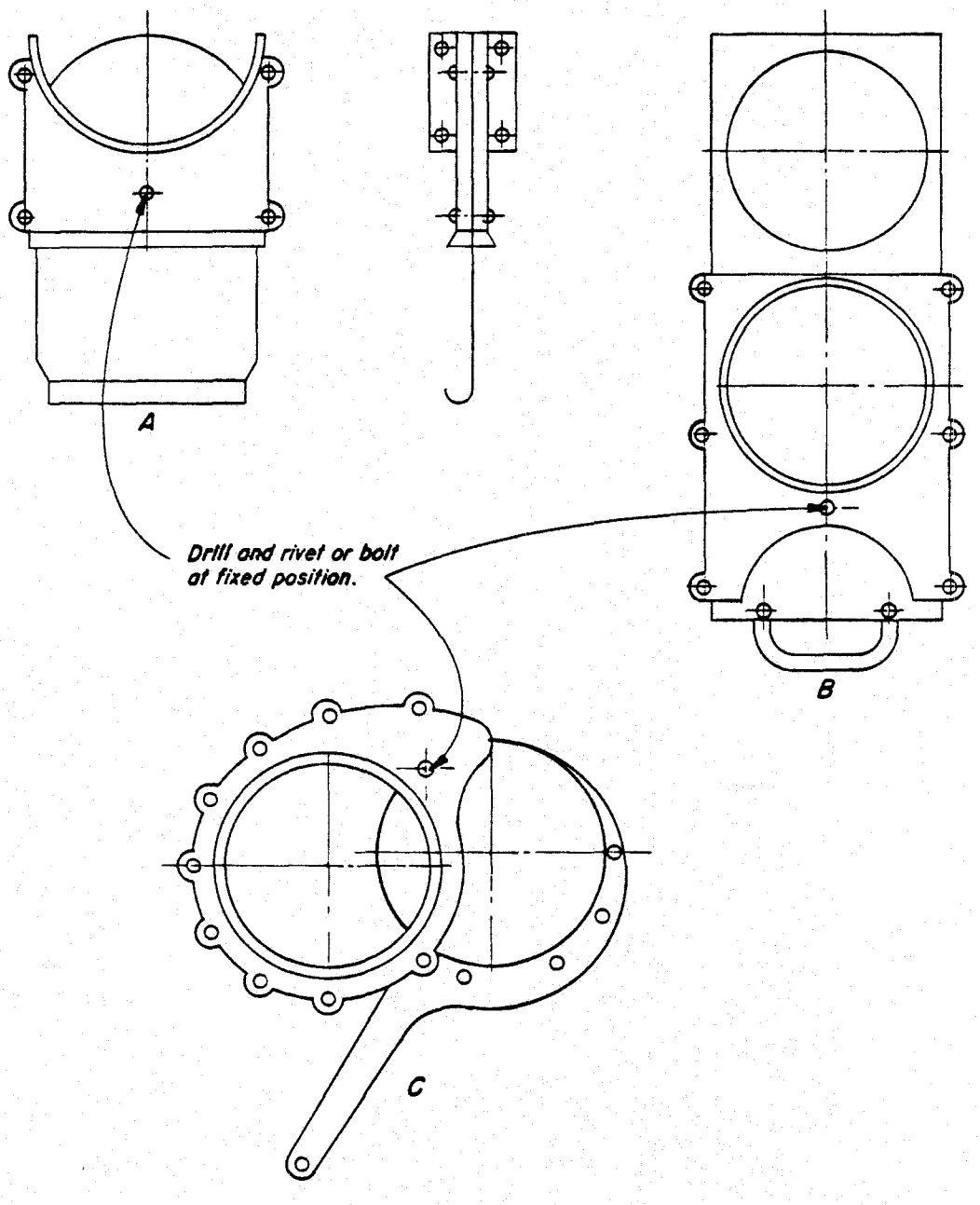


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CLEANOUT OPENINGS

DATE 1-56 | Fig. 8-1

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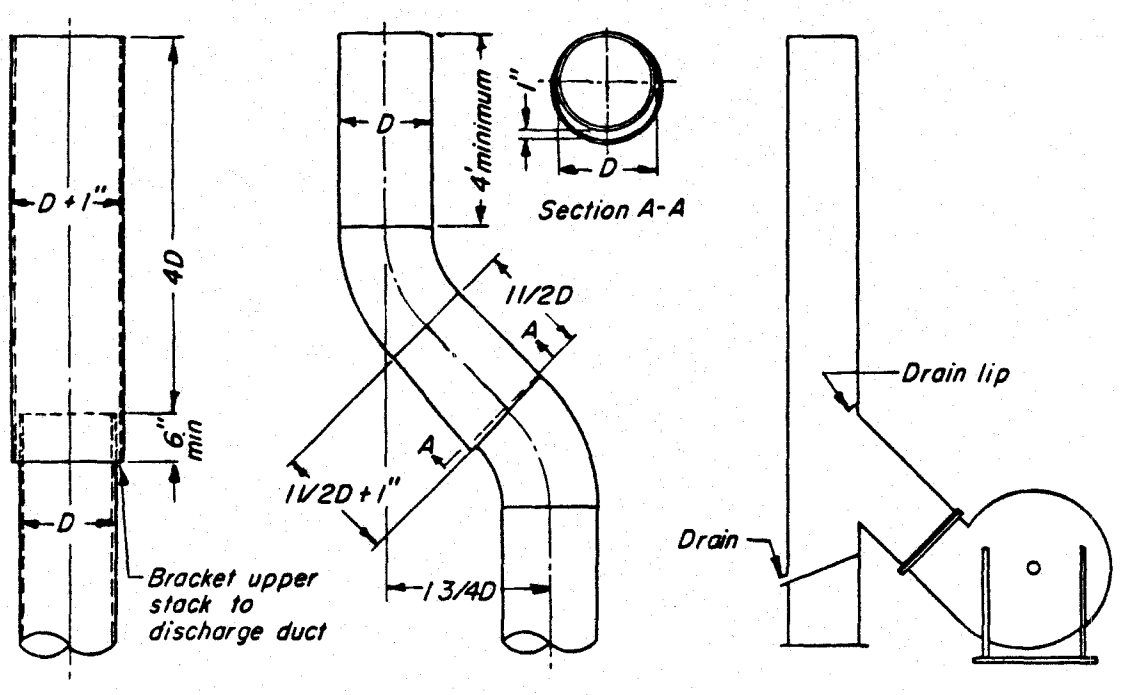
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FIXED DAMPERS

DATE 8-9-55 | Fig. 8-2

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VERTICAL DISCHARGE (87)

No loss

OFFSET ELBOWS (106)

Calculate losses due to elbows

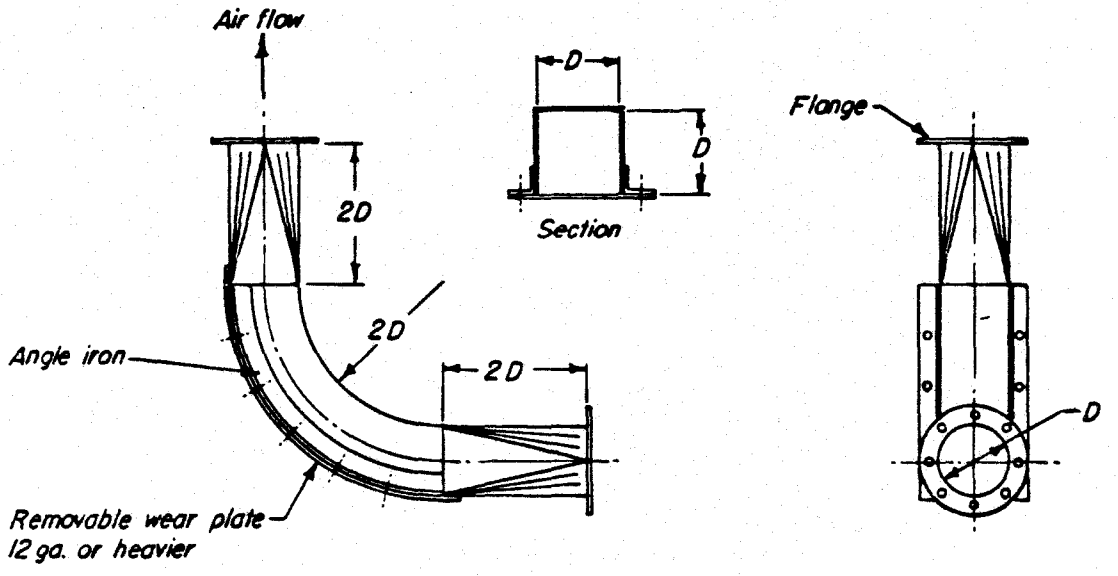
OFFSET STACK (106)

1. Rain protection characteristics of these caps are superior to a deflecting cap located 0.75D from top of stack.

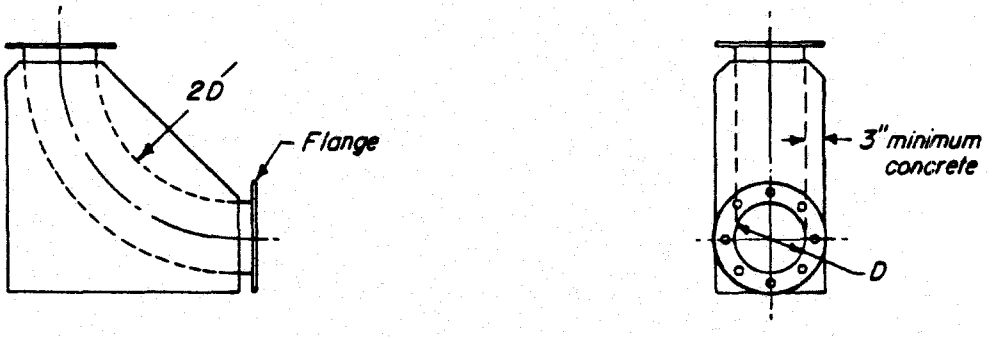
2. The length of upper stack is related to rain protection. Excessive additional distance may cause "Blowout" of effluent at the gap between upper and lower sections. (86)

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STACKHEAD DESIGNS	
DATE 1-72	Fig. 8-3

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FLAT BACK ELBOW



CONCRETE REINFORCED ELBOW

Note:
Provide solid mounting for concrete reinforced elbows.

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HEAVY DUTY ELBOWS	
DATE 1-60	Fig. 8-4

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Chemical Type	Trade Names	Max. Opr. Temp. F.	Flammability	Resistance to:							
				Gasoline	Mineral Oil	Strong Alk.	Weak Alk.	Strong Acid	Weak Acid	Salt Solution	Solvents
Urea Formaldehyde	Beetle Plaskon Sylplast	170	Self Ext.	Good	Good	None	Fair	Poor	Poor	---	Good
Melamine Formaldehyde	Cymel Plaskon Resimene	210-300	Self Ext.	Good	Good	Poor	Good	Poor	Good	---	Good
Phenolic	Bakelite Durits Durez G.E. Resinox	250-450	Self Ext.	Fair	---	Poor	Fair	Poor	Fair	---	Fair
Alkyd	Plaskon	---	Self Ext.	Good	---	None	Poor	---	Good	---	Good
Silicone	Bakelite G. E.	550	---	Good	Good	---	---	Good	Good	---	None
Epoxy	Epiphen Araldite Maraset Ren-ite Tool Plastik Epon Resin	50-200	Self Ext.	Good	---	Good	Good	Good	Good	---	Good
Cast Phenolic	Marblette	---	Self Ext.	---	---	None	Fair	Good	Good	---	Good to None
Allyl & Polyester	Laminac Bakelite Plaskon Glykon Paraplex	300-450	Self Ext.	---	---	Poor	Fair	Poor	Fair	---	Fair
Acrylic	Lucite Plexiglas Wascolite	140-200	0.5-2.0 in/min.	---	---	---	Good	None	Good	---	Good to None
Poly Ethylene	Tenite Irrathene	140-200	Burns Slowly	---	---	---	---	---	---	---	None
Tetrafluoroethylene Chlortrifluoroethylene	Teflon Kel F	500	Non-Fl.	Good	---	Good	Good	Good	Good	---	Good
Polyvinyl formal & butyral	Vinylite Butacite Saflex Butvar Formuar	---	Slow Burning	Good	Good	Good	Good	None	None	---	None
Vinyl chloride Polyner & Colpolyner	Krene Bakelite vinyl Dow pvc vygen	130-175	Slow Burning	---	---	Good	Good	Good	Good	---	None
Vinylidene chloride	Saran	160-200	Self Ext.	Good	Good	Good	Good	Good	Good	---	Fair
Styrene	Bakelite Catalin Styron Dylene Lustrex	150-165	0.5-2.0 in/min.	None	Fair	Good	Good	---	---	Good	Poor
Cellulose acetate	Celanese acetate Tenite	Thermo Plastic	0.5-2.0 in/min.	Good	Good	None	None	None	Fair	---	Poor
Nylon	Plaskon Zytel Tynex	250	Self Ext.	Good	Good	Good	Good	None	Good	---	Good
Asbestos-cement	Transite	550	Non-Fl.	Good	Good	Fair	Good	Poor	Fair	Good	Good
Glass	Pyrex	450	Non-Fl.	Good	Good	Good	Good	Good	Good	Good	Good

TABLE 8-1. TYPICAL PHYSICAL AND CHEMICAL PROPERTIES OF FABRICATED PLASTICS (58) AND OTHER MATERIALS

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Section 9

TESTING OF VENTILATION SYSTEMS

Air flow measurements and test data are often needed in connection with the proper functioning and design of industrial exhaust systems. The importance and value of obtaining test data can be noted in the following applications:

1. To determine whether a new exhaust system is functioning in accordance with design data.
2. To obtain air flow data necessary for proper setting of blast gates on systems designed for blast-gate balancing.
3. To determine by periodic checks if further maintenance or repairs of a system are necessary to assure efficient operation.
4. To obtain measurements necessary to determine whether the system has sufficient capacity for additional hoods or future exhaust equipment.
5. To obtain design data from existing satisfactorily controlled operations for future installations of similar character.
6. To obtain air flow data necessary to determine the degree of compliance with state codes, regulations or trade association standards.

In most instances, the most important measurement in testing exhaust systems is the measurement of air quantity. Inasmuch as most field meters are the velocity-meter type rather than the quantity-meter type, it is necessary to obtain not only the average air velocity into a hood or duct but also the cross-sectional area at the point of measurement. The quantity of air can then be determined from the simple equation:

$$Q = VA$$

where Q = Quantity of air flowing, cfm
A = Cross-sectional area of duct or hood, sq ft, at the measurement location
V = Average linear velocity, fpm

Quantity meters are thin-plate or sharp-edged orifice flow nozzles and venturi meters. These meters are very infrequently applied to industrial exhaust systems but are important in laboratory studies. They can be used as fixed metering devices for calibration of instruments, fan testing and experimental work.

Pressure measurements are useful in determining resistances or pressure drops through hoods, dust collectors and other parts of an exhaust system. Pressure measurements are also used to determine fan static pressure and to estimate air flow into hoods and other exhaust openings by the throat-suction method.

Measurement of Air Flow

For determining air velocity, the standard Pitot tube and the use of orifices and nozzles are considered reliable and are accepted in engineering practices. However, only the Pitot tube is suitable for field work.

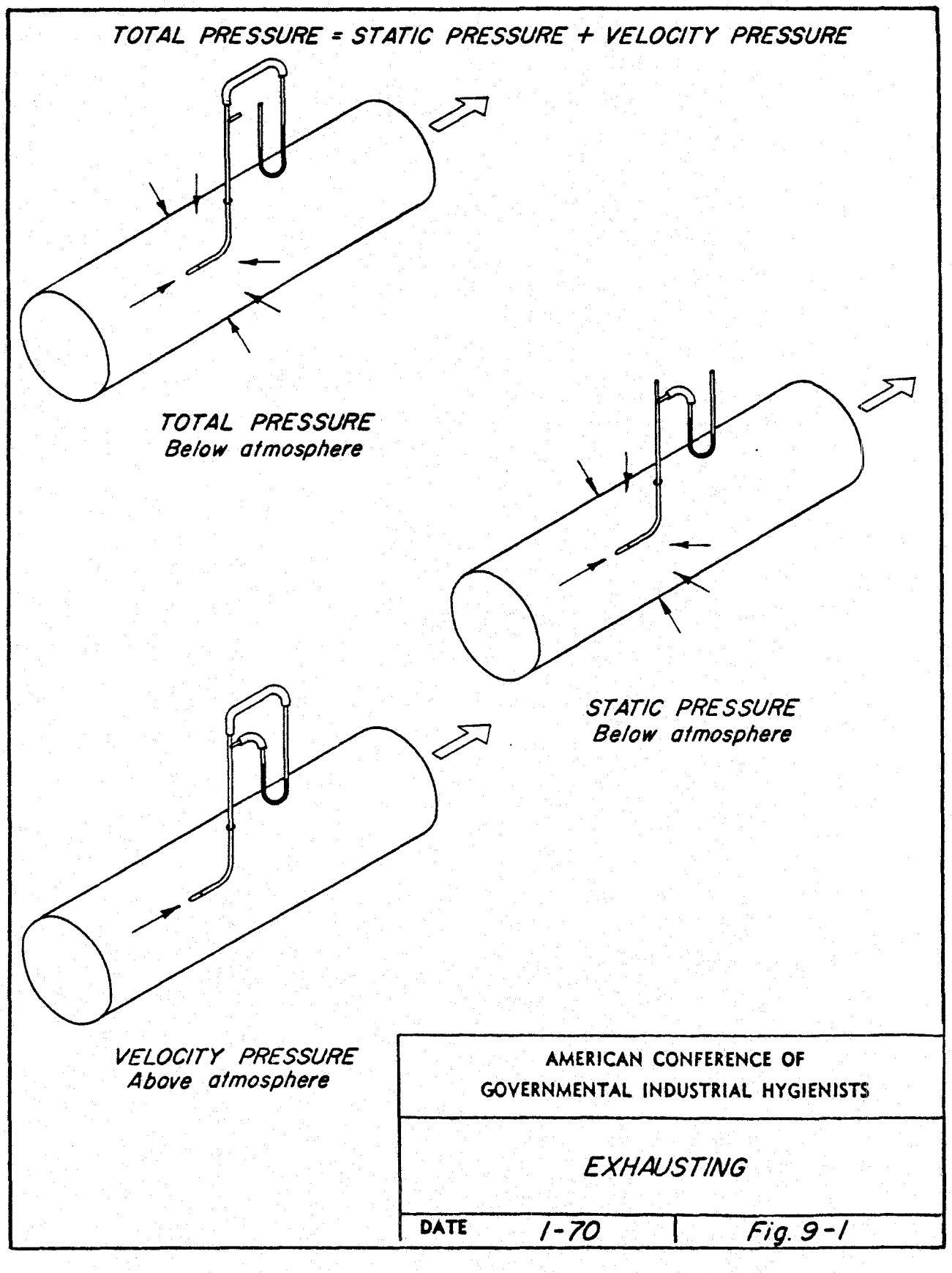
Air velocities in the field can be approximated by a number of various types of field instruments. Low nondirectional air movements in space cannot be measured by the Pitot tube and require special instruments.

Pitot Tube

The Pitot tube is the standard air velocity meter. A large volume of research and many publications have been devoted to the subject of flow measurement by this instrument. A standard Pitot tube as used in the United States (see Figure 9-2) needs no calibration if carefully made and velocity pressure readings obtained are considered accurate. For more details concerning specifications and the application of the Pitot tube, see the "Standard Test Code" published by the Air Moving and Conditioning Association (28) and the ASHRAE (2). The use of the Pitot tube is shown in Figure 9-1.

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The device consists of two concentric tubes, one serving to measure the total or impact pressure existing in the air stream, the other to measure the static pressure only. When the annular space and the center tube are connected across a U-tube manometer, the difference between the total pressure and the static pressure is indicated on the manometer. This difference between the total pressure and the static pressure is the velocity pressure.

The velocity pressure can be used to compute the velocity of the air stream if the density of the air is known. The following equation can be used:

$$V = 1096 \sqrt{\frac{VP}{0.075\ d}}$$

where d = density factor (Figure 6-14) or calculated from: $d = \frac{530}{460 + t} \times \frac{B}{29.92}$

where B = barometric pressure, "Hg
t = air temperature, F

This formula does not consider moisture present in the air stream. Under conditions of elevated moisture content, obtain the density factor directly from the psychrometric chart, page 13-17. Where air is at standard conditions (d = 1.0), the first equation above becomes:

$$V = 4005 \sqrt{VP}$$

Figure 6-16 is a velocity vs. velocity pressure table for standard air. This table can be used for air at densities other than standard conditions by correcting the measured velocity pressure inversely as the density factor as in the following equation:

$$\text{Corrected VP} = \text{Measured VP} \times \frac{1}{d}$$

The corrected VP can then be used in the velocity vs. velocity pressure table, Figure 6-16, to give the actual velocity at duct conditions.

From Figure 6-16 it can be seen that at low velocities (below 1000 fpm) the VP values are small (below 0.06" wg). The accuracy of the Pitot tube is limited at these velocities as the manometer is not precise enough to accurately measure the small pressures. A carefully made and accurately leveled 10:1 inclined manometer calibrated against a hook gauge can be read to approximately ± 0.005" wg. A standard Pitot tube with an inclined manometer can be used with the following degree of accuracy:

Velocity, fpm	% Error (±)
4000	0.25
3000	0.3
2000	1.0
1000	4.0
800	6.0
600	15.0

It can be seen that the use of the Pitot tube in the field is limited at velocities lower than 600-800 fpm.

Inasmuch as the air flow in the cross-section of a duct is not uniform, it is necessary to obtain the average by measuring VP at points in a number of equal areas in the cross-section. The approved method is to make two traverses across the diameter of the duct at right angles to each other. Twenty readings are taken at the center of annular rings of equal area (see Figure 9-3). Tables 9-1, 9-2 and 9-3 give traverse points for various duct diameters. Whenever possible the traverse should be made 7.5 duct diameters or more downstream from any major air disturbance such as an elbow, hood, branch entry, etc. Where measurements are made closer to disturbances than 7.5 duct diameters, the results must be considered subject to some doubt and checked against a second location. If agreement within 10% is obtained, reasonable accuracy can be assumed and the average of the two readings used. Where variation exceeds 10% a third location should be selected and the two volumes in best agreement averaged and used.

For round ducts 6" and smaller, at least 6 traverse points should be used. For round ducts larger than 6" diameter, at least 10 traverse points should be employed. For very large ducts and discharge stacks with wide variation in velocity, 20 traverse points will increase the precision of the air flow measurement. Six, ten and twenty point traverse dimensions are given in Tables 9-1, 9-2 and 9-3. Ducts smaller than 12" diameter will require a Pitot tube smaller than the standard 5/16" O. D.

With square or rectangular ducts the procedure is to divide the cross-section into a number of equal rectangular areas and measure the velocity pressure at the center of each. The number of readings should not be less than 16. However, enough readings should be made so the greatest distance between centers is approximately six inches. (See Figure 9-4).

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The use of a single centerline reading for obtaining average velocity is, at best, a very coarse approximation. When a centerline reading is taken, the location must be 10 diameters of straight duct downstream from the nearest disturbance. The centerline velocity pressure thus obtained should be multiplied by 0.81 or the velocity by 0.9 to obtain an approximation of the average velocity.

The following data are essential and more detailed data may be taken if desired:

The diameter of the duct at the traverse location
Velocity pressure at each point in the traverse or, for estimation, the centerline velocity pressure
Temperature of the air stream at the time and location of traverse

If the temperature of the air stream varies more than 30 F from the standard temperature, if the altitude is greater than 1,000 feet and/or the moisture content of the air is 0.02 lb/lb of dry air or greater, it is advisable to make a correction for density change as given in the first and third equations, pages 9-28 and 9-29.

The velocity pressure readings are then converted to velocities and the velocities, not the velocity pressures, are averaged. Where more convenient, the square root of the velocity pressures may be averaged and this value then converted to velocity (average). The measured air volume at the temperature in the duct is then the average velocity multiplied by the cross-sectional area of the duct ($Q = VA$).

Limitations: The Pitot tube cannot be used for measuring low velocities in the field. It is not a direct-reading air meter. If used with a liquid manometer, a vibration-free mounting is necessary. Because of the distance between the impact and static holes, it cannot be used to measure flow through orifice-type openings. It is susceptible to plugging in air streams with heavy dust and/or moisture loadings.

Modified Pitot Tubes

Modifications of Pitot tubes have been made in an effort to reduce plugging difficulties encountered in heavy dust streams or to increase manometer differentials enabling the measurement of lower velocities in the field. These may be called "double Pitot" tubes since they usually take the form of a relatively large impact opening facing upstream and another such opening facing downstream. Such tubes are useful also when thick walled ducts, such as boiler stacks, make difficult the insertion of conventional Pitot tubes through any reasonable port opening.

Other modified forms of the Pitot tube are the air foil pitometer (50), the Pitot venturi and the air speed nozzle (61), to name a few. Some of these instruments are of considerable size.

Limitations: A handicap for field use is that double-Pitot tubes and other modifications require calibration under conditions similar to those in which they are to be used. In addition, some are of considerable size and create a problem of insertion in ductwork.

Orifices and Nozzles

The use of the orifice, nozzle or like metering instruments as permanent measuring stations is well accepted in engineering practice.

The rounded approach orifice or nozzle of the general type described in the ASHRAE Unit Heater and Unit Ventilator Codes is an accurate measuring device. When it is well made, the coefficient closely approaches unity. The exact value depends on the location of connections, the pressure drop, the diameter or ratio of orifice to pipe and the contour of the orifice edge. The discharge from such a nozzle is reasonably uniform and provides a fairly good location for calibration of air velocity instruments.

The ASME Power Test Code 19.5.4 (3) should be consulted for details of use and application of orifice and nozzle meters.

Estimation of Air Flow by Throat-Suction Method

The "Throat-Suction" method of estimating air flow into an exhaust hood or duct is based on the principle of the orifice--the inlet end of the duct simulating the orifice. This method is quick, simple and practical. It is a fairly accurate estimation of rate of air flow in branch exhaust pipes if the suction measurement can be made at a point one to three pipe diameters of straight pipe downstream from the throat of the exhaust inlet, and if an accurate analysis of the coefficient of entry can be made.

This technique involves the measuring of hood static suction by means of a U-tube manometer at one or more holes (preferably four, spaced 90° apart), one duct diameter downstream from the throat for all hoods having tapers, and three duct diameters from the throat for flanged or plain duct ends. The holes should be drilled 1/16" - 1/8" in diameter or less; the hole should not be punched as inwardly projecting jagged edges of metal disturb the air stream. The U-tube manometer is connected to each hole in turn by means of a thick-walled soft rubber tube and the difference in the height of the water columns is read in inches.

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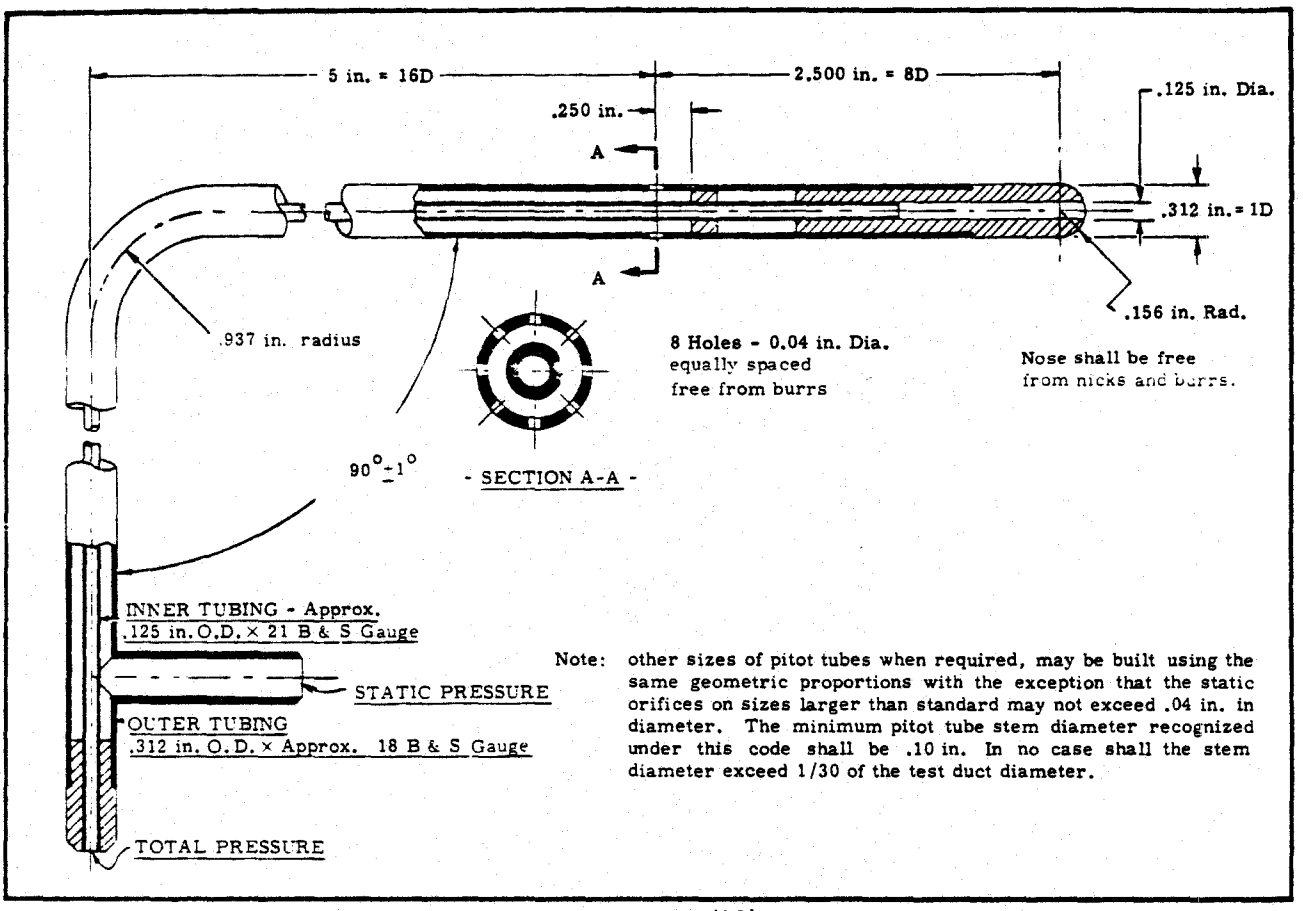


Fig. 9-2[28]

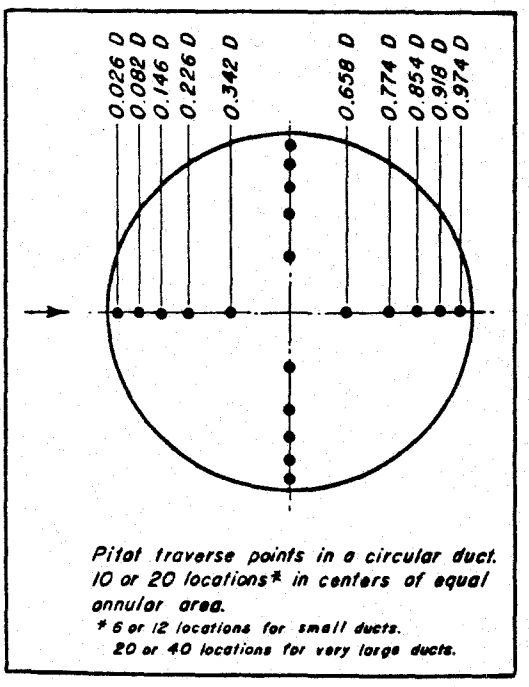


Fig. 9-3

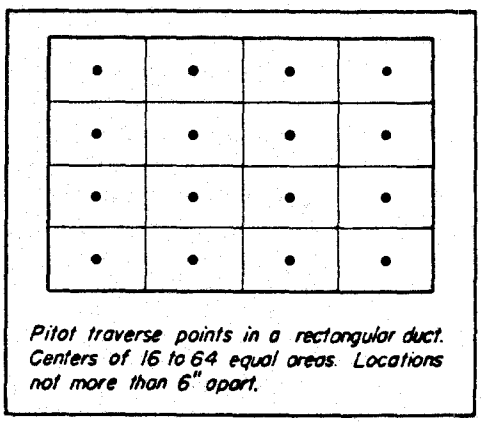


Fig. 9-4

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TABLE 9-1

DISTANCE FROM WALL OF ROUND PIPE TO POINT OF READING (NEAREST 1/8 INCH) FOR 10-POINT TRAVERSE.

DUCT DIA	R_1 0.026 DIA	R_2 0.082 DIA	R_3 0.146 DIA	R_4 0.226 DIA	R_5 0.342 DIA	R_6 0.658 DIA	R_7 0.774 DIA	R_8 0.854 DIA	R_9 0.918 DIA	R_{10} 0.974 DIA
4	1/8	3/8	5/8	7/8	1 3/8	2 5/8	3 1/8	3 3/8	3 5/8	3 7/8
4 1/2	1/8	3/8	5/8	1	1 1/2	3	3 1/2	3 7/8	4 1/8	4 3/8
5	1/8	3/8	3/4	1 1/8	1 3/4	3 1/4	3 3/4	4 1/4	4 5/8	4 7/8
5 1/2	1/8	1/2	3/4	1 1/4	1 7/8	3 5/8	4 1/4	4 3/4	5	5 3/8
6	1/8	1/2	7/8	1 3/8	2	4	4 5/8	5 1/8	5 1/2	5 7/8
7	1/8	5/8	1	1 3/8	2 3/8	4 5/8	5 3/8	6	6 3/8	6 7/8
8	1/4	5/8	1 1/8	1 3/4	2 3/4	5 1/4	6 1/4	6 7/8	7 3/8	7 3/4
9	1/4	3/4	1 1/4	2	3 1/8	5 7/8	7	7 3/4	8 1/4	8 3/4
10	1/4	7/8	1 1/2	2 1/4	3 3/8	6 5/8	7 3/4	8 1/2	9 1/8	9 3/4
11	1/4	7/8	1 5/8	2 1/2	3 3/4	7 1/4	8 1/2	9 3/8	10 1/8	10 3/4
12	3/8	1	1 3/4	2 3/4	4 1/8	7 7/8	9 1/4	10 1/4	11	11 5/8
13	3/8	1	1 7/8	2 7/8	4 1/2	8 1/2	10 1/8	11 1/8	12	12 5/8
14	3/8	1 1/8	2	3 1/8	4 3/4	9 1/4	10 7/8	12	12 7/8	13 5/8
15	3/8	1 1/4	2 1/4	3 3/8	5 1/8	9 7/8	11 5/8	12 3/4	13 3/4	14 5/8
16	3/8	1 1/4	2 3/8	3 5/8	5 1/2	10 1/2	12 3/8	13 5/8	14 3/4	15 5/8
17	1/2	1 3/8	2 1/2	3 7/8	5 3/4	11 1/4	13 1/8	14 1/2	15 5/8	16 1/2
18	1/2	1 1/2	2 5/8	4 1/8	6 1/8	11 7/8	13 7/8	15 3/8	16 1/2	17 1/2
19	1/2	1 1/2	2 3/4	4 1/4	6 1/2	12 1/2	14 3/4	16 1/4	17 1/2	18 1/2
20	1/2	1 5/8	2 7/8	4 1/2	6 7/8	13 1/8	15 1/2	17 1/8	18 3/8	19 1/2
22	5/8	1 3/4	3 1/4	5	7 1/2	14 1/2	17	18 3/4	20 1/4	21 3/8
24	5/8	2	3 1/2	5 1/2	8 1/4	15 3/4	18 1/2	20 1/2	22	23 3/8
26	5/8	2 1/8	3 3/4	5 7/8	8 7/8	17 1/8	20 1/8	22 1/4	23 7/8	25 3/8
28	3/4	2 1/4	4 1/8	6 3/8	9 5/8	18 3/8	21 5/8	23 7/8	25 3/4	27 1/4
30	3/4	2 1/2	4 3/8	6 3/4	10 1/4	19 3/4	23 1/4	25 5/8	27 1/2	29 1/4
32	7/8	2 5/8	4 5/8	7 1/4	11	21	24 3/4	27 3/8	29 1/8	31 1/8
34	7/8	2 3/4	5	7 3/4	11 5/8	22 3/8	26 1/4	29	31 1/4	33 1/8
36	1	3	5 1/4	8 1/8	12 3/8	23 5/8	27 1/8	30 3/4	33	35
38	1	3 1/8	5 1/2	8 5/8	13	25	29 1/8	32 1/2	34 7/8	37
40	1	3 1/4	5 7/8	9	13 5/8	26 3/8	31	34 1/4	36 3/4	39
42	1 1/8	3 3/8	6 1/4	9 1/2	14 3/8	27 5/8	32 1/2	35 7/8	38 5/8	40 7/8
44	1 1/4	3 5/8	6 5/8	10	15	29	34	37 1/8	40 3/8	42 7/8
46	1 1/4	3 3/4	6 3/4	10 3/8	15 3/4	30 1/4	35 5/8	39 1/4	42 1/4	44 3/4
48	1 1/4	4	7	10 7/8	16 1/8	31 1/8	37 1/8	41	44	46 3/4

TABLE 9-2

DISTANCE FROM WALL OF ROUND PIPE TO POINT READING (NEAREST 1/8 INCH) FOR 6-POINT TRAVERSE.

DUCT DIA	R_1 .043 DIA	R_2 .146 DIA	R_3 .296 DIA	R_4 .704 DIA	R_5 .854 DIA	R_6 .957 DIA
3	1/8	1/2	7/8	2 1/8	2 1/2	2 7/8
3 1/2	1/8	1/2	1	2 1/2	3	3 3/8
4	1/8	5/8	1 1/8	2 7/8	3 3/8	3 7/8
4 1/2	1/4	5/8	1 3/8	3 1/8	3 7/8	4 1/4
5	1/4	3/4	1 1/2	3 1/2	4 1/4	4 3/4
5 1/2	1/4	3/4	1 5/8	3 7/8	4 3/4	5 1/4
6	1/4	7/8	1 3/4	4 1/4	5 1/4	5 3/4

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TABLE 9-3

DISTANCE FROM WALL OF ROUND PIPE TO POINT OF READING (NEAREST 1/8 INCH) FOR 20-POINT TRAVERSE.

Duct dia	R_1 0.013D	R_2 0.039D	R_3 0.067D	R_4 0.097D	R_5 0.129D	R_6 0.165D	R_7 0.204D	R_8 0.250D	R_9 0.306D	R_{10} 0.388D
	R_{11} 0.612D	R_{12} 0.694D	R_{13} 0.750D	R_{14} 0.796D	R_{15} 0.835D	R_{16} 0.871D	R_{17} 0.903D	R_{18} 0.933D	R_{19} 0.961D	R_{20} 0.987D
40	1/2	1 1/2	2 5/8	3 7/8	5 1/8	6 5/8	8 1/8	10	12 1/4	15 1/2
	24 1/2	27 3/4	30	31 7/8	33 3/8	34 7/8	36 1/8	37 3/8	38 1/2	39 1/2
42	1/2	1 5/8	2 7/8	4 1/8	5 3/8	6 7/8	8 5/8	10 1/2	12 7/8	16 1/4
	25 3/4	29 1/8	31 1/2	33 3/8	35 1/8	36 5/8	37 7/8	39 1/8	40 3/8	41 1/2
44	1/2	1 3/4	3	4 1/4	5 5/8	7 1/4	9	11	13 1/2	17 1/8
	26 7/8	30 1/2	33	35	36 3/4	38 3/8	39 3/4	41	42 1/4	43 1/2
46	5/8	1 3/4	3 1/8	4 1/2	6	7 5/8	9 3/8	11 1/2	14 1/8	17 7/8
	28 1/8	31 7/8	34 1/2	36 5/8	38 3/8	40	41 1/2	42 7/8	44 1/4	45 3/8
48	5/8	1 7/8	3 1/4	4 5/8	6 1/4	7 7/8	9 3/4	12	14 3/4	18 5/8
	29 3/8	33 1/4	36	38 1/4	40 1/8	41 3/4	43 3/8	44 3/4	46 1/8	47 3/8
50	5/8	2	3 3/8	4 7/8	6 1/2	8 1/4	10 1/4	12 1/2	15 3/8	19 3/8
	30 5/8	34 5/8	37 1/2	39 3/4	41 3/4	43 1/2	45 1/8	46 5/8	48	49 3/8
52	5/8	2	3 1/2	5	6 3/4	8 1/2	10 5/8	13	15 7/8	20 1/8
	31 7/8	36 1/8	39	41 3/8	43 1/2	45 1/4	47	48 1/2	50	51 3/8
54	5/8	2 1/8	3 5/8	5 1/4	7	8 7/8	11	13 1/2	16 1/2	21
	33	37 1/2	40 1/2	43	45 1/8	47	48 3/4	50 3/8	51 7/8	53 3/8
56	3/4	2 1/8	3 3/4	5 3/8	7 1/4	9 1/4	11 3/8	14	17 1/8	21 3/4
	34 1/4	38 7/8	42	44 5/8	46 3/4	48 3/4	50 5/8	52 1/4	53 7/8	55 1/4
58	3/4	2 1/4	3 7/8	5 5/8	7 1/2	9 1/2	11 7/8	14 1/2	17 3/4	22 1/2
	35 1/2	40 1/4	43 1/2	46 1/8	48 1/2	50 1/2	52 3/8	54 1/8	55 3/4	57 1/4
60	3/4	2 3/8	4	5 7/8	7 3/4	9 7/8	12 1/4	15	18 3/8	23 1/4
	36 3/4	41 5/8	45	47 3/4	50 1/8	52 1/4	54 1/8	56	57 5/8	59 1/4
62	3/4	2 3/8	4 1/8	6	8	10 1/4	12 5/8	15 1/2	19	24 1/8
	37 7/8	43	46 1/2	49 3/8	51 3/4	54	56	57 7/8	59 5/8	61 1/4
64	3/4	2 1/2	4 1/4	6 1/4	8 1/4	10 1/2	13 1/8	16	19 5/8	24 7/8
	39 1/8	44 3/8	48	50 7/8	53 1/2	55 3/4	57 3/4	59 3/4	61 1/2	63 1/4
66	7/8	2 5/8	4 3/8	6 3/8	8 1/2	10 7/8	13 1/2	16 1/2	20 1/4	25 5/8
	40 3/8	45 3/4	49 1/2	52 1/2	55 1/8	57 1/2	59 5/8	61 5/8	63 3/8	65 1/8
68	7/8	2 5/8	4 1/2	6 5/8	8 3/4	11 1/4	13 7/8	17	20 7/8	26 3/8
	41 5/8	47 1/8	51	54 1/8	56 3/4	59 1/4	61 3/8	63 1/2	65 3/8	67 1/8
70	7/8	2 3/4	4 3/4	6 3/4	9	11 1/2	14 1/4	17 1/2	21 1/2	27 1/8
	42 7/8	48 1/2	52 1/2	55 3/4	58 1/2	61	63 1/4	65 1/4	67 1/4	69 1/8
72	7/8	2 3/4	4 7/8	7	9 1/4	11 7/8	14 3/4	18	22	28
	44	50	54	57 1/4	60 1/8	62 3/4	65	67 1/8	69 1/4	71 1/8
74	7/8	2 7/8	5	7 1/8	9 1/2	12 1/8	15 1/8	18 1/2	22 5/8	28 3/4
	45 1/4	51 3/8	55 1/2	58 7/8	61 7/8	64 1/2	66 7/8	69	71 1/8	73 1/8
76	1	3	5 1/8	7 3/8	9 7/8	12 1/2	15 1/2	19	23 1/4	29 1/2
	46 1/2	52 3/4	57	60 1/2	63 1/2	66 1/8	68 5/8	70 7/8	73	75
78	1	3	5 1/4	7 1/2	10 1/8	12 7/8	15 7/8	19 1/2	23 7/8	30 1/4
	47 3/4	54 1/8	58 1/2	62 1/8	65 1/8	67 7/8	70 1/2	72 3/4	75	77
80	1	3 1/8	5 3/8	7 3/4	10 3/8	13 1/8	16 3/8	20	24 1/2	31
	49	55 1/2	60	63 5/8	66 7/8	69 5/8	72 1/4	74 5/8	76 7/8	79

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If an elbow intervenes between the hood and the suction-measurement location, the pressure loss caused by the elbow should be determined as given in Figure 6-11 and should be subtracted from the reading to give the suction produced by the hood and throat alone.

The values for entry coefficients for various hood shapes are given in Figure 6-10. The volume rate of air flow is then determined by the equation (for normal air conditions):

$$Q = 4005\, C_e A \sqrt{SP_h}$$

where Q = Quantity of air flowing in cubic feet per minute
C_e = Coefficient of entry (Figure 6-10)
A = Area of duct in square feet
SP_h = U-tube manometer reading in inches of water

If the temperature of the air stream is greater than 30° from the standard temperature of 70 F and/or if the altitude is greater than 1,000 feet, it is advisable to make a correction for density change as follows:

$$Q = 1096\, C_e A \sqrt{\frac{SP_h}{0.075\, d}}$$

where d = relative density of air from Figure 6-14.

Other Methods and Instruments

The volume handled by exhaust systems is sometimes approximated by use of various types of field instruments at the exhaust or discharge opening. Such results are suitable as an approximation only since they are subject to many errors. Any instrument used for this purpose should be handled in strict compliance with the manufacturers' recommendations and directions. All such measurements are fundamentally based on the measurement of the air velocities at a number of points in the opening and averaging the results. Naturally, these methods are highly subject to human error.

There are many instruments involving a great many physical and chemical principles which can be adapted to the measurement of air velocity or volume ratings. For more information, the reader is referred to Brandt (7), ASHVE (2) and Drinker and Hatch (11). A few characteristics of the more popular instruments are listed below.

Rotating Vane Anemometer (See Figure 9-5): This instrument is accurate and can be used to determine air flow through large supply and exhaust openings. The standard instrument consists of a propeller or revolving vane connected through a gear train to a set of recording dials that read the linear feet of air passing in a measured length of time. It is made in various sizes, 3", 4" and 6" being most common. It gives average flow for time of test (usually one minute). Each instrument requires frequent calibration and the use of a calibration card or curve to determine actual velocity. The instrument may be used for either pressure or suction measurements using the necessary correction factors, Table 9-4. The standard instrument has a useful range of 200-3000 fpm; especially-built models will read lower velocities.

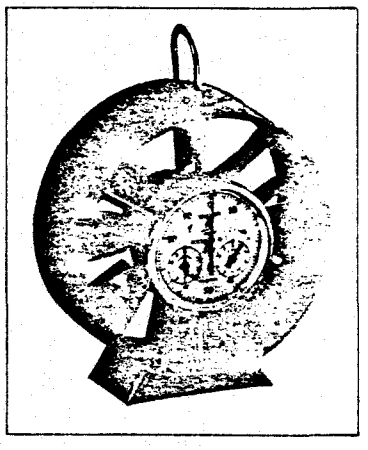


Fig. 9-5

Direct recording and direct reading rotating vane anemometers are available. These instruments record and meter electrical pulses developed by a capacitance transducer. The impulses are fed to the indicator unit where they are integrated to operate a conventional meter. Readings as low as 25 fpm can be measured and recorded.

Limitations: The rotating vane anemometer is unsuited for measurement in ducts as it has too large a finite area. The conventional meter is not direct reading and must be timed. It is fragile and cannot be used in dusty and corrosive atmospheres.

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TABLE 9-4. CORRECTION FACTOR FOR ROTATING VANE ANEMOMETER

Opening	Correction Factor*
Pressure openings, more than 4 in wide, up to 600 sq in area, with free opening 70% or more of gross area, no directional vanes	1.03
Suction opening, more than 4 in wide, up to 600 sq in area, with flange 2 in wide, free-open area 60% or more of gross area	0.85

Volume: For suction openings, cfm = (factor) (velocity) (gross area)

For pressure openings, cfm = (factor) (velocity) $\left(\frac{\text{gross area + net area}}{2}\right)$

*If the opening is covered with a grille, the instrument should touch the grille face but should not be pushed in between the bars. For a free opening without a grille, the anemometer should be held in the plane of the entrance edges of the opening. The anemometer must always be held in such a manner that the air flow through the instrument is the same direction as was used for calibration (usually from the back toward the dial face).

Swinging Vane Anemometer (Velometer) (Figure 9-6): This instrument is extensively used in field measurements because of its portability, wide-scale range and instantaneous reading features. Where accurate readings are desired, the correction factors in Table 9-5 should be applied. The instrument has wide application and by a variety of fittings, can be used to check static pressures and a wide range of linear velocities. The minimum velocity is 50 fpm, unless specially adapted for a low range. The instrument is fairly rugged and accuracy is suitable for most field checks.

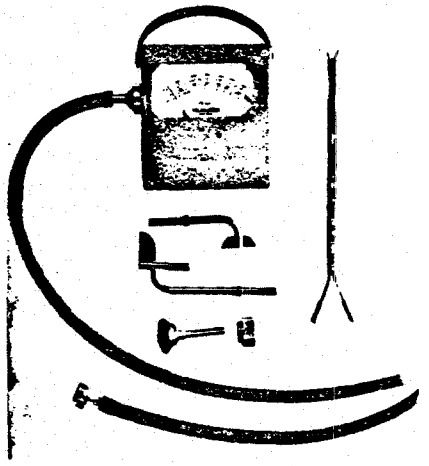


Fig. 9-6

Before using, check the meter for zero setting by holding the meter horizontal and covering both ports so that no air can flow through it. If pointer does not come to rest at zero turn the "Z" adjuster to make the necessary corrections. Check the meter for balance. After setting the zero as above, the pointer should not deviate more than 1/8" from zero when both ports are closed regardless of the position in which the meter is held. A velometer with its fittings was originally calibrated as a unit. Fittings cannot be switched from one set to another. The serial number on the fittings and on the meter must agree. If the meter was originally calibrated for a filter it must always be used.

The meter should be used always in an upright position (handle on top) and, when using fittings, it must be held out of the air stream so that the air flows directly into the opening. The length and inside diameter of the connecting tubing affect the calibration of the meter. Use only connecting tubing of the same length and inside diameter as that originally supplied with the meter. Changes in tubing do affect the calibration of the meter.

A newer model, Series 6000, of this instrument (see Figure 9-8) has been developed which does not require individually calibrated fittings. Other operating characteristics are similar to those described above. Figure 9-9 illustrates some applications of this model.

Where temperatures of an air stream vary more than 30° from the standard temperature of 70 F and/or if the altitude is greater than 1,000 feet, it is advisable to make a correction for temperature and pressure. Day to day variations in barometric pressure do not necessitate pressure corrections. Corrections for change in density from variations in altitude and temperature can be made by applying the following equations:

$$\text{True Velocity } (V_t) = V_{read} \sqrt{\frac{1}{d}}$$

$$\text{True Velocity } (V_t) = V_{read} \sqrt{\frac{460 + t}{530}}$$

Uses of the swinging vane anemometer and of its various fittings have been illustrated in Figure 9-7.

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Use at Supply Openings: On large (at least 3 square feet) supply openings where the instrument itself will not seriously block the opening and the velocities are low, the instrument itself may be held in the air stream with the air impinging directly in the left hand port. When the opening is smaller than 3 square feet and/or where the velocities are above the "No Jet" scale, appropriate fittings must be used. On modern air conditioning grilles, the velometer or the fitting should be held between one and two inches in front of the grille.

Use at Exhaust Openings: If the exhaust opening is large (at least 3 square feet) and the air velocities low, as in spray booths, chemical hoods, etc., the velometer itself can be held in the air stream. The instrument should be held so that the left hand port of the meter is flush with the exhaust opening. When the opening is smaller than 3 square feet and/or where the velocities are above the "No Jet" scale, appropriate fittings must be used as illustrated in Figure 9-7.

Because the velocity and static gradient in front of an exhaust opening is steep, the finned opening of the fitting must be held flush with the exhaust opening. If the opening is covered by a grille, hold the fin directly against the grille and use the correction factors listed in Table 9-5 when computing exhaust volumes.

TABLE 9-5

CORRECTION FACTORS FOR THE SWINGING VANE ANEMOMETER (VELOMETER) (40)

Opening	Correction Factor
Pressure More than 4 in. wide and up to 600 sq. in. area, free opening 70% or more of gross area, no directional vanes. Use free-open area.	0.93
Suction Square punched grille (use free-open area) Bar grille (use gross area) Strip grille (use gross area) Free open, no grille Volume: cfm = (factor) (area) (velocity)	 0.88 0.78 0.73 1.00

Limitations: While it can be used to measure air velocities in ducts, static pressure and total pressure, it has several disadvantages. Used in place of a Pitot tube for velocity or total pressure measurements, it necessitates a much larger hole in the duct, oftentimes difficult and impractical to provide. When the velocities are high there may be appreciable errors at the high end of the scale and the instrument tends to read low on the blowing side of the fan and high on the suction side.

On measurements at the face of exhaust openings of less than 3 square feet, fittings are required which make readings below 100 fpm impossible.

The presence of dust, moisture or corrosive material in the atmosphere presents a problem since the air passes through the instrument. In those instruments calibrated for use with a filter (the filter must always be used), the filter itself is a source of error since as the filter becomes plugged its resistance increases and thus alters the amount of air passed to the swinging vane. The instrument requires periodic calibration and adjustment.

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VELOMETER APPLICATIONS

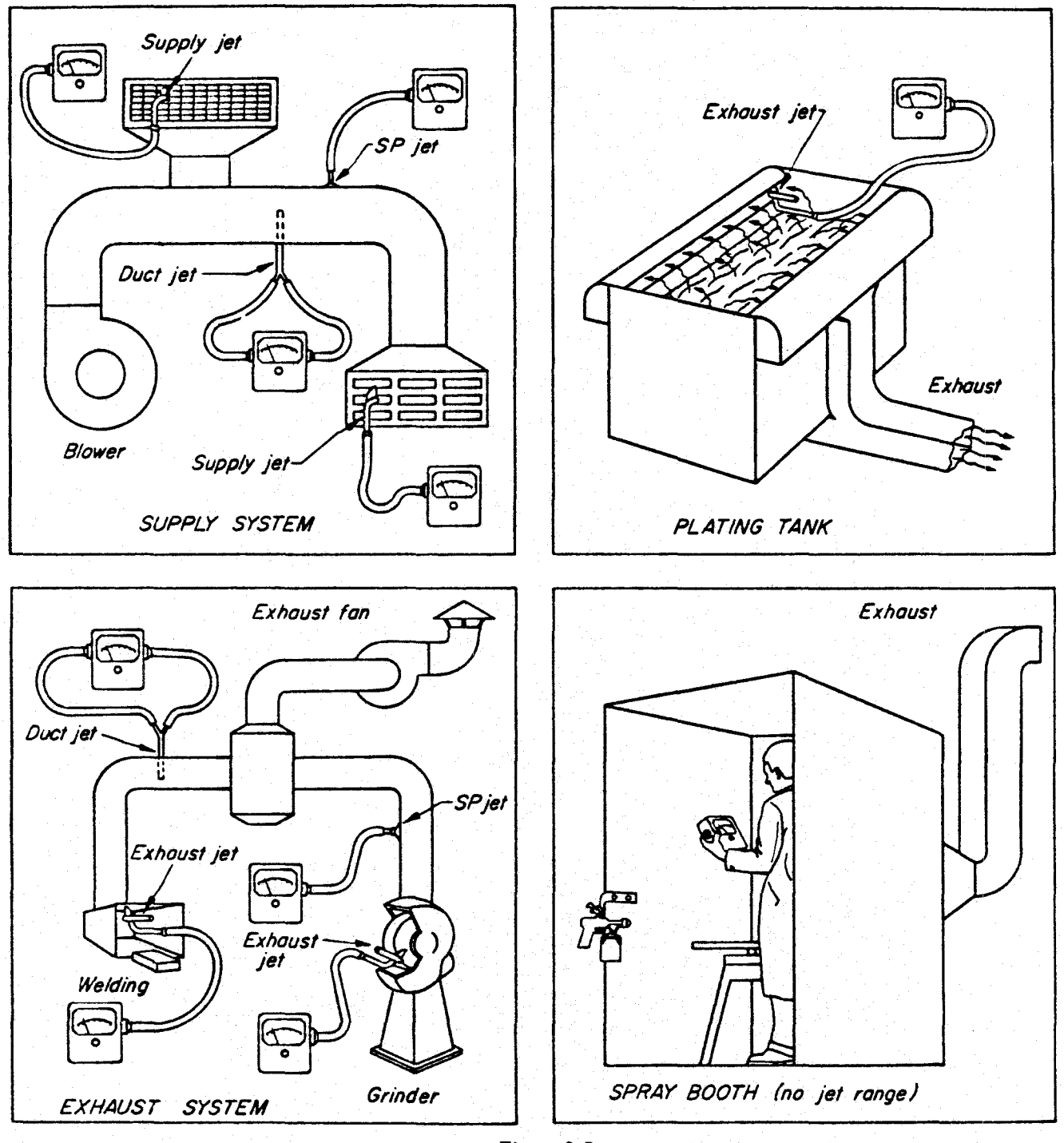


Figure 9-7

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Heated Wire Anemometer (5)(See Figure 9-10): The hot-wire anemometer depends on the variation of the resistance of a wire with temperature. When a stream of air passes over a heated wire, heat removal from the wire depends on the velocity of the air stream and thus the temperature of the wire and its resistance, vary with the air velocity.

The Anemotherm Air Meter (5) is a unique example of this type. In this instrument, the probe consist of two coils of fine nickel wire which connect through a cable to form the arms of a Wheatstone bridge. One of these coils is heated by a separate current passing through a third coil of nichrome wire—in thermal contact but electrically insulated from it—forming a conductive junction. Air passing over the probe element cools the heated wire and varies its resistance. This is reflected as a variation in air velocity on the pointer type scale. A push button switching arrangement provides scales for measuring air velocities from 10 to 8000 fpm. Use of a balancing circuit makes errors due to ambient temperature changes or radiant heat sources negligible.



Fig. 9-8

Means are provided for disconnecting the heater current; the unheated wire then acts as a temperature sensitive resistance in the bridge circuit. The range of temperature measurements available is 0 to 255 F. Static pressure can also be measured directly over a range of 9-10" wg, negative or positive.

This instrument is available also for permanent station air flow measurement and recording. The permanent station instrument is available with a probe of corrosion resistant material which requires a hole of at least 1" diameter for insertion into a duct or stack where air velocity is to be measured.

Limitations: The probe on the portable instrument is subject to fouling by dust and corrosion. It should be calibrated at regular intervals.

Heated Thermocouple Anemometers (Figure 9-11): This type instrument employs the principle that heat removal by an air stream passing a heated object is related to the velocity of the air stream. A hot junction thermocouple is used to sense the temperature of a heated probe in the air stream; a second cold junction thermocouple senses the temperature of the air. A voltage is generated between the heated and unheated junctions. Air flow tends to cool the heated thermocouple, decreasing its voltage output. This voltage output is an accurate measure of velocity of air flow. By using hot and cold thermocouple junctions with balancing circuits, errors due to radiant heat and ambient temperature fluctuations may be made negligible.

A number of instruments of this type are available commercially. Low velocities in the range of 10-25 fpm can be estimated. The response is fairly rapid, approximately one minute or less. In some instruments of this type the small sensing area gives essentially a non-directional reading. These instruments are light in weight and can derive the necessary electric power from either batteries or a line-connected, constant voltage transformer.

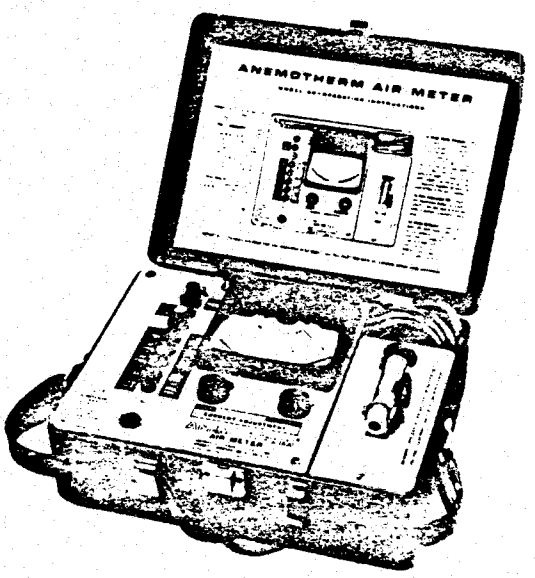


Fig. 9-10

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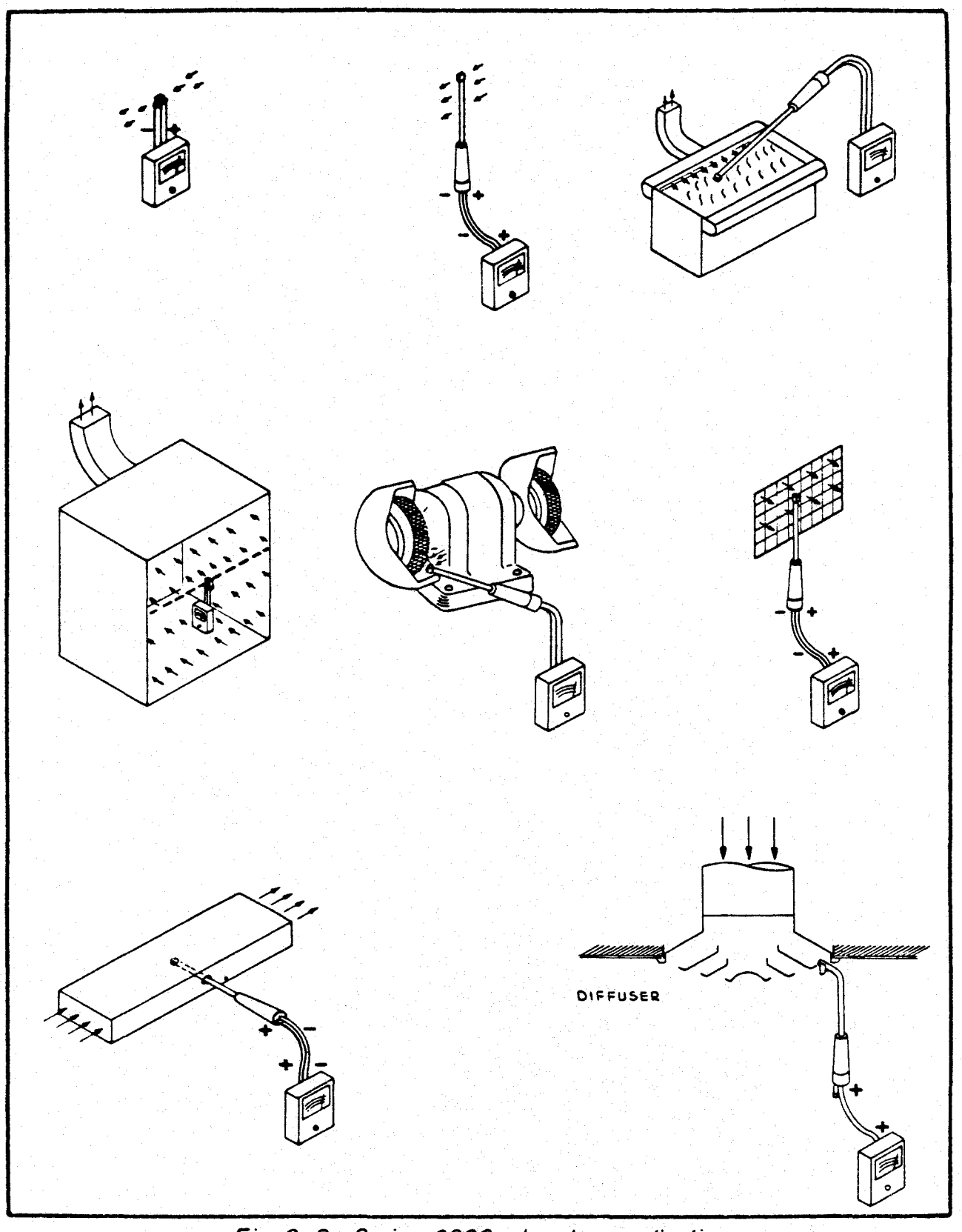


Fig. 9-9. Series 6000 velometer applications

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The instruments are most suited for measuring low velocities, room air currents and hood opening velocities. Certain instruments with small probes can be used for measurement of duct velocities lower than the capability of velocity pressure sensing devices.

Limitations: Portable battery-powered meters tend to fade in voltage during use necessitating frequent adjustment. Probes tend to be fragile and must be handled carefully. There is a need for frequent calibration. The delicate wires in the probe are easily damaged. The instrument should not be used in corrosive or dusty atmospheres.

Smoke Tubes: Low velocity measurements may be made by timing the travel of smoke clouds through a known distance. Smoke trail observations are limited to velocities less than 150 fpm since high air velocities diffuse the smoke too rapidly. Commercially available, the smoke tube or candle is useful in the observation of flow patterns surrounding exhaust or supply openings. They can be used also for checking air movement and direction in plant space.

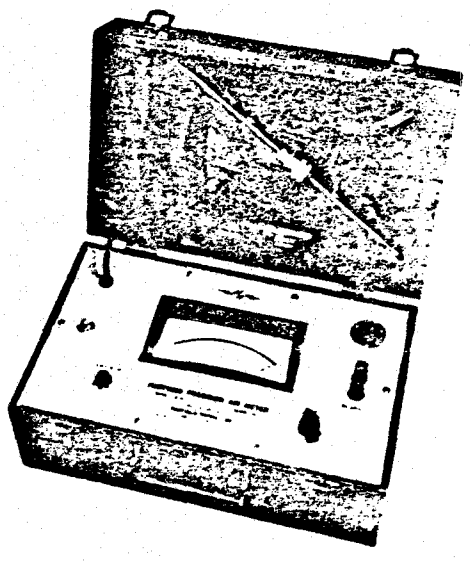


Fig. 9-11

Limitations: They can be used for low velocities and estimation purposes only. Smoke candles are incendiary and thus cannot be used in flammable atmospheres. Preferably they should not be hand held.

Tracer Gas-Dilution: The principle of dilution is sometimes used to determine rate of air flow. A tracer or test gas is continuously metered into one or more intake ports (hood or duct openings) along with the entering air stream. After thorough mixing and system equilibrium has been established, air samples are collected at some point downstream--usually at or near the effluent point--and the concentration of the test gas in the exit stream determined. The rate of air flow is readily calculated from the degree of dilution noted in the exit and feed gas concentrations (rate of air flow equals rate of feed divided by test gas concentration).

The test gas is usually selected on the basis of the following: (1) ease of collection and analysis, (2) not present naturally in the process being studied, (3) not absorbed chemically or physically in the duct system (4) non-reactive with other constituents of the gas stream (5) non-toxic or explosive.

When flow rates are low enough to allow thorough and intimate mixing, the method may be applied to the estimation of dilution ventilation rates in a general area or room.

Limitations: Necessitates use of air sampling and analytical procedures. Judicious choice of readily available test gas necessary. Method usually limited to special and/or permanent applications.

Calibration of Air Measuring Instruments

Direct reading meters need regular calibration as they are in many cases fragile, easily impaired by shock (dropping, jarring), dust, high temperatures and corrosive atmospheres. Meters should be calibrated regularly and must be calibrated if they do not zero properly and if they have been subjected to rough handling and adverse atmospheres.

Design of a Calibrating Wind Tunnel (98, 99, 100)

A calibrating wind tunnel for testing air flow meters must have the following components:

1. A satisfactory test section. This is the section where the sensing probe or instrument is placed; it must be uniform in air flow both across the air stream and in line with the air flow. A section with a pronounced vena contracta and turbulence will not give satisfactory results.
2. A satisfactory means of precisely metering the air flow. The meter on this system must be accurate and with large enough scale graduations so that the volume is indicated within ± 1%. For convenience and time-saving, a fixed single reading meter such as a venturi meter or orifice meter is preferable to a multi-point traverse type instrument such as a Pitot tube.

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TABLE 9-6. CHARACTERISTIC OF AIR METERS

Instruments	Range, fpm	Hole Size (for ducts)	Range, Temp.*	Dust, Fume Difficulty	Calibration Requirements	Rugged-ness	General Usefulness and Comments
PITOT TUBES with inclined manometer	600 - up	3/8"	Wide	Some	None	Good	
Standard	600 - up	3/8"	Wide	Some	None	Good	Good except at low velocities
Small Size	600 - up	3/16"	Wide	Yes	Once	Good	Good except at low velocities
Double	500 - up	3/4"	Wide	Small	Once	Good	Special
SWINGING VANE ANEMOMETERS							
Alnor Velometer	25-10,000	1/2" - 1"	300 F	Some	Frequent	Fair	Good
ROTATING VANE ANEMOMETERS							
Conventional	30-10,000	Not for duct use	Narrow	Yes	Frequent	Poor	Special; limited use
Electronic (Airflow Development)	25-200 25-500 25-2000 25-5000	Not for duct use	Narrow	Yes	Frequent	Poor	Special; can record; direct reading
Digital (Airflow Development)	200-5000	Not for duct use	Narrow	Yes	Frequent	Poor	Special
BRIDLE VANE ANEMOMETERS							
Florite Air Velocity Meter	50-2500	Not for duct use	Narrow	Yes	Frequent	Fair	Special
HEATED WIRE ANEMOMETERS							
Anemotherm Model 60	10-8000	3/8"	Medium	Some	Frequent	Poor	Good
Anemotherm Gas Flow Meter	10-5000	1"	300 F	No	Frequent	Good	Not portable; for permanent station air flow
Flowtronic Air Meter 55A	0-1000 1000-2000 2000-4000	1/2"	Medium	Yes	Frequent	Poor	Good
HEATED THERMOCOUPLE ANEMOMETERS							
Alnor Thermo-anemometer Model 8500	10-2000 2 scales	5/16"	Narrow	Yes	Frequent	Poor	Good
Hasting Precision Air Meter B-22	10-500 500-10,000	5/16"	Narrow	Yes	Frequent	Poor	Good
Flow Corporation Series 800	10-4000	1/2"	Narrow	Yes		Poor	Good
Alnor Air Velocity Transducer System (AVT)	20-500 50-1000 100-2000	5/16"	Narrow	Yes	Frequent	Poor	Special; for permanent station use
VARIABLE AREA METER							
Airmeter F. W. Dwyer Co.	200-1200 1000-4000	Not for duct use	Narrow	Yes	Occasional (Needs cleaning)	Good	Satisfactory for estimates of flow

*Range of Temperatures: Narrow - 20-150 F
Medium - 20-300 F
Wide - 0-800 F

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3. A means of regulating and effecting air flow through the tunnel. For usual calibrations of instruments used on heating, ventilating and industrial exhaust systems, test velocities from approximately 50 to 8000 fpm are needed. Air flow regulation must be such that there is no disturbance in the test section. The regulating device must be easily and precisely set to the desired velocities. The fan must have sufficient capacity to develop the maximum velocity in the test section against the static pressure of the entire system.

To provide a satisfactory uniform flow test section, a bell-shaped streamline entry is necessary (see Figure 9-12). There are various designs for this entry. One type is the elliptical approach in which curvature is similar to a one-quarter section of an ellipse, in which the semi-major axis of the ellipse is equal to the duct diameter to which the entry is placed and the semi-minor axis is two-thirds of the semi-major axis.

If A = semi-major axis, inches
B = semi-minor axis, inches
D = duct diameter adjacent to elliptical approach, inches

then A = D
B = 2/3 D

This type of entry can be made on a spinning lathe. Actually, any type of smooth curved, bell-shaped entry which directs the air into the duct over a 180° angle will be satisfactory. A readily available entry is a Sousaphone bell. This bell entry should be connected to a 5-1/2" diameter smooth, seamless plastic tube. Ridges, small burrs or obstructions should be filed so a smooth connection between horn and tube results.

For calibrating larger instruments such as the lower velocity swinging vane anemometer (Alnor velometer) and the rotating vane anemometer, a large rectangular test section of transparent plastic at least 2-1/2 sq ft in cross-sectional area can be constructed with curved air foil inlets as shown in Figure 9-12. A fine mesh screen placed deep in the enclosure assists in giving uniform air flow across the test portion. Checks on a great many traverse points indicate satisfactory uniformity for calibration.

A sharp-edged orifice, venturi meter or a flow nozzle can be used as a metering device. The sharp-edged orifice has more resistance to flow but is more easily constructed. It can also be made readily interchangeable for several orifice sizes. The orifice can be mounted between two flanged sections sealed with rubber gaskets. Three orifice sizes, 1.400", 2.625" and 4.900" diameters, can be used to meter flow rates from 50-8000 fpm. If the orifice and pipe taps are made to exact dimensions, the calculated air volume will be within 1% of actual flow for standard air.

The orifice can be calibrated with a standard Pitot tube. A micromanometer is needed to read velocity pressures below 2000 fpm. At 2000-3000 fpm, with a 10:1 inclined manometer, an accuracy of $\pm$ 0.3-1.0% can be expected; at 3000-4000 fpm an accuracy of $\pm$ 0.25-0.3% can be expected. If the orifice is made to the precise dimensions of Table 9-7 no calibration is needed and the tabulated calculation can be used. Table 9-7 gives computer calculations for three sizes of orifices, 1.400", 2.625" and 4.900" diameters. When the orifices are placed in a 7" diameter duct and are made to the precise dimensions given, the calculated data in the table will give air flows within $\pm$ 1%. The orifice sizes cover a range of measurable air flows from 18-1155 cfm.

A centrifugal fan with sufficient capacity to exhaust 1100 cfm at 10" wg static pressure is needed for a wind tunnel with a 5-1/2" diameter test section using an orifice meter. Radial blade centrifugal fans are available with the required characteristics. The air flow can be changed with either an adjustable damper at the discharge or a variable speed drive on the fan.

Use of Calibrating Wind Tunnel

For accurate results, air flow measuring instruments must be calibrated in the manner in which they are to be used in the field. Swinging vane and rotating vane anemometers are placed in the large rectangular test section on a suitable support and air velocity is varied through the operating range. Low velocity heated thermocouple and heated thermometer instruments are calibrated in the same manner. Special Pitot tubes and duct probes of direct reading instruments are placed through a suitable port in the circular duct section and again, calibrated throughout the operating range (see Figure 9-13).

Calculation of Flow for Orifice Meter (7)

The air flow for a sharp-edged orifice with pipe taps located 1" on either side of the orifice can be accurately computed from the following equations for standard air (density 0.075#/cu ft)* for ducts 2" - 14" in diameter.

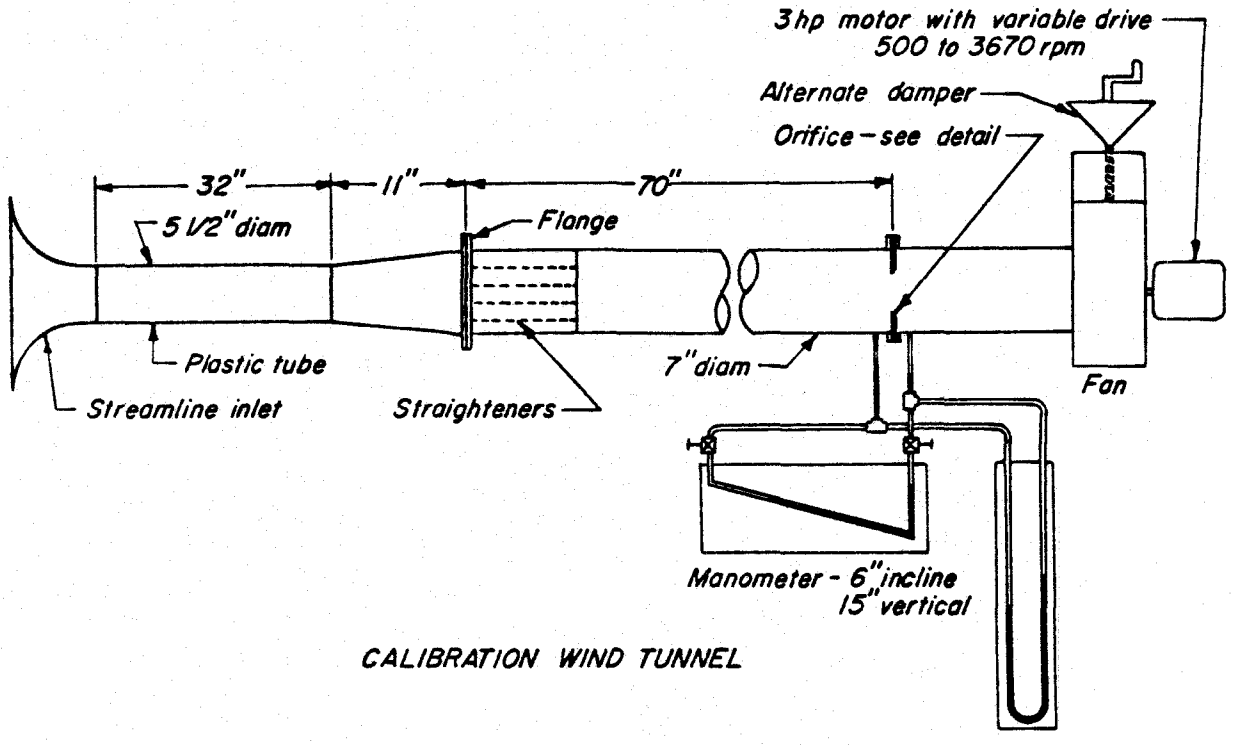
$$Q = 21.8\ KD^2\sqrt{h}$$

*For densities other than standard, the following equation can be used as a good approximation:

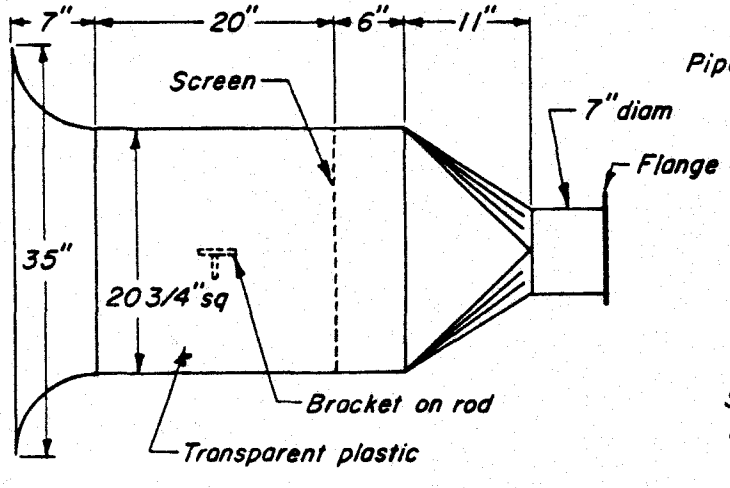
$$Q = 6KD^2\sqrt{\frac{h}{0.075\ d}}$$ where d = density factor

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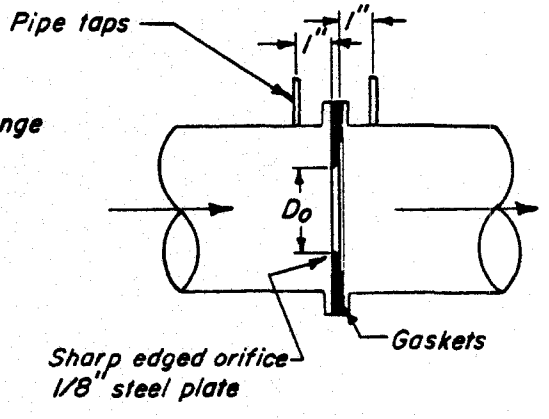


CALIBRATION WIND TUNNEL



TEST SECTION

For low velocity meters with large area in test air stream



ORIFICE DETAIL

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
CALIBRATION WIND TUNNEL	
DATE 1-70	Fig. 9-12

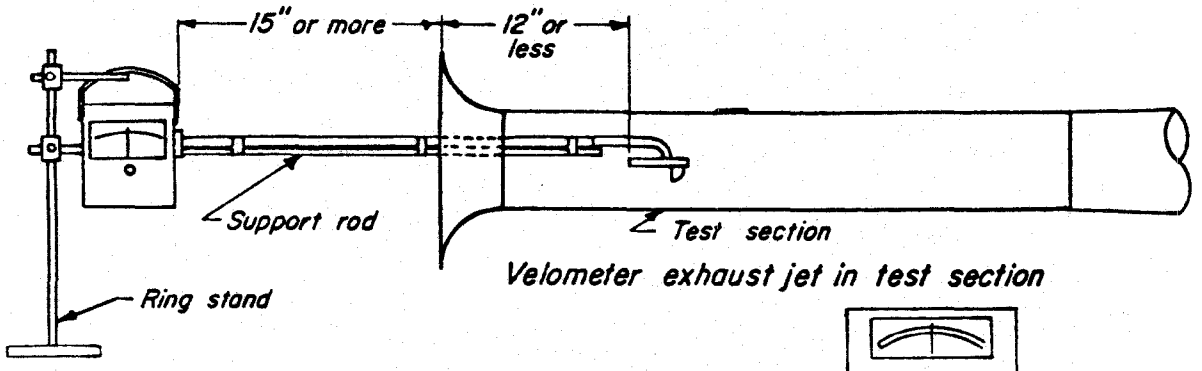
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TABLE 9-7. ORIFICE FLOW RATE (SCFM) VERSUS PRESSURE DIFFERENTIAL (in. of Water)

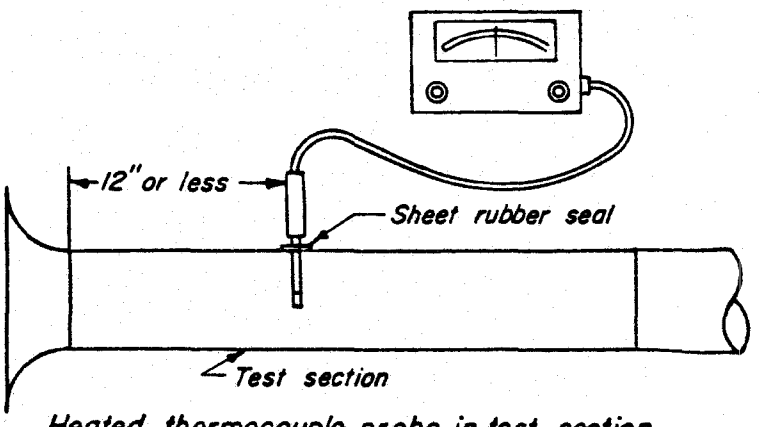
ΔP	ORIFICE SIZE			ΔP	ORIFICE SIZE			ΔP	ORIFICE SIZE		
"WC	1.4"	2.625"	4.90"	"WC	1.4"	2.625"	4.90"	"WC	1.4"	2.625"	4.90"
0.02			57.1	1.22	28.7	101.4	410.3	4.10	52.3	185.3	746
0.04		18.7	78.8	1.24	28.9	102.3	413.6	4.20	52.9	187.5	755
0.06		22.8	95.3	1.26	29.2	103.1	416.9	4.30	53.5	189.7	763
0.08		26.2	109.2	1.28	29.4	103.9	420.1	4.40	54.1	191.9	772
0.10		29.3	121.5	1.30	29.6	104.7	423.4	4.50	54.7	194.0	781
0.12		32.1	132.6	1.32	29.8	105.5	426.5	4.60	55.3	196.2	789
0.14		34.6	142.8	1.34	30.1	106.3	429.7	4.70	55.9	198.3	797
0.16		37.0	152.3	1.36	30.3	107.1	432.9	4.80	56.5	200.4	806
0.18		39.2	161.2	1.38	30.5	107.9	436.0	4.90	57.1	202.4	814
0.20		41.3	169.6	1.40	30.7	108.6	439.1	5.00	57.6	204.4	822
0.22		43.3	177.6	1.42	30.9	109.4	442.2	5.10	58.2	206.5	830
0.24		45.2	185.2	1.44	31.2	110.2	445.2	5.20	58.8	208.5	838
0.26		47.0	192.6	1.46	31.4	110.9	448.3	5.30	59.3	210.4	846
0.28		48.8	199.6	1.48	31.6	111.7	451.3	5.40	59.9	212.4	854
0.30		50.5	206.5	1.50	31.8	112.4	454.3	5.50	60.4	214.3	862
0.32		52.1	213.0	1.52	32.0	113.2	457.2	5.60	61.0	216.3	869
0.34		53.7	219.4	1.54	32.2	113.9	460.2	5.70	61.5	218.2	877
0.36		55.3	225.6	1.56	32.4	114.6	463.1	5.80	62.0	220.0	884
0.38		56.8	231.6	1.58	32.6	115.4	466.0	5.90	62.6	221.9	892
0.40		58.3	237.5	1.60	32.8	116.1	468.9	6.00	63.1	223.8	899
0.42		59.7	243.2	1.62	33.0	116.8	471.8	6.10	63.6	225.6	907
0.44		61.1	248.8	1.64	33.2	117.5	474.7	6.20	64.1	227.4	914
0.46		62.4	254.3	1.66	33.4	118.2	477.5	6.30	64.6	229.2	921
0.48		63.8	259.6	1.68	33.6	118.9	480.3	6.40	65.1	231.0	928
0.50	18.5	65.1	264.9	1.70	33.8	119.6	483.1	6.50	65.6	232.8	935
0.52	18.8	66.4	270.0	1.72	34.0	120.3	485.9	6.60	66.1	234.6	942
0.54	19.2	67.6	275.0	1.74	34.2	121.0	488.7	6.70	66.6	236.3	949
0.56	19.5	68.9	280.0	1.76	34.4	121.7	491.5	6.80	67.1	238.1	956
0.58	19.9	70.1	284.8	1.78	34.6	122.4	494.2	6.90	67.6	239.8	963
0.60	20.2	71.3	289.6	1.80	34.8	123.1	496.9	7.00	68.1	241.5	970
0.62	20.6	72.4	294.3	1.82	35.0	123.8	499.7	7.10	68.5	243.2	977
0.64	20.9	73.6	298.9	1.84	35.2	124.4	502.4	7.20	69.0	244.9	984
0.66	21.2	74.7	303.4	1.86	35.4	125.1	505.0	7.30	69.5	246.5	990
0.68	21.5	75.8	307.9	1.88	35.5	125.8	507.7	7.40	69.9	248.2	997
0.70	21.8	76.9	312.3	1.90	35.7	126.4	510.4	7.50	70.4	249.9	1003
0.72	22.1	78.0	316.7	1.92	35.9	127.1	513.0	7.60	70.9	251.5	1010
0.74	22.4	79.1	320.9	1.94	36.1	127.8	515.6	7.70	71.3	253.1	1017
0.76	22.7	80.2	325.2	1.96	36.3	128.4	518.2	7.80	71.8	254.7	1023
0.78	23.0	81.2	329.3	1.98	36.5	129.1	520.8	7.90	72.2	256.4	1029
0.80	23.3	82.2	333.5	2.00	36.6	129.7	523.4	8.00	72.7	257.9	1036
0.82	23.6	83.2	337.5	2.10	37.5	132.9	536.2	8.10	73.1	259.5	1042
0.84	23.9	84.2	341.6	2.20	38.4	136.0	548.6	8.20	73.6	261.1	1048
0.86	24.1	85.2	345.5	2.30	39.3	139.0	560.8	8.30	74.0	262.7	1055
0.88	24.4	86.2	349.4	2.40	40.1	142.0	572.6	8.40	74.5	264.2	1061
0.90	24.7	87.2	353.3	2.50	40.9	144.9	584.3	8.50	74.9	265.8	1067
0.92	25.0	88.1	357.2	2.60	41.7	147.8	595.7	8.60	75.3	267.3	1073
0.94	25.2	89.1	361.0	2.70	42.5	150.6	606.9	8.70	75.7	268.8	1079
0.96	25.5	90.0	364.7	2.80	43.3	153.3	617.9	8.80	76.2	270.4	1085
0.98	25.8	91.0	368.4	2.90	44.0	156.0	628.6	8.90	76.6	271.9	1091
1.00	26.0	91.9	372.1	3.00	44.8	158.7	639.2	9.00	77.0	273.4	1097
1.02	26.3	92.8	375.7	3.10	45.5	161.3	649.6	9.10	77.4	274.9	1103
1.04	26.5	93.7	379.3	3.20	46.2	163.8	659.9	9.20	77.9	276.4	1109
1.06	26.8	94.6	382.9	3.30	46.9	166.4	670.0	9.30	78.3	277.8	1115
1.08	27.0	95.5	386.4	3.40	47.6	168.8	679.9	9.40	78.7	279.3	1121
1.10	27.3	96.3	390.0	3.50	48.3	171.3	689.7	9.50	79.1	280.8	1127
1.12	27.5	97.2	393.4	3.60	49.0	173.7	699.3	9.60	79.5	282.2	1132
1.14	27.8	98.1	396.9	3.70	49.7	176.1	708.8	9.70	79.9	283.6	1138
1.16	28.0	98.9	400.3	3.80	50.3	178.4	718.2	9.80	80.3	285.1	1144
1.18	28.2	99.8	403.7	3.90	51.0	180.7	727.5	9.90	80.7	286.5	1150
1.20	28.5	100.6	407.0	4.00	51.6	183.0	736.6	10.00	81.1	287.9	1155

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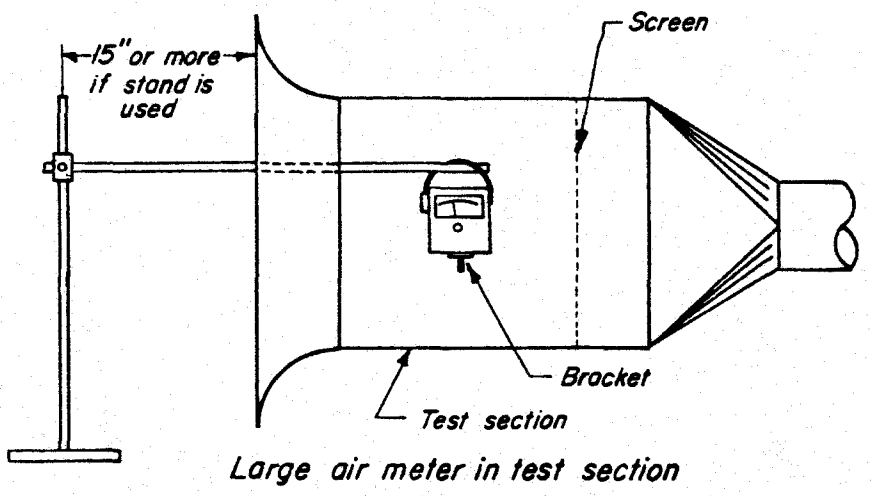
MT-PWHD-004725



Velometer exhaust jet in test section



Heated thermocouple probe in test section



Large air meter in test section

Keep test section entrance clear of obstructions and free of drafts

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CALIBRATION

DATE 1-70 | Fig. 9-13

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MT-PWHD-004726

where Q = air volume, cfm
K = coefficient of air flow (7)
D = orifice diameter, inches
h = pressure drop across orifice, "wg

The constant K is affected by the Reynolds number, a dimensionless value expressing flow conditions in a duct. The following equation gives a simplified method of calculating Reynolds number for standard air.

$$R = 8.4\ DV$$

where R = Reynolds number
V = velocity of air through orifice, fpm

The constant "K" can be selected from tables (7).

Venturi meters can be used also for metering air flow. They impose less resistance to flow; however, they are more difficult to construct.

Pressure Measurement

Static Pressure

Pressure measurements are useful in determining resistances or pressure drops through hoods, dust collectors and other parts of an exhaust system. Pressure measurements are also used to determine fan static pressure and to estimate air flow into hoods and other exhaust openings by the throat-suction method.

The measurement of static pressure is quite simple and well understood by most engineers. It is measured by means of some pressure measuring device, usually a simple U-tube manometer filled with oil or water and is graduated in inches water gauge. A vertical manometer is suitable for most static pressure measurements. The use of an inclined manometer with a 10 to 1 slope gives increased accuracy and permits lower readings. For field measurement, one leg of the manometer is furnished with flexible tubing and the other end of the tube is held flush and tight against a small static pressure opening in the side of the pipe. Special fittings may be used if desired. Specific information in great detail concerning manometers may be found in the A.S.M.E. Power Test Code 19.2.5 (4).

The static pressure hole is of some importance in obtaining a correct pressure measurement. The location of the static pressure opening is not usually of too much importance except that one should avoid, if possible, pressure measurement at the heel of an elbow or other such points where static pressure may be incorrect because the direction of the velocity component is not parallel with the pipe walls. It is usually advisable to drill from two to four pressure holes at uniform distances around the pipe in order to obtain an average and to indicate any discrepancy.

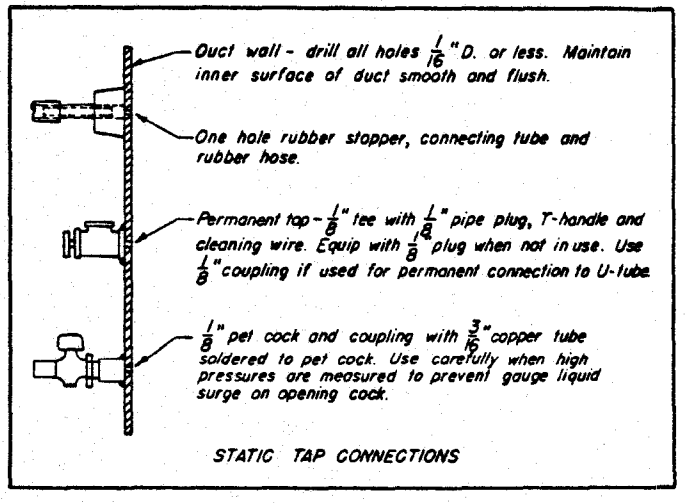


Fig. 9-14

The static pressure openings should be flush with the inner surface of the pipe wall and there should be no burrs or projections on the inner surface. The hole should be drilled, not punched. A 1/16 inch to 1/8 inch hole is usually satisfactory since the size is not too important except for some types of instruments where air actually flows through the device. (See Fig. 9-14). In such cases, the manufacturers' recommendations should be followed concerning the size of the static pressure opening.

A second method less likely to involve error is the use of the static pressure element of a Pitot tube as shown in the illustration. A static tube of the same general design as the Pitot may also be used, omitting the center tube. In using the instrument, it should be pointed upstream, avoiding impact or eddies.

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Manometers

U-Tube: The vertical U-tube is the simplest type of pressure gauge. Usually calibrated in inches of water, it is used with various fluid media--such as alcohol, mercury, oil, water, kerosene and special manometer fluids. The U-tube may be used for either portable or stationary applications. Available commercial units offer a wide latitude in range, number of columns and styles. Tubes are usually of all-plastic construction to minimize breakage. One leg may be replaced by a reservoir or well (well-type manometer) with the advantage of easier manometer reading.

Inclined Manometer: Increased sensitivity and scale magnification is realized by tilting one leg of the U-tube to form an inclined manometer or draft gauge. The inclined manometer, usually with 10 to 1 slope, gives increased accuracy and permits lower readings. In commercial versions, only one tube of the small bore is used and the other leg is replaced by a reservoir. The accuracy of the gauge is dependent on the slope of the tubes. Consequently the base of the gauge must be leveled carefully and the mounting must be firm enough to permit accurate leveling. The better draft gauges are equipped with a built-in level, leveling adjustment and, in addition, a means of adjusting the scale to zero. Some models include over-pressure safety traps to prevent loss of fluid in event of pressure surges beyond the manometer range.

A modification of the inclined manometer is the inclined-vertical gauge in which the indicator leg is bent or shaped to give both a vertical and inclined (10 to 1) portion--the advantage being smaller physical size for a given range while retaining the refined measurement afforded by the inclined manometer. As in the U-tube and inclined gauges the commercial units available offer a wide choice in range, number of columns, and calibration units.

Specific information in great detail concerning manometers may be found in the ASME Power Test Code 19.2.5 (4).

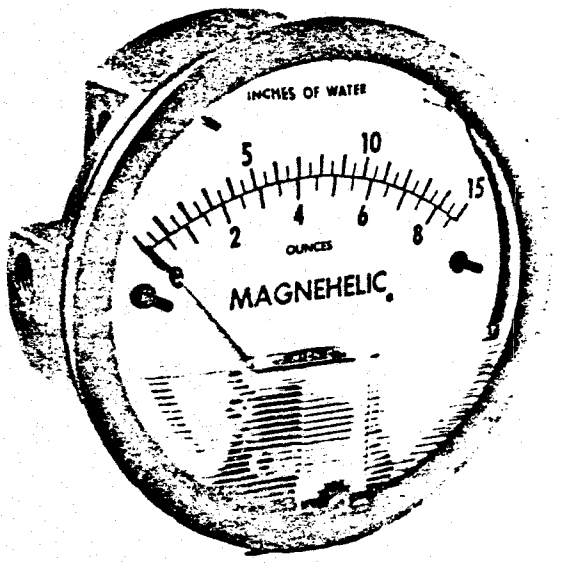


Fig. 9-15

Aneroid Type Gauges: This type of gauge is used as a field instrument in ventilation studies for measuring static, velocity or total pressure with a Pitot tube or for single tube static pressure measurements. There are a number of manufacturers offering gauges suitable for the measurement of the low pressures encountered in ventilation studies. Perhaps the best known of this type is the Magnehelic gauge (63) (See Figure 9-15). Principal advantages of this gauge may be listed as follows: easy to read, greater response than manometer types, very portable--of small physical size and weight, absence of fluid means less maintenance and mounting and use in any position is possible without loss of accuracy. Principal disadvantages are that, being a mechanical-type device, the gauge is subject to mechanical failure, requires periodic calibration checks and occasional recalibration.

Miscellaneous: For measuring low pressure differences to within 0.001 inches of water, very sensitive micromanometers are available such as the Illinois (21) or Wahlen (43) and hook gauges. Such instruments are usually employed in the laboratory for experimental and calibration purposes rather than for collection of ventilation data in the field.

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TABLE 9-8. CHARACTERISTICS OF PRESSURE MEASURING INSTRUMENTS
(Static Pressure, Velocity Pressure, Differential Pressure)

Instrument	Range, "wg	Mfg's. Stated Precision, "wg	Comments
LIQUID MANOMETERS			
Vertical U-tube	No limit	0.1	Portable. Needs no calibration.
Inclined 10:1 Slope	Usually up to 10	0.005	Portable. Needs no calibration. Must be leveled.
Hook Gage	0-24	0.001	Not a field instrument. Tedious, difficult to read. For calibration only.
Micromanometer (Meriam Model 34FB2TM)	0-10 0-20	0.001	Heavy. Need to locate on vibration-free surface. Not difficult to read; uses magnifier.
Micromanometer (Vernon Hill Type C)	0.001-1.2	0.0004	Small; portable. Uses magnifier. Need experience to read to manufacturer's precision. Calibration needed.
Micromanometer[105] (Electric Microtectic F. W. Dwyer, Mfg.)	0-2	0.0003	Portable. Needs vibration-free mount. No magnifier. Slow to use. No eyestrain. No calibration needed.
DIAPHRAM AND MECHANICAL			
Diaphram-Magnehelic Gage	0-0.5 0-1 0-4	0.01 0.02 0.10	Calibration recommended. No leveling, no mounting needed. Direct reading.
Swinging Vane Anemometer Alnor Velometer	0-0.5 0-20	5% scale	Calibration recommended. No leveling, no mounting needed. Use manufacturer's exact recommendation for size of SP hole.
PRESSURE TRANSDUCERS AND ELECTRONIC INSTRUMENTS			
Pressure Transducers	0.05-6	0.3%	Must be calibrated. Remote reading responds to rapid change in pressure.

Evaluating Exhaust Systems

Knowledge of the air measurement equipment and methods discussed above is essential before an exhaust system can be checked after its installation has been completed and at intervals during operation to verify its maintained effectiveness.

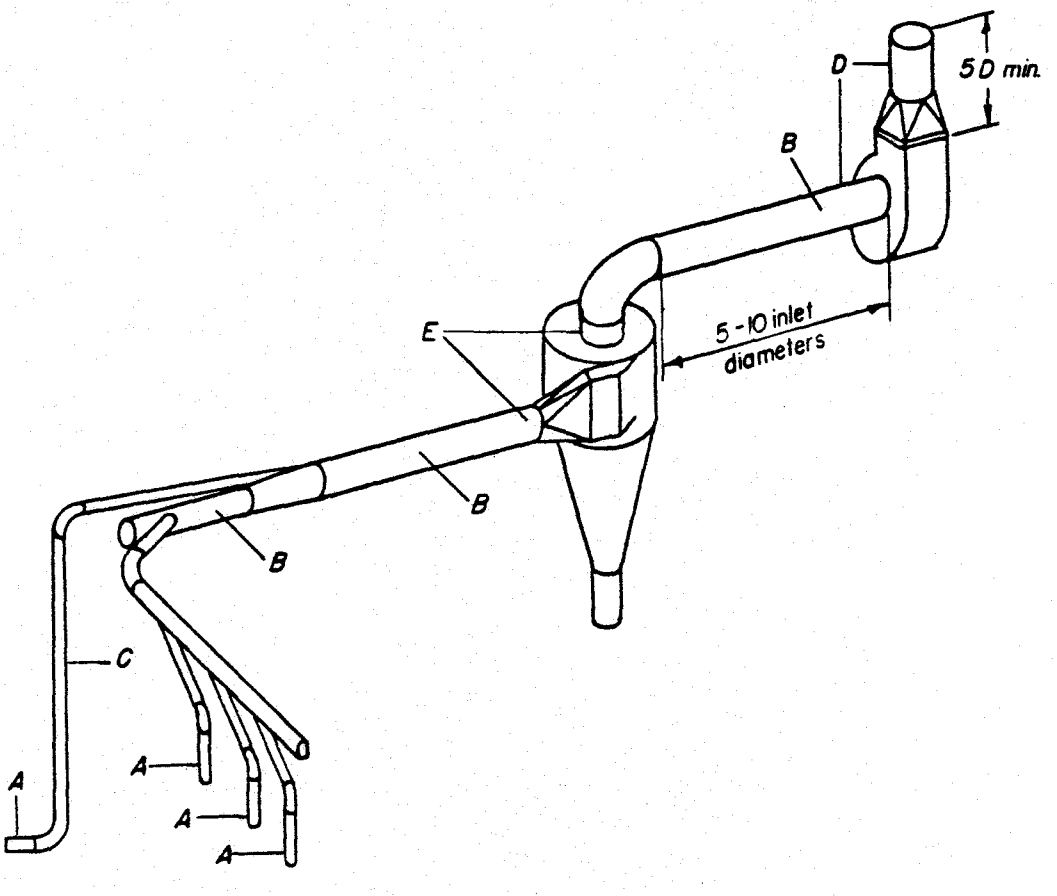
New Installations

Sufficient data should be taken on completion of every installation to verify (1) that exhaust volumes, distribution and system balance are in agreement with design data; (2) that contaminant control is effective. As a first step, a sketch of the system, not necessarily to scale, but indicating size, length and relative location of all ducts, fittings and associated system components should be made. The sketch will serve as a guide in selection of measuring points and very often will bring to light incorrect installation and poor design features. Physical system changes which may occur at a later date (addition of branches, alteration of hoods or ductwork) are easily noted if such a sketch is available as a permanent record.

Initial air measurements should include cfm (velocity) and static pressure measurements in each branch and in the main, static pressure measurements (throat suction) at each exhaust opening, static and total pressure measurements at both fan inlet and outlet, and pressure measurements at collection equipment inlet and outlet (differential pressure). Measurement data will indicate any variation from design data, will indicate need for balancing to obtain needed distribution and will verify that transport velocities in branches and main are ample to convey the material handled. Where imbalance is found, it is advisable to again take pressure readings after the system has been balanced. All air measurements and location of measuring points should be recorded to serve as a basis for future checks designed to spot any variations in exhaust volumes from original values.

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Point	Measurement	Location of measurement	Measurement use
A	Hood static pressure	Distance from hood – 3 pipe diameters-flanged or plain hood 1 pipe diameter – tapered hood	1. estimate flow: $Q = 4005\, Ce\, A\sqrt{SP_h}$ 2. check point for hood and system performance.
B	Velocity and static pressure	Branch and mains - preferably 7.5 diameters straight run downstream from nearest air disturbance (el, entry, etc.)	1. transport velocity 2. exhaust volume: $Q = VA$ 3. SP as system check point
C	Centerline VP	Small ducts location as above. Centerline velocity reading only.	Round duct only. Use on small ducts where traverse impractical or where approximate volume wanted.
D	Static, velocity and total pressures	Inlet and outlet of fan – any two of three readings at each location	1. Fan static and total pressures $FSP = SP_o + SP_i - VP_i$ $TP = SP_o + SP_i + VP_o - VP_i$ 2. Motor size or CFM estimate $BHP = \frac{CFM \times TP}{6356 \times ME \text{ of fan}}$ 3. SP as system check point
E	Static pressure	Inlet and outlet of collector Differential pressure	1. Compare pressure drop with normal operating range 2. Checkpoints for maintainence. Readings above or below normal indicate plugging, wear or damage to collector elements, need of cleaning

In addition to the above, face velocity (hood face) and capture velocity (point of contaminant dispersion) measurements are usually made to define hood performance. Observation of air flows surrounding exhaust openings may be visually augmented by use of smoke generators, trails and streamers.

Fig. 9-16

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Plant _____ Dept. _____ Date _____

Operation exhausted _____ By _____

Line sketch showing points of measurement

Date system installed _____

Hood and transport velocity

Point	Duct		VP in. H_2O	SP in. H_2O	FPM (Fig. 6-16)	CFM Q = VA	Remarks
	D	Area (Fig. 6-18)					

Pitot traverse

Pitot readings - See Fig. 6-16 & Tables 9-1, 9-2 9-3

Points	VP	Vel.	VP	Vel.	VP	Vel.
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
Total Vel.						
Average Vel.						
CFM						

Fan

Type _____

Size _____

Point	Dia.	SP	VP	TP	CFM
Inlet					
Outlet					

Fan SP _____ (See Section 6)

Motor

Name _____ Size _____

HP _____ E _____ I _____ W _____

Collector

Type & size _____

Point	Dia.	SP	ΔSP
Inlet			
Outlet			

Notes _____

Fig. 9-17

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Hood design checks should verify that the contaminant source is hooded as completely as possible without interfering with the operation. Air analysis will vary with contaminant, using air sampling at operator's breathing zone where toxic materials are involved and probably only observation for visual escapement where non-toxic and nuisance materials are exhausted.

In Figure 9-16 is pictured an example of an exhaust system with possible testing points. Obviously selection of testing points will be dictated by the system under consideration and rarely will it be possible to attain the ideal--as in laboratory test installations. However, with judicious selection of measuring stations to avoid excessively turbulent flow and with proper attention to calibration, alignment, and positioning of instruments, measurements approaching the accuracy of design calculations are possible.

Figure 9-17 illustrates one type of survey form. Collection of data will serve little purpose if a permanent record is not maintained so that periodic test data can be compared. Any type of form which suits the individual's needs will suffice.

Existing Installations

For most existing installations, elaborate air sampling studies are seldom needed at frequent intervals. Unless the process is changed, the hoods or enclosures altered or the method of materials handling revised, the hazard should remain controlled as long as the exhaust system functions properly.

The word "properly" can rightly be underscored because in many cases little attention is given to such an installation after the project has been completed. Yet mechanical exhaust equipment and dust collectors require the same attention that machine tools and other plant equipment require and usually receive.

The tools required under most cases for a routine check on the performance of an exhaust system are a manometer (U-gauge) or an inclined gauge, depending on the static pressure values involved.

While hood suction readings have rightfully fallen into a state of ill repute as a means of measuring air flow, they do offer a quick and accurate method of measuring relative air flow. If the hood suction is known while an exhaust system is functioning properly, its continued effectiveness can be assured so long as the hood suction does not reduce from its original value. Any change from the original hood suction can only indicate a change in velocity in the branch and consequently a change in air volume removed from the hood. This relation will be true unless (1) hood design has been changed which would affect the ease of exhausting the air volume (entrance loss), (2) there are obstructions or accumulations in hood or branch ahead of the point of hood suction reading or (3) the system has been altered or added to. Restrictions of the cross-sectional area will reduce the air volume, although hood suction may even increase, dependent on location and degree of accumulation.

The hood suction method of checking can more readily be delegated to an assistant without technical training than the Pitot tube where care must be exercised in reading velocity pressures in the correct location with the tube paralleling the flow of air. U-gauges have been standard plant equipment long enough to eliminate any feeling of uncertainty in their use.

Since pressure readings vary as the square of the velocity or volume in question, a slight change is magnified by comparison of gauge readings. To illustrate, an indicated reduction in static pressure readings of 19 to 30 per cent would reflect a volume (or velocity) decrease of 10 to 15 per cent.

A marked reduction in hood suction can often be traced to one or more of the following items:

1. Reduced performance by the exhaust fan caused by reduced speed due to belt slippage, wear on rotor or casing or accumulation on rotor or casing that would obstruct air flow.
2. Reduced performance caused by defects in the exhaust piping, such as accumulations in branch or main ducts due to insufficient conveying velocities, condensation of oil or water vapors on duct walls, adhesive characteristics of material exhausted or leakage losses caused by loose clean-out doors, broken joints, holes worn in duct (most frequent in elbows), poor connection to exhauster inlet, accumulations in ducts or on fan blades.
3. Losses in suction can also be charged to additional exhaust points added to the system (sometimes systems are designed for future connections and more air than required is handled by present branches until future connections are made), change of setting of blast gates in branch lines. (Blast gates adjust the air distribution between the various branches. Tampering with the blast gates can seriously affect such distribution and therefore gates should be locked in place immediately after the system has been installed and its effectiveness checked.)
4. Reduced exhaust volume may be caused by increased pressure loss through dust collector due to lack of maintenance, improper operation, wear, etc. These items will vary with the collector design. Refer to operation and maintenance instructions furnished with the collector or consult the equipment manufacturer. Also, see section on Air Cleaning Devices (Section 11).

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Check-out Procedure

The following check-out procedure may be used on systems which were designed to balance without the aid of blast gates. It is intended as an initial check on the design computations and contractor's construction in new systems, but it may be used also for existing systems when design calculations are available or can be recomputed. It does not detect poor choices of design criteria such as low conveying or capture velocities and consequently will not reveal inadequate control due to this type of error. Agreement with design within ± 10% is considered acceptable.

The following equipment will be adequate to perform the tests required for this check-out procedure:

Pitot tubes—various lengths
Pressure gauges—inclined manometer or magnehelic
Rotational speed measuring device—revolution counter or stroboscope
Air velocity meter—low range (velometer or thermal anemometer)
Diameter tape

1. Measure flow in duct on inlet side of fan with a pitot traverse. If flow is too low, proceed to No. 1a; if correct, go to No. 4.
   a. Check fan size against plan
   b. Check fan speed and direction of rotation against design
   c. Check fan inlet and outlet configuration against plan.
2. If a discrepancy is found and corrected, return to No. 1. If not, measure fan inlet and outlet static pressures and compute the fan static pressure. Using fan table, check flow, fan static pressure and RPM. If agreement is acceptable although at some other operating point than specified, fan is satisfactory and trouble is elsewhere in system. Proceed to No. 3.
3. If fan inlet static pressure is greater (more negative) than calculated in design, proceed to No. 4. If fan outlet static pressure is greater (more positive) than design, proceed to No. 8.
4. Measure hood static pressure on each hood and check against design. If too high on any hood, proceed to No. 4a; if too low, go to No. 6. If correct, go to No. 10.
   a. Check size and design of hoods and slots against plan.
   b. Examine hood for obstructions.
5. After all hood construction errors and obstructions have been corrected, if hood static pressures are correct, return to No. 1; if too low, proceed to No. 6.
6. Measure static pressure at various junctions in ducts and compare with design calculations. If too high at a junction, proceed up-stream until static pressures are too low and isolate the trouble. In area where losses exceed design:
   a. Check angle of entries to junctions against plan
   b. Check radii of elbows against plan
   c. Check duct diameters against plan
   d. Check duct for obstructions
7. After correcting all construction details which deviate from specifications, return to No. 1.
8. Measure pressure differential across air cleaning device and check against manufacturer's data. If loss is excessive, make necessary corrections and return to No. 1. If loss is less than anticipated, proceed to No. 8a.
   a. Check ducts, elbows and entries as in No. 6a to 6d.
   b. Check system discharge type and dimensions against plans.
9. If errors are found, correct and return to No. 1. If no errors can be detected, recheck design against plan, recalculate and return to No. 1 with new expected design parameters.
10. Measure control velocities at all hoods where possible. If control is inadequate, redesign or modify hood.
11. The above process should be repeated until all defects are corrected and the hood static pressures and control velocities are in reasonable agreement with design. The actual hood static pressures

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should then be recorded for use in periodic system checks. A file should be prepared containing the following documents:

System plan
Design calculations
Fan rating table
Hood static pressures after check-out
Maintenance schedule
Periodic hood static pressure measurement log
Periodic maintenance log

Air Flow Measurements on Discharge Stacks

It is often necessary, in connection with the evaluation and control of air pollution, to determine the velocity and quantity of air in discharge stacks. These measurements are of importance for the following reasons:

1. It is necessary to know the volume of air coming from a discharge stack to select the proper size of air-cleaning equipment.
2. The measurement of the quantity of air discharged is necessary in conjunction with stack-sampling data in determining the total quantity of contaminant coming from the stack per unit time.
3. The linear velocity in the discharge stack is necessary for accurate stack-sampling technique. (The collection of a representative dust sample requires that the velocity in the sampling nozzle and the air stream be nearly equal. This is known as sampling under isokinetic conditions.)

Difficulties Encountered in Measuring Stack Flows or Density

The general procedures and instrumentation for the measurement of airflow have been previously discussed in this chapter. However, special problems connected with airflow measurement in discharge stacks necessitate a somewhat more detailed discussion.

Some of the special problems are as follows:

1. Measurement of airflows in highly contaminated air which may contain corrosive gases, dusts, fumes, or mists.
2. Measurement of airflows at high temperatures.
3. Measurement of airflow in high concentrations of water vapor and mist.
4. Measurement of airflow where the velocity is very low.
5. Measurement of airflow in locations of turbulence and non-uniform airflow; i.e., discharge of cupolas, locations near bends or enlargements.
6. Measurement of airflow in connection with isokinetic sampling where the velocity is constantly changing.

Selection of Instruments

The selection of the proper instrument will depend on the range of airflow to which the instrument is sensitive, its vulnerability to high temperatures, corrosive gases and contaminated atmospheres, its portability and ruggedness, and its size of measuring probe relative to the available sampling hole in the stack. A brief summary of the characteristics of a few of the instruments which have been used is given in Tables 9-6 and 9-8.

In many cases, conditions for airflow measurement are so severe that it is difficult to select an instrument. Generally speaking, the Pitot tube is the most serviceable instrument, inasmuch as it has no moving parts and it is rugged and will stand high temperatures and corrosive atmospheres when it is made of stainless steel. It is subject to plugging, however, when it is used in a dusty atmosphere. It cannot be used for measurement of low velocities. A special design of Pitot tube can be used for dusty atmospheres. In many cases, it is difficult to set up an inclined manometer in the field because many readings are made from ladders, scaffolds, and difficult places. This greatly limits the lower range of the Pitot tube. A mechanical gauge has been used in place of the liquid U-tube manometer. This gauge is estimated to be accurate to 0.02" of water; however, the gauge should be frequently calibrated against an inclined U-tube manometer.

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For lower velocities, the swinging-vane anemometer previously described can be used if conditions are not too severe. The instrument can be purchased with a special dust filter which allows its use in light dust loadings. It can be used in temperatures up to 1000 F if the jet is exposed to the high temperature gases only for a very short period of time (30 seconds or less). It cannot be used in corrosive gases. If the very low velocity jet is used, a hole over 1" in diameter must be cut into the duct or stack.

For very low velocities, anemometers utilizing the heated thermocouple principle can be used under special conditions. In most cases, these anemometers cannot be used in high temperatures above 300 F. One manufacturer claims that the exposed materials in the termocouple probe have been selected for non-corrosiveness and that the probe can be inserted into corrosive gases.

In most stack work, it is necessary to make a traverse as previously described on pp. 9-3. Center-line readings only, may lead to serious error. This is true in cupolas where the depth of charge may greatly vary the velocity across the cross-sectional area of the stack and in locations near bends, dust collectors, etc.

In stack-sampling work where a match of velocities in the sampling nozzle and air stream under changing velocities is required, the null method is sometimes used. This method uses two static tubes or inverted impact tubes, one located within the sampling nozzle and the other in the air stream. Each is connected to opposite legs of the same manometer; the sampling rate is adjusted so the manometer reading is zero.

Corrections for Temperature and Moisture

Air velocities in discharge stacks are sometimes measured at elevated air temperature or moisture content. If these factors are ignored there can be serious errors introduced in the measurement of actual duct velocity for isokinetic sampling and the determination of the actual or standard air volume flowing in the system. Corrections for these conditions can be made in the following manner:

Air velocity. Actual velocity, V_s.

Elevated Temperature, Normal Moisture

Pitot tube: Use Formula 1 at the end of this section; see Example 2.
Swinging vane anemometer: Use Formula 2.
Other instruments: Follow manufacturer's recommendations.

Elevated Temperature and Moisture

Pitot tube: Use Formula 3; see Example 3.
Other instruments: Follow manufacturer's recommendations.

Air Volume

Actual air volume at stack conditions, Q_s: Use Formula 4.

Air Volume at standard conditions, Q

Elevated temperature, normal moisture: Use Formula 5; see Example 2.
Elevated temperature and moisture: See Example 3.

Air volume at non-standard temperature, t_a (F)

Elevated temperature, normal moisture: Use Formula 6.
Elevated temperature and moisture: Determine Q at standard conditions.

Use formula: $Q_a = Q \times \frac{t_a + 460}{530}$

Formulae for Correcting Air Flow Measurements

1. Velocity in discharge duct - using Standard Pitot Tube
   VP = velocity pressure in inches of H_2O
   V_s = velocity in fpm
   t_s = stack temperature, F

$$V_s = 174 \sqrt{VP(t_s + 460)}$$

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2. Velocity in discharge duct - using Alnor Velometer

$$V_s = (\text{velocity reading}) \times \sqrt{\frac{460 + t_s}{460 + 70}}$$

3. Velocity in discharge duct where density of air may vary because of varying amounts of other gases or vapors, such as CO_2 and H_2O vapor.
   V = velocity in discharge duct
   VP = velocity pressure in inches of H_2O
   d = density factor (see Fig. 6-14; see page 13-16 for density factors for air-water vapor mixture)
   ρ = density in lbs. per cubic foot

$$V = 1096 \sqrt{\frac{VP}{\rho}}$$

or where density factor d is used

$$V = 1096 \sqrt{\frac{VP}{0.075\ d}}$$

4. Gas volume in discharge duct
   Q_s = CFM in stack at stack temperature
   A = cross-sectional area of stack in square feet

$$Q_s = V_s \text{ average} \times A$$

5. Conversion of stack gas volume to 70 F
   Q = CFM corrected to 70 F

$$Q = Q_s \times \frac{530}{t_s + 460}$$

6. Conversion of stack gas volume to any temperature t_a (F)

$$Q_a = Q_s \times \frac{460 + t_a}{460 + t_s}$$

Pitot Traverse Calculations

Measurement of air velocity at non-standard conditions requires calculation of the true air velocity, accounting for difference in air density due to air temperature, humidity and barometric pressure. The following calculations illustrate the method of calculation and the effect of varying air density.

1. Standard Conditions: Air Temp. = 79 F; Wet Bulb Temp. = 50 F
   Barometer = Std; 24" ∅ Duct

Pitot Traverse #1			Pitot Traverse #2 (⊥ to Traverse #1)		
Traverse Pt.	VP	Velocity (Fig. 6-16)	Traverse Pt.	VP	Velocity (Fig. 6-16)
1	0.22	1879	1	0.23	1921
2	0.28	2119	2	0.27	2081
3	0.32	2260	3	0.33	2301
4	0.33	2301	4	0.34	2335
5	0.34	2335	5	0.34	2335
6	0.35	2369	6	0.35	2369
7	0.33	2301	7	0.34	2335
8	0.31	2230	8	0.32	2260
9	0.30	2193	9	0.31	2230
10	0.24	1962	10	0.25	2003
		21949			22170

$$\text{Average Velocity} = \frac{21949 + 22170}{20} = \frac{44119}{20} = 2205.9 = 2206 \text{ fpm}$$

$$Q = VA = 2206 \times 3.142 = 6931.2 = 6931 \text{ scfm}$$

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2. Elevated Temperature: Air Temp = 150 F; Wet Bulb Temp. = 80 F
Barometer = Std.; 24" ∅ Duct

Pitot Traverse #1			Pitot Traverse #2 (⊥ to Traverse #1)		
Traverse Pt.	VP	$V_S = 174\sqrt{VP(t_s + 460)}$	Traverse Pt.	VP	V_S = (as at left)
1	0.22	2015	1	0.23	2060
2	0.28	2275	2	0.27	2235
3	0.32	2430	3	0.33	2465
4	0.33	2470	4	0.34	2505
5	0.34	2505	5	0.34	2505
6	0.35	2540	6	0.35	2540
7	0.33	2470	7	0.34	2505
8	0.31	2395	8	0.32	2430
9	0.30	2355	9	0.31	2395
10	0.24	2105	10	0.25	2150
		23560			23790

Average Velocity, $V_S = \frac{23560 + 23790}{20} = \frac{47350}{20} = 2367.5 = 2368$ fpm

$Q_S = VA = 2368 \times 3.142 = 7440.3 = 7440$ cfm

$Q = Q_S \times \frac{70 + 460}{t_s + 460} = 7440 \times \frac{530}{150 + 460} = 6464$ scfm

Short Method:

Find: "standard velocity" average from measured VP's = 2206 fpm (From #1)
VP for 2206 fpm = 0.30 (Fig. 6-16)
at 150 F, density factor "d" = 0.87 (Fig. 6-14)
$VP_S = \frac{VP}{d} = \frac{0.30}{0.87} = 0.345$, say 0.35"
$V_S = 2369$ fpm

3. Elevated Temperature and Moisture: Air Temp. = 150 F; Wet Bulb Temp. = 140 F;
Barometer = Std; d = 0.80 (Page 13-16);
24" ∅ Duct

Pitot Traverse #1			Pitot Traverse #2 (⊥ to Traverse #1)		
Traverse Pt.	VP	$V_S = 1096\sqrt{\frac{VP}{0.075d}}$	Traverse Pt.	VP	V_S (as at left)
1	0.22	2100	1	0.23	2145
2	0.28	2370	2	0.27	2325
3	0.32	2530	3	0.33	2570
4	0.33	2570	4	0.34	2610
5	0.34	2610	5	0.34	2610
6	0.35	2645	6	0.35	2645
7	0.33	2570	7	0.34	2610
8	0.31	2490	8	0.32	2530
9	0.30	2450	9	0.31	2490
10	0.24	2190	10	0.25	2235
		24525			24770

Average velocity, $V_S = \frac{24525 + 24770}{20} = \frac{49295}{20} = 2464.7 = 2465$ fpm. (V_S may be found also by the Short Method shown in #2.)

$Q_S = VA = 2465 \times 3.142 = 7745$ cfm of air and water mixture.
Weight of mixture = $Q_S \times 0.075 \times d = 7745 \times 0.075 \times 0.80 = 465$ lb.
From page 13-16, weight of water in mixture = 0.16 lb H_2O/lb dry air.

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Weight of dry air = $\frac{\text{weight of mixture}}{\text{weight of dry air \& moisture}} = \frac{465}{1.16} = 401$ lb.

$Q = \frac{401 \text{ lb}}{\text{Std. density}} = \frac{401}{0.075} = 5345$ scfm

Alternate method: From page 13-16, humid volume = 19.3 cu ft of mixture /lb dry air (Interpolate).

Weight of dry air = $\frac{Q_s}{19.3} = \frac{7745}{19.3} = 401$ lb.

$Q = \frac{401 \text{ lb}}{0.075} = 5345$ scfm

4. High or Low Altitudes: V_s: Use #3. Obtain d from Fig. 6-14; interpolate for altitudes below sea level.

$Q_s = V_s \times A$

$Q = Q_s \times d$

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Section 10

FANS

The following is a brief summary of the information needed to properly select and specify fans. Fans can be divided into the following main groups:

A. Axial Flow (See Figure 10-1)

1. Propeller fan: This type is used for moving large quantities of air against very low static pressures and is most commonly used for general ventilation or dilution ventilation work.

   a. Disc or bucket blade type: Used for moving clean air against no duct resistance.

   b. Narrow or propeller type blade: Used for moving air against low static pressures. It is commonly used for exhausting spray booths. Air volume exhausted is sensitive to added resistance, small increase making marked reduction in volume handled.

   c. Tubeaxial type (Duct Fan): This is the same fan as described in "b" except that it is fabricated within a short section of round duct. It is best suited to moving air containing condensable fumes, pigments and other materials that will collect on fan blades. Larger fans running at slower speeds will give less trouble where such accumulations or where abrasion occurs than smaller fans running at higher speeds.

2. Vane Axial Fan: Provides economy in horsepower and space of propeller type and will develop higher pressures. To be used only with clean air.

B. Centrifugal (See Figure 10-2)

1. Forward-curved blade types: A multi-bladed, "Squirrel Cage" wheel in which the leading edges of the fan blades curve toward the direction of rotation. These fans have low space requirements, low tip speeds and are quiet in operation. They are usually used against low to moderate static pressures such as encountered in heating and air conditioning work. Not recommended for dusts or fumes that would adhere to the short curved blades, causing unbalance and making cleaning difficult.

2. Straight or Radial-blade (paddle wheel, long shaving wheel): The "workhorse" for most exhaust system applications, they are used for systems handling materials likely to clog the fan wheel as the name indicates. Such fans usually have a medium tip speed and a medium noise factor and are used for buffing exhaust, woodworking exhaust or for applications where a heavy dust load passes through the fan.

3. Backward blade type: The type in which the fan blades are inclined in a direction opposite to the fan rotation. This type usually has a high tip speed, provides high fan efficiency and has non-overloading characteristics. Except in case of direct driven arrangements, non-over-loading feature is over emphasized in exhaust ventilation work as the exhaust system acts as a load limiting orifice to make overloading of any exhauster motor from variations in system conditions improbable. Blade shape is conducive to buildup of material and fans in this group should be used only on clean air containing no condensable fumes or vapors.

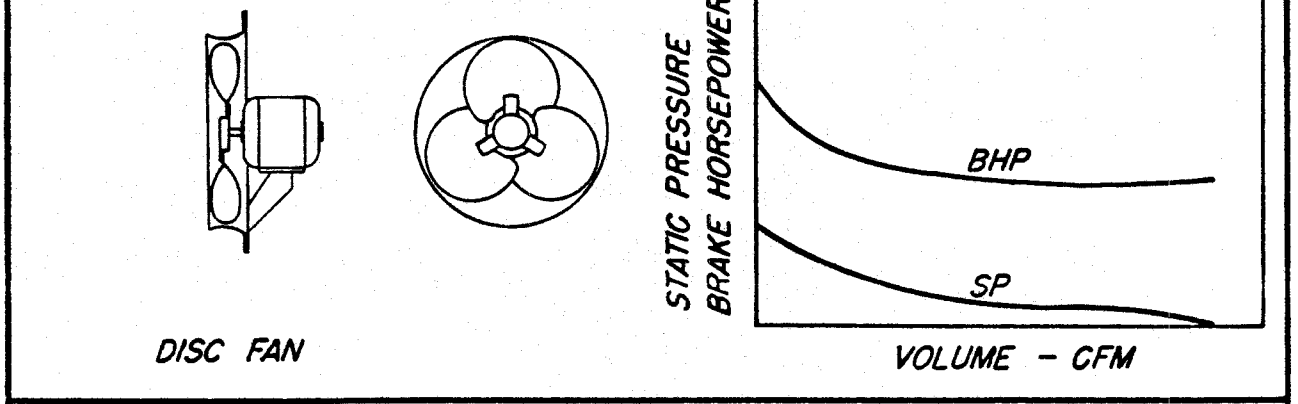
C. Special Fan Types (See Figure 10-3)

1. Airfoil - Backward curved blade centrifugal: has variations in characteristics from one manufacturer to another depending on blade shape. In general, however, when this blade is properly designed, the fan is quieter, has higher efficiency and functions smoothly without pulsation throughout its complete performance range.

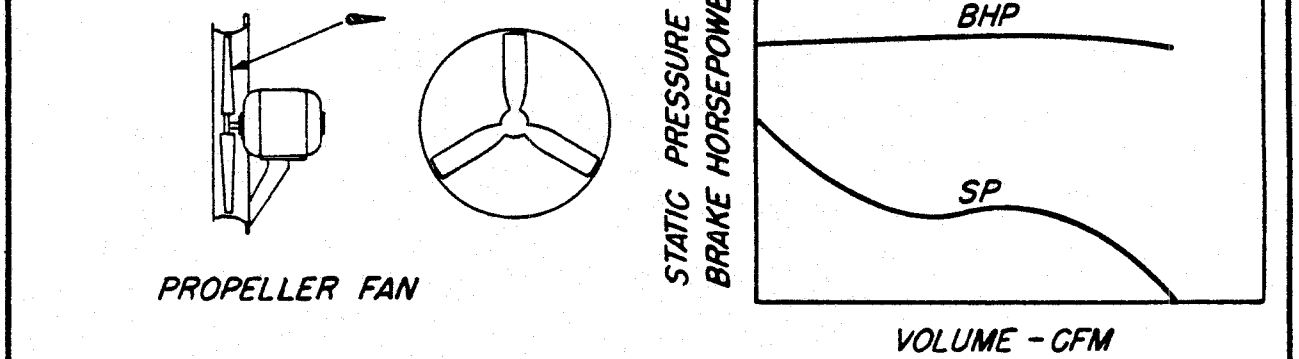
2. In-line flow centrifugal: is a backwardly-curved bladed fan with a special housing which permits a space-saving straight line duct installation. Pressure-volume-horsepower performance curves are similar to a scroll type centrifugal fan of the same blade type. Space requirements are similar to a vane axial fan.

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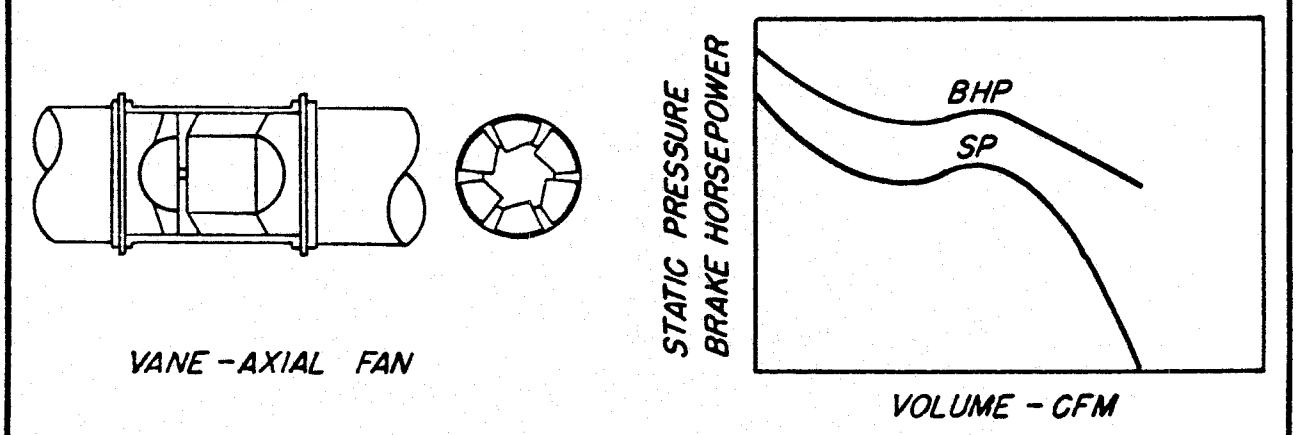
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DISC FAN



PROPELLER FAN



VANE-AXIAL FAN

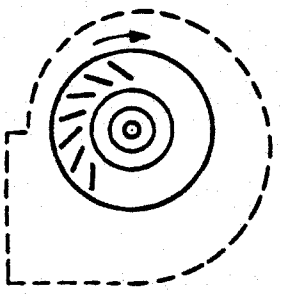
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AXIAL FLOW FANS

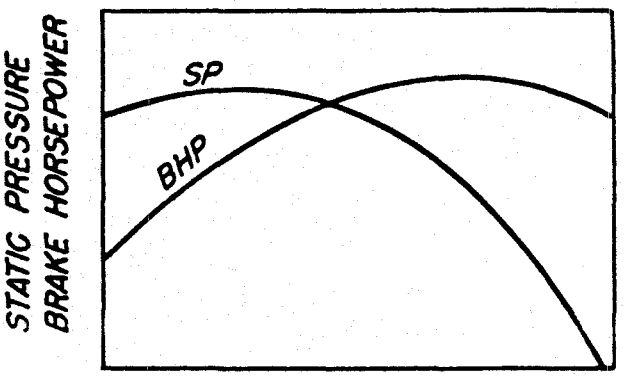
DATE 1-70 | Fig. 10-1

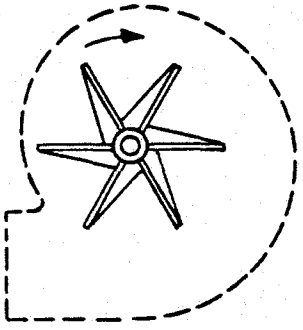
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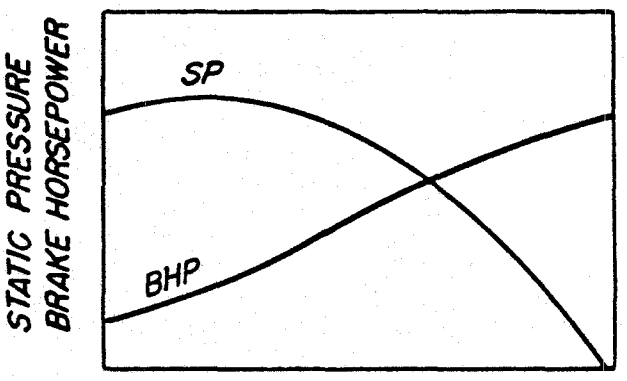


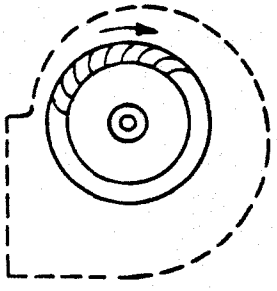
BACKWARD CURVED BLADES



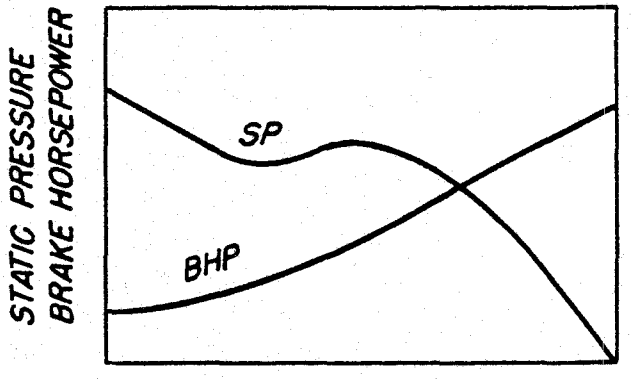


STRAIGHT OR RADIAL BLADES





FORWARD CURVED BLADES



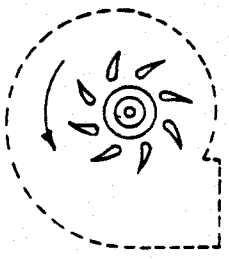
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CENTRIFUGAL FANS

DATE 1-66 | Fig. 10-2

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JM - 83

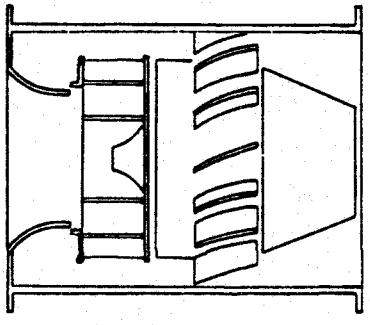
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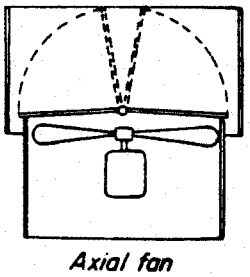


Airfoil blade crossection

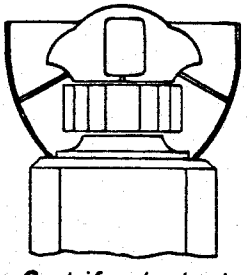
AIRFOIL - backward curved blades



INLINE FLOW CENTRIFUGAL - backward curved centrifugal wheel



Axial fan
Propeller or disc blades



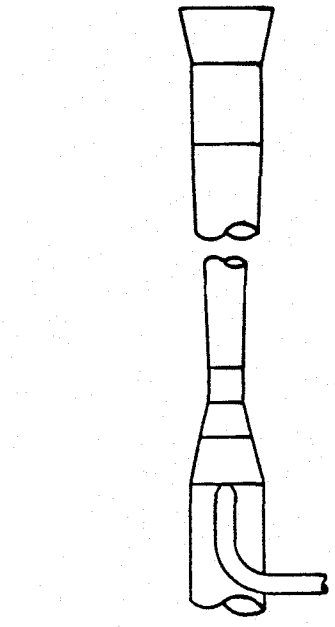
Centrifugal wheel
Backward curved blades

POWER ROOF EXHAUSTERS - upblast type

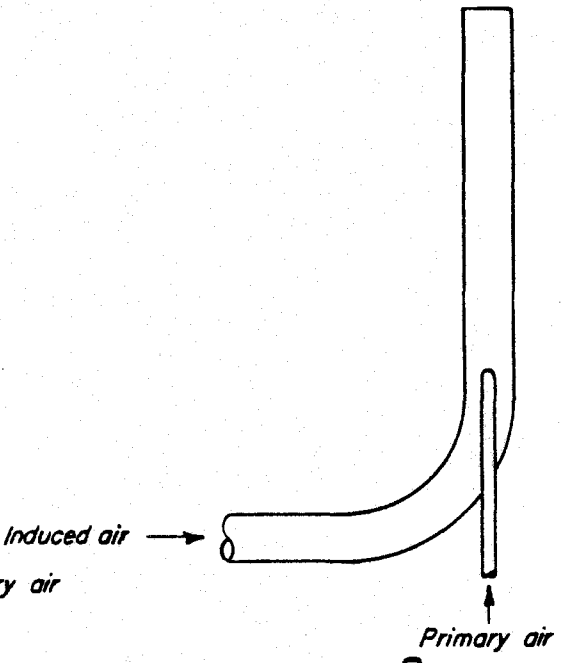
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SPECIAL FAN TYPES	
DATE 1-66	Fig. 10-3

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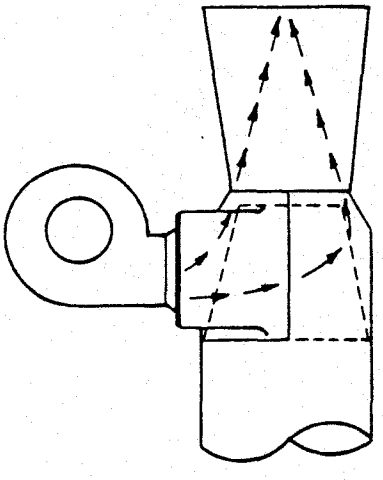
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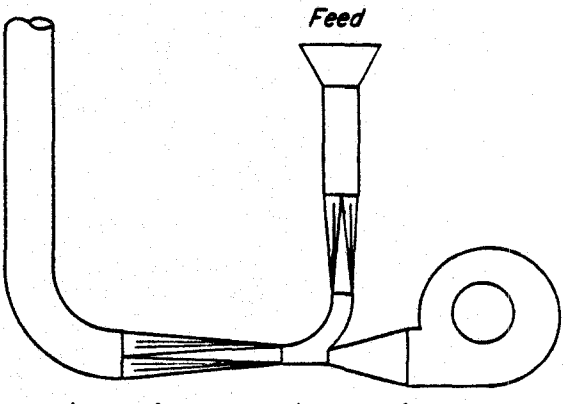
A
Reference 90



B
Reference 91



C
Reference 92, 93



Ejector for pneumatic conveying

D
Reference 94

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AIR EJECTORS

DATE 1-72 | Fig. 10-4

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3. Power exhausters, power roof ventilators: are package fan-stack-weather cap units. They can be of either axial flow or centrifugal fan type. The centrifugal type does not use a scroll housing but discharges around periphery of ventilator directly to outdoors. The unit can be obtained with either the downward deflecting or upblast discharge.

4. Combination fan and dust collector: There are several types of combined fans and dust collectors on the market and if use of such equipment is contemplated, the manufacturer should be consulted for the proper application.

D. Air Ejectors (See Figure 10-4)

In certain types of installation it is not desirable to have the contaminated air pass through the fan. Corrosive, flammable, hot or sticky materials may affect the fan performance. Ejectors can be used for handling these materials. Also, with certain pneumatic conveying systems it may be advantageous to prevent abrasion and clogging of the fan by using ejectors.

Several designs are shown: "A" illustrates a venturi ejector; "B" illustrates a straight pipe ejector; "C" shows a commercially available ejector and "D" illustrates an ejector for pneumatic conveying.

Ejectors are generally very low in efficiency (5 to 12%). They are applied usually on low pressure systems, 1" to 1-1/2" SP water gauge; however, the commercially available ejector can be applied to much higher static pressures through special design. In pneumatic conveying by means of a venturi, a suction or exhaust is produced at the product feed hopper ("D") to draw the material into the air stream.

Fan Selection

Necessary Information for Fan Selection:

1. Volume required (cfm).
2. Fan static pressure.
3. Type of material handled through fan.
   a. Fibrous material, heavy dust load through fan, etc.; choose radial-blade type.
   b. Ordinary service; choose centrifugal (or axial flow appropriate to the pressure requirements).
4. Explosive or inflammable material; use non-sparking construction (explosion-proof motor if motor is in air stream). Conform to the standards of the National Board of Fire Underwriters and the National Fire Protection Association and State and Local Ordinances.
5. Direct driven vs. belt driven. Direct driven exhausters offer a more compact assembly and assure constant fan speed as they eliminate belt slippage that does occur where belt driven fan drives are not maintained. Fan speeds are limited to available motor speeds, introducing a very inflexible unit (except in case of Direct Current application). Flexibility of quick change in fan speed with a belt driven fan is of definite importance in many applications, accounting for the pronounced preference of ventilating engineers for the belt driven arrangement. Increase in fan speed is often required to provide for increase in system capacity or pressure requirements due to changes in process, hood design, equipment location or air cleaning equipment.
6. Space limitations.
7. Noise (Can be a factor.)
8. Operating temperature. Sleeve bearings are suitable to 250 F; ball bearings to 550 F; and special cooling devices are required at higher temperatures. See the manufacturers' recommendations for the particular fan involved.
9. Efficiency. Select fan size that will handle the required volume and pressure with minimum horsepower.
10. Corrosive applications. Refer to fan manufacturers for special coatings or construction.

Fan Rating Tables

The actual selection of fan size and speed is usually made from a rating table published by the fan manufacturer. The best form of table is a "multi-rating table" (See Figure 10-5) which shows the complete range of capacities for a particular size fan. On this table will be found ratings over the entire range of pressures and

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Volume C. F. M.	*Outlet Velocity Feet Per Min.	1" S. P.			1½" S. P.			1½" S. P.			1½" S. P.			2" S. P.			2½" S. P.			3" S. P.		
		Tip Speed	R. P. M.	B. H. P.	Tip Speed	R. P. M.	B. H. P.	Tip Speed	R. P. M.	B. H. P.	Tip Speed	R. P. M.	B. H. P.	Tip Speed	R. P. M.	B. H. P.	Tip Speed	R. P. M.	B. H. P.	Tip Speed	R. P. M.	B. H. P.
5418	700	4488	440	1.20	4964	487	1.56	5474	537	2.03	5883	577	2.31	6290	617	2.67	7071	688	3.52	7667	753	4.38
6192	800	4522	443	1.32	4981	488	1.70	5491	538	2.10	5899	578	2.50	6307	618	2.95	7058	690	3.57	7684	753	4.72
6966	900	4556	446	1.46	4998	490	1.85	5508	540	2.29	5916	580	2.72	6324	620	3.17	7065	692	4.13	7701	755	5.15
7740	1000	4624	454	1.60	5032	494	2.01	5525	542	2.45	5933	582	2.95	6341	622	3.39	7072	693	4.48	7718	757	5.64
8514	1100	4709	462	1.78	5083	498	2.19	5543	544	2.67	5967	586	3.13	6358	624	3.63	7089	695	4.74	7735	758	5.82
9288	1200	4862	476	1.97	5202	510	2.42	5598	548	2.91	6001	588	3.38	6375	626	3.94	7106	697	5.06	7753	760	6.22
10062	1300	5015	492	2.18	5321	522	2.74	5695	558	3.14	6052	594	3.65	6409	628	4.20	7123	698	5.35	7769	762	6.57
10836	1400	5168	506	2.41	5474	536	2.90	5831	572	3.43	6137	602	3.93	6494	636	4.49	7140	700	5.65	7803	765	6.90
11610	1500	5338	524	2.67	5644	554	3.19	5984	586	3.78	6273	616	4.22	6579	646	4.82	7191	705	6.00	7837	768	7.30
12384	1600	5525	542	3.05	5814	570	3.49	6137	602	4.03	6443	632	4.60	6732	660	5.18	7259	712	6.44	7871	772	7.78
13158	1700	5712	560	3.28	5984	586	3.78	6307	618	4.39	6596	646	4.98	6885	676	5.58	7378	723	6.81	7986	778	8.18
13932	1800	5899	578	3.68	6171	606	4.17	6477	636	4.75	6749	662	5.36	7038	690	6.01	7531	738	7.35	8087	785	8.63
14706	1900	6128	600	4.06	6375	626	4.60	6664	654	5.15	6902	678	5.75	7191	706	6.45	7684	753	7.80	8199	796	9.15
15480	2000	6358	624	4.53	6579	646	5.06	6851	672	5.61	7089	696	6.19	7344	720	6.90	7837	768	8.34	8279	812	9.70
17028	2200	6817	668	5.33	6970	684	6.05	7225	708	6.68	7497	736	7.35	7684	754	7.92	8160	800	9.40	8605	843	11.19
18576	2400	7276	714	6.65	7446	730	7.30	7650	750	7.93	7837	768	8.59	8075	792	9.30	8500	834	10.70	8925	875	12.36
20124	2600	7820	766	7.96	7922	776	8.69	8109	796	9.38	8279	812	10.00	8466	830	10.85	8874	870	12.58	9248	907	13.85
21672	2800	8330	816	9.59	8466	830	10.28	8585	842	10.95	8755	858	11.99	8908	874	12.68	9248	907	14.85	9588	940	15.96
23220	3000	8857	868	11.23	8959	878	12.05	9095	892	12.84	9231	906	13.63	9367	918	14.44	9656	947	15.98	9979	978	17.64
24768	3200	9418	924	13.28	9503	932	14.18	9605	942	14.86	9690	950	15.78	9843	966	16.64	10132	993	18.23	10387	1018	20.06
26316	3400	9979	978	15.48	10030	984	16.33	10115	992	17.28	10217	1002	18.00	10319	1012	18.88	10608	1040	20.58	10863	1065	22.48

Fig. 10-5. Typical Fan Rating Table

speeds within the limits of the fan construction. A particular fan may be offered in various construction classes identified as I through IV (Ref. 107). A fan designated as meeting the requirements of a particular class must be physically capable of operating safely at any point within the performance limits for that class. Operating limits for each class are established in terms of outlet velocity and static pressure. Multi-rating tables will usually be shaded to indicate the selection zones for various classes and will state the maximum rpm.

For the given pressure, the highest mechanical efficiency, and therefore the best selection, will usually be in the middle third of the volume column. Some manufacturers show the rating of maximum efficiency for each pressure by underscoring or similar device. In the absence of such a guide, the design engineer must either calculate the efficiency from the air horsepower formula and the rated brake horsepower or assume that the middle of the column will represent a range of high efficiency.

Even with a multi-rating table it is usually necessary to interpolate in order to select a fan for the exact conditions desired. In many cases a double interpolation will be necessary. First, the interpolation should be made for the desired pressure, using the rated volume below the desired volume, and then the volume interpolation should be made, using the previously interpolated values of the speed and horsepower to arrive at the

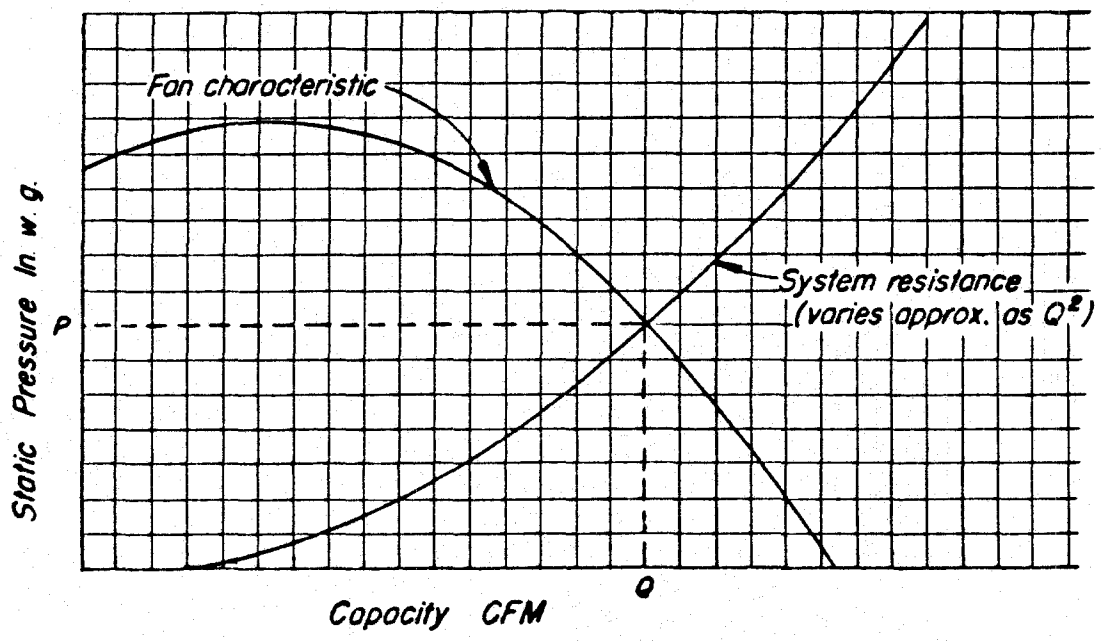
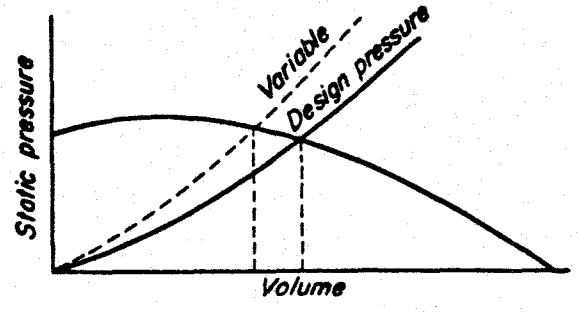


Fig. 10-6. Typical Point of Rating

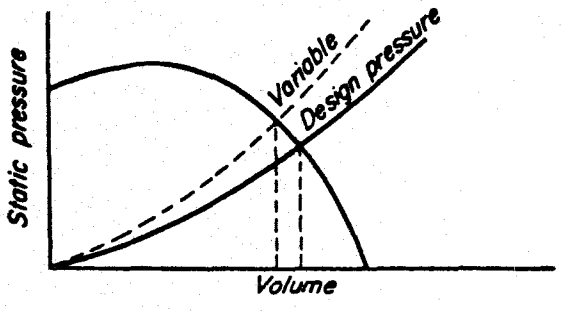
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POOR SELECTION

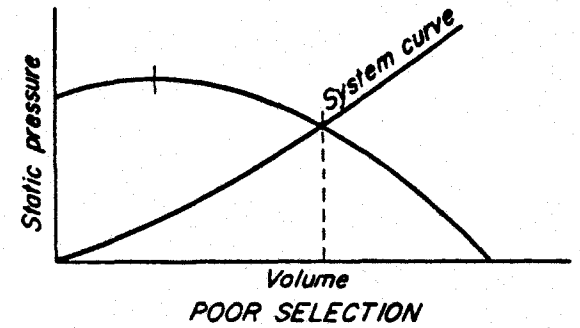
Fan with flat pressure curve gives wide volume variation with pressure change.



GOOD SELECTION

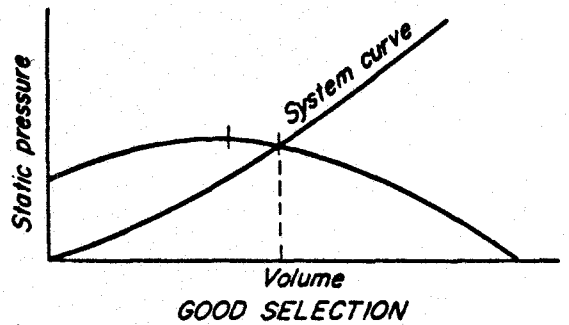
Fan with steep pressure curve gives small volume variation with pressure change.

EFFECT OF FAN CURVE SLOPE



POOR SELECTION

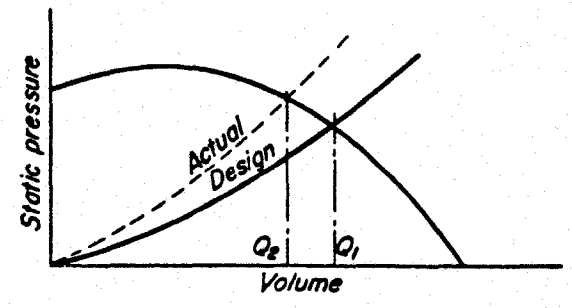
Small fan used with system curve crossing fan too far to right of peak.
Excessive horsepower
Low efficiency



GOOD SELECTION

Large fan used with curve crossing fan curve to right of peak.
Low horsepower
High efficiency

EFFECT OF FAN SIZE



Volume of air delivered less than design flow
To obtain design flow:

increase fan speed $\frac{Q_1}{Q_2}$

increase fan SP $\left(\frac{Q_1}{Q_2}\right)^2$

increase fan BHP $\left(\frac{Q_1}{Q_2}\right)^3$

EFFECT OF VARIATION BETWEEN DESIGN AND ACTUAL RESISTANCE

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FAN SELECTION

DATE 11-68 | Fig. 10-7

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final desired rating. Straight line interpolations of a complete multi-rating table will introduce only negligible errors in the rating.

Rated capacity tables which attempt to show the ratings for a whole series of homologous fans on one sheet cannot be used accurately unless the rating desired happens to be listed on the chart. Interpolation is practically impossible as actually only one point of the fan curve for a given speed is defined in such a table.

The system designer must always bear in mind that a fan operating at a given speed can have an infinite number of ratings anywhere along the length of its characteristic curve. These ratings can range anywhere from "static no delivery" to "free delivery." When the fan is installed in a duct system, however, the point of rating can be only that point at which the system resistance curve intersects the fan characteristic curve. (See Figure 10-6) Thus in a given system, a fan at a fixed speed can have only a single rating. This rating can be changed only by changing the fan speed or by changing the system resistance.

Fan Laws

These principles governing fan operation provide a most useful tool for determining requirements where change in exhaust capacity is required for a given system. At the new speed, the new operating point will be determined by the following fan law:

CFM varies directly as Fan Speed
TP and SP varies as the square of fan speed
HP varies as the cube of the fan speed

These relationships:

1. apply only to a given system where exhaust volume change is desired without making changes in number of branches, duct sizes, or any other physical change.
2. apply only where pressure losses of each component varies as the square of the velocity through that portion. This variation does apply to hood suction, entrance loss at hoods, duct resistance, acceleration and deceleration losses and centrifugal types of dust collectors. However, pressure loss through collectors like Fabric Arresters and some Wet Type designs does not increase as rapidly. Fabric collector resistance for a given system will vary directly with the exhaust volume. Under such circumstances it will be necessary to recalculate system pressure losses before going to fan table for new fan speed.
   (One common error in the use of fan tables is the failure to recognize the increase in SP and TP that is involved with increase in exhaust volume. Five inches pressure loss for a system at a known exhaust volume will increase to $5 \times (1.20)^2$ or 7.2" if exhaust volume is to be increased 20%.)

   HP Formula: For rapid estimates of probable exhaust volumes or for estimating the CFM available for a given motor size, the equation for brake horsepower can often be useful:

$$BHP = \frac{CFM \times TP}{6356 \times ME \text{ of fan}}$$

Mechanical Efficiency (ME) for most centrifugal fan operating points will be 0.50 to 0.65.

TABLE 10-1

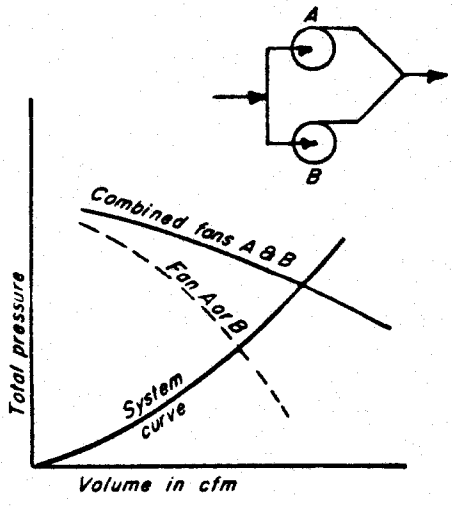
STANDARD CLASSIFICATIONS FOR SPARK RESISTANT CONSTRUCTION
Reference 68

Type	Construction (See notes)
A	All parts of the fan in contact with the air or gas being handled shall be made of non-ferrous material.
B	The fan shall have an entirely non-ferrous wheel and non-ferrous ring about the opening through which the shaft passes.
C	The fan shall be so constructed that a shift of the wheel or shaft will not permit two ferrous parts of the fan to rub or strike.

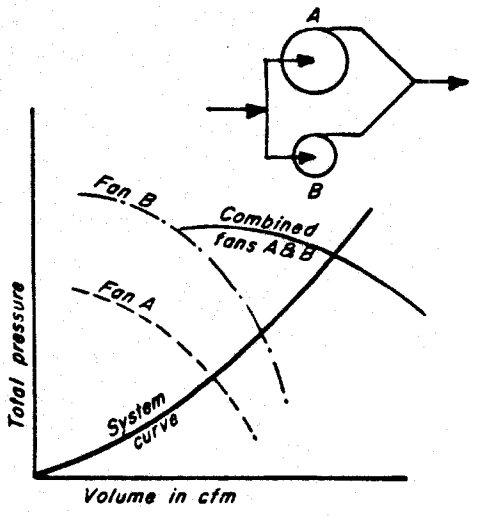
Notes:
(1) Bearings shall not be placed in the air or gas stream.
(2) The user shall electrically ground all fan parts.

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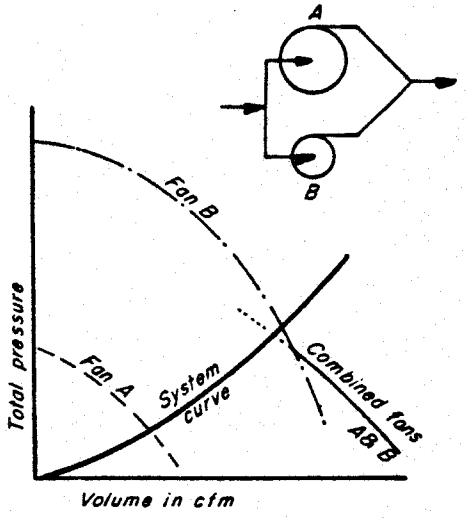
MT-PWHD-004747



Two identical fans
Recommended for best efficiency



Two different fans
Satisfactory



Two different fans
Unsatisfactory

When system curve does not cross combined fan curve, or crosses projected combined curve before fan B, fan B will handle more air than fans A and B in parallel.

Notes:

1. To establish combined fan curve, the combined air volume, Q, is the sum of individual fan air volumes at points of equal pressure
2. To establish system curve, include losses in individual fan connections.
3. System curve must intersect combined fan curve or higher pressure fan may handle more air alone.

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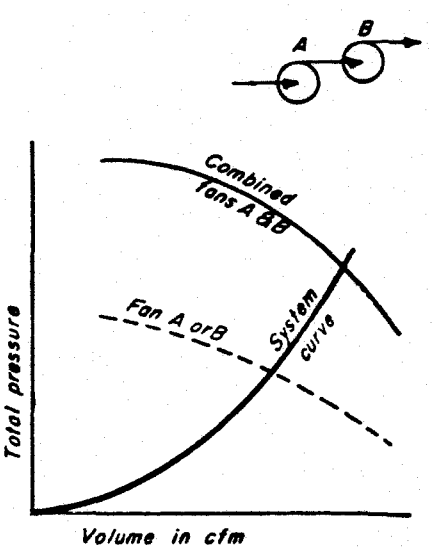
FANS
PARALLEL OPERATION

DATE 1-72 | Fig. 10-8

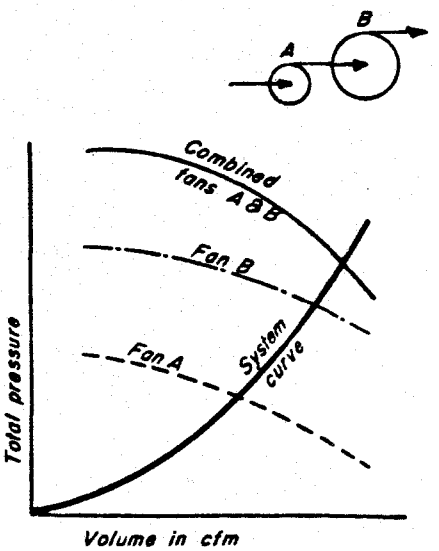
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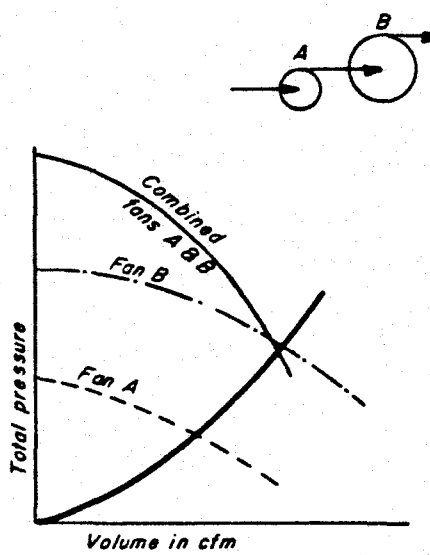
MT-PWHD-004748



Two identical fans
Recommended for best efficiency



Two different fans
Satisfactory



Two different fans
Unsatisfactory

When system curve does not intersect combined fan curve, or crosses projected combined curve before fan B curve, fan B will move more air than fan A and B in series.

Notes:

1. To establish combined fan curve, the combined total pressure is the sum of individual fan pressures at equal air volumes, less the pressure loss in the fan connections.
2. Air volume through each fan will be the same, since air is considered incompressible.
3. System curve must intersect combined fan curve or large volume fan may handle more air alone.

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FANS
SERIES OPERATION

DATE 1-72 | Fig. 10-9

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Fan Selection at Gas Densities Other Than Standard

Variations in density due to normal fluctuations of ambient temperature and humidity are small and need not be considered. When heat-producing processes are ventilated it is necessary to make temperature corrections for density. Unless corrections are made the ventilation system will not handle the designed air volumes.

Rating tables or performance charts are based on handling standard air with a density of 0.075 lbs per cu ft. The density of air decreases with rise in temperature, humidity and altitude, while it increases with decrease in temperature, altitude and increase in pressure. If temperature, humidity and pressure are known, the actual density can be determined from psychrometric charts (see Appendix). Density factor is the ratio of actual density to density for standard air (see Figure 6-14). Multiply 0.075 lb/cu ft by the density factor to obtain actual density.

The duct friction charts (Figures 6-15A and 6-15B) are based on standard air. If these charts are used directly, only the friction loss for a given volume rate of standard air can be determined. However, if the friction loss for standard air (read from the chart) is multiplied by appropriate density factors, true friction loss is obtained for air at other densities.

In selecting a fan for operation with a gas density other than standard, one characteristic of the fan is of prime importance—when operated at a fixed RPM in an unaltered system (no changes to ductwork and fittings), the fan is a constant volume machine. Even though temperature and consequently density of air entering a hood is changed, the fan will continue to move the same volume cfm. Assume an exhauster connected to an enclosure at a melting furnace and capable of moving 10,000 cfm of standard air through that system. If the entering air is heated to 600 F, the volume handled by the exhauster is still 10,000 cfm, however, at 600 F. At room temperature (70 F) this volume (10,000 acfm at 600 F) could be 5000 scfm. The flow of room temperature air into the hoods would be reduced 50%. The fan static pressure would vary in direct ratio to changes in density.

It is possible with this knowledge to select a fan from standard air rating tables to handle air at other than standard conditions. The following procedure should be used:

1. Design system using actual air volumes involved. Do not correct air volumes to standard air conditions.
2. Calculate fan static pressure as though system were handling standard air.
3. Select fan from fan rating tables using actual air volumes and fan static pressure calculated. Do not use corrected fan static pressure. The RPM thus selected is the actual speed at which the fan must be run.
4. Correct the bhp (given in fan tables) by multiplying it by the density factor.

The above procedure is applicable where the weight flow or air density do not change within the duct system. If weight flow rate or density vary within the system, the effect is comparable to a system alteration. In this case system resistance must be calculated in each component based on the actual density in that component and the fan selected as in Section 6, Example 6.

As most applications involving non-standard air are created by elevated temperatures which result in lower densities and density factors less than one, the operating power requirement will frequently be lower than the value read from the table. In this case motor size should be selected with caution. When the fan is first started, air in the system may be at lower temperature with higher density and power requirements will likely approach the value published in the rating tables. To protect the motor from overloading it is frequently sized to accommodate the tabulated value and said to have been selected from cold start-up. An alternative is to install a damper for use while the system comes up to operating temperature. This limits the volume handled and power required and allows selection of a motor only large enough to provide operating power.

In recent years ventilation systems have been designed to operate at higher static pressures. Much of this is due to the use of high energy venturi type dust collectors. Static pressures at fan inlet may easily exceed 20" wg which is nearly 5% of an atmosphere (407" wg). In these cases the volume used for fan selection should be corrected to reflect the actual conditions under this high negative pressure. Volume varies indirectly and density directly with changes in absolute pressure.

Fan Installation

Fan rating tests for volume and static pressure performance are conducted under ideal conditions, including uniform straight air flow at the fan inlet and outlet. Often, field installation creates problems of air flow which will reduce the fan's air delivery. A poor duct system can detract from the performance of any fan, no matter how well manufactured or selected.

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Fan discharge connections affect fan performance by increasing the system resistance. In general, elbows on a fan discharge have an increased SP loss due to the normal non-uniform fan discharge velocity. Figure 10-10 illustrates typical discharge conditions and the losses which may be anticipated.

Figure 10-11 illustrates typical effects of non-uniform flow caused by typical fittings at the inlet of an industrial centrifugal fan and were determined by a major fan manufacturer (76). These data are not precise because of the infinite variations that can occur. They are intended to illustrate the magnitude of the problem and encourage good initial system design. These results are typical of the effect of poor air flow on all fans, axial or centrifugal.

Spinning flow, experienced by fans exhausting from cyclone collectors, poor inlet boxes and multiple inlet ducts, is not shown. Where such air "spin" cannot be avoided, splitters or egg-crate straighteners ahead of the fan will help reduce the effect.

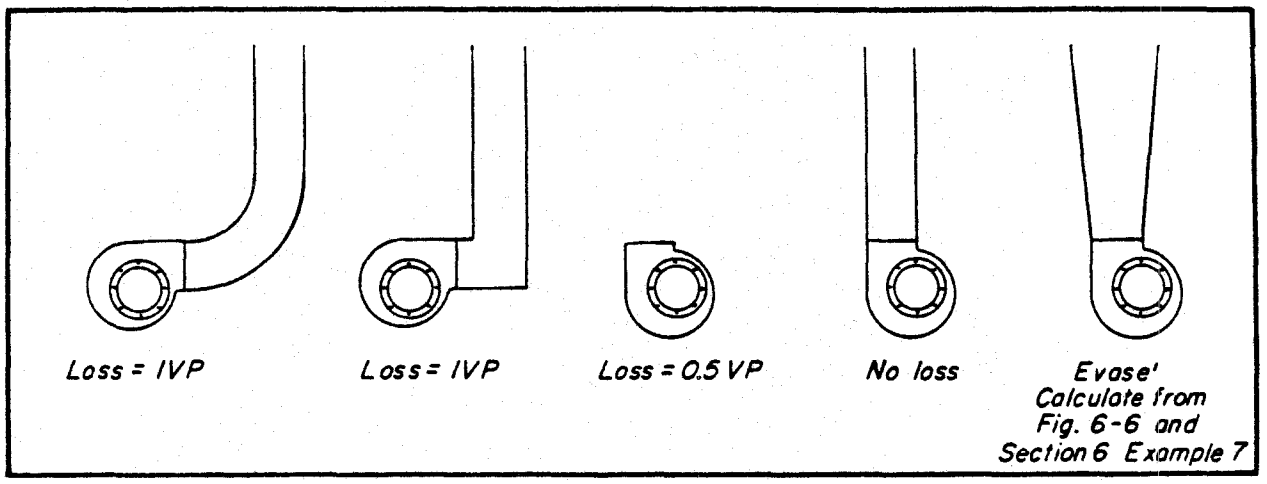


Fig. 10-10

Considerations as to Location:

1. Locate the fan down-stream from the dust collector if possible in order to minimize erosion and abrasion on the fan.
2. Eliminate elbows and other inlet obstructions if at all possible. Sharp elbows at the fan inlet will seriously reduce the volume discharged.
3. If practical, select the discharge and rotation of the fan so that the discharge is in the direction desired, thus eliminating additional bends.
4. Fan should be located for easy inspection and service.

Inspection and Maintenance

Scheduled inspection of fans is recommended. Items checked should include:

1. bearings for overheating (greasing as required).
2. belt drives for proper tension.
3. fan wheel for proper rotation and freedom from accumulations.

Accumulations on a wheel will cause vibrations that can normally be detected as bearings are checked. Fan rotation is often reversed with repair or alterations to wiring circuits or starters. As fans do move a fraction of their rated capacity when running backward, such incorrect operation often goes unnoticed in spite of less effective performance of exhaust system.

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PROBABLE EFFECTS OF VARIOUS INLET CONNECTIONS

(These losses do not include friction losses)

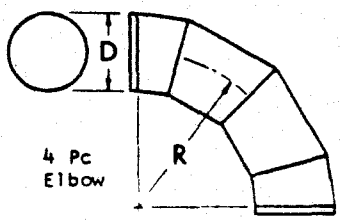
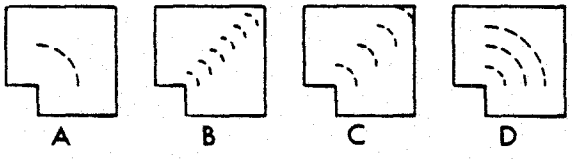
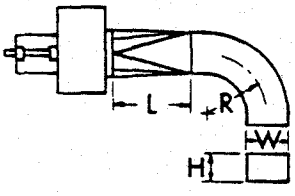
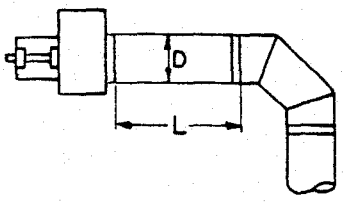
DESCRIPTION		% LOSS IN CFM IF NOT CORRECTED	% INCREASE NEEDED IN FAN SP TO COMPENSATE
	3 piece elbow R/D = .5	12	30
	1.0	6	13
	2.0	5	11
	6.0	5	11
	4 piece elbow R/D = 1.0	6	13
	2.0	4	9
	8.0	4	9
	5 or more piece elbow R/D = 1.0	5	11
	2.0	4	9
	8.0	4	9
	Mitered elbow	16	42
Square Ducts with Vanes 	No Vanes	17	45
	A	8	18
	B	6	13
	C	5	11
	D	4	9
Rectangular Elbows without Vanes*  The maximum included angle of any element of the transition should never exceed 30°. If it does, additional losses will occur. If angle is less than 30° and L is not longer than the fan inlet diameter, the effect of the transition may be ignored. If it is longer, it will be beneficial because elbow will be farther from the fan.	*In all cases use of 3 long, equally spaced vanes will reduce loss and needed sp increase to 1/3 the values for unvaned elbows.		
	$\frac{H}{W}$ = .25, & $\frac{R}{W}$ = .5	7	15
	1.0	4	9
	2.0	4	9
	$\frac{H}{W}$ = 1.00, & $\frac{R}{W}$ = .5	12	30
	1.0	5	11
	2.0	4	9
	$\frac{H}{W}$ = 4.00, & $\frac{R}{W}$ = .6	15	39
	1.0	8	18
	2.0	4	9
	Each 2½ diameters of straight duct between fan and elbow or inlet box will reduce the adverse effect about 20%. For example, in the case of the poorest 3 pc. elbow above:		
	No duct . . . . CFM loss = 12%	Additional fan	30%
	L/D = 2½ 10%	SP needed =	24%
	5 7%		18%
	7½ 5%		12%
	10 2½%		6%

Fig. 10-11

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Section 11

AIR CLEANING DEVICES

Air cleaning devices remove contaminants from an air or gas stream. They are available in a wide range of designs to meet variation in air cleaning requirements. Degree of removal required, quantity and characteristics of the contaminant to be removed and conditions of the air or gas stream will all have a bearing on the device selected for any given application.

Air cleaning devices are divided into two basic groups: AIR FILTERS and DUST COLLECTORS. Air filters are designed to remove dust concentrations of the order found in outside air and are employed in ventilation, air conditioning and heating systems where dust loadings seldom exceed four grains per thousand cubic feet of air.

Dust collectors are usually designed for the much heavier loads from industrial processes where the air or gas to be cleaned originates in local exhaust systems or process stacks gas effluents. Loadings will vary from 0.1 to 20 grains or more per cubic foot. Therefore, concentrations in dust collectors are some 100 to 20,000 times greater than that for which air filters are designed.

Selection of Dust Collection Equipment

Dust collection equipment is available in numerous designs utilizing a number of principles and featuring wide variation in effectiveness, first cost, operating and maintenance cost, space, arrangement and materials or construction. Consultation with the equipment manufacturer is the recommended procedure in selecting a collector for any problem where extensive previous plant experience on the specific dust problem is not available. Factors influencing equipment selection include:

1. Concentration and particle size of contaminant
2. Degree of collection required
3. Characteristics of air or gas stream
4. Characteristics of contaminant
5. Method of disposal

1. Concentration and Particle Size of Contaminant. Contaminants in exhaust systems cover an extreme range in loadings and particle sizes. Concentration can range from 0.1 to 20.0 or more grains of dust per cubic foot of air. In low pressure conveying systems, usual dusts range from 0.5 to 100 or more microns. Deviation from mean size (the range of over and under the mean) will also vary with the material. Some indication of the mean particle size and deviation of typical contaminants has been included in the composite chart, Figure 11-14.

2. Degree of Collection Required. A basic decision must be made concerning the type of collector needed to do a satisfactory cleaning job for the specific problem under consideration. Evaluation will consider the need for high efficiency high cost equipment such as electrostatic precipitators, high efficiency moderate cost equipment such as fabric or wet collector units and the lower cost primary units such as the dry centrifugal group. If either of the first two groups is indicated, the question of combination with primary collectors should be weighed.

Degree of collection required can depend on plant location; comparison of quantities of material released to atmosphere with different types of collection; nature of contaminant—its salvage value or its potential as a health hazard, public nuisance or ability to damage property—and the requirements of the local or state air pollution regulations. In remote locations damage to farms or contribution to air pollution problems of remote cities can indicate the need and importance of effective collection equipment. Many industries, originally located away from residential areas, failed to anticipate the influx of residential building which frequently develops around a plant. Such lack of foresight has required installation of air cleaning equipment at greater expense than initially would have been necessary. Today, the remotely located plant must comply, in most cases, with the same regulations as the plant located in urban areas. With present emphasis on public nuisance, public health and preservation and improvement of community air quality, management can continue to expect criticism for excessive emissions of air contaminants whether located in a heavy industry section of a city or in an area closer to residential zones.

Quantity of escapement (mass rate of emission) will also influence equipment. For a given concentration, the larger the exhaust volume, the greater the need for better collection equipment. Large central steam

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generating stations will select high efficiency electric precipitators for their pulverized coal boiler stacks while a smaller industrial pulverized fuel boiler could use slightly less efficient collectors.

One safe recommendation in equipment selection can be summed up as: select the collector that will allow the least possible amount of contaminant to escape and still be reasonable in first cost and maintenance as well as meet all prevailing air pollution regulations. For some applications even the question of reasonable cost and maintenance must be sacrificed to meet established standards for air pollution control or to prevent damage to health or property.

It must be remembered that visibility of an effluent will be a function of the light reflecting surface area of the escaping material. Surface area per pounds increases inversely as the square of particle size which means that the removal of 80 to 90% of a dust load can remove the coarse particles without altering the stack discharge appearance.

3. Characteristics of Air or Gas Stream. The characteristics of the carrier gas stream can have a marked bearing on equipment selection. High temperature gas streams exceeding 180 F. will prevent the use of standard cotton media in fabric collectors; presence of steam or condensation of water vapor will cause packing and plugging of air or dust passages in fabric and dry centrifugal collectors; chemical composition can attack fabric or metal in dry collectors and cause extremely corrosive conditions when mixed with water in wet type collectors.

4. Characteristics of Contaminant. The contaminant characteristics will also affect equipment selection. Chemical composition can cause attack on collector elements or corrosion in wet type collectors. Sticky materials like metallic buffing dust impregnated with buffing compounds can adhere to collector elements plugging collector passages. Linty materials such as dust from the textile opener, picker and napper will adhere to certain types of collector surfaces or elements. Abrasiveness of many materials in moderate to heavy concentrations such as dust from sand blasting will cause rapid wear particularly on dry type centrifugal collectors. Particle size and shape will rule out certain collector designs. The parachute shape of particles like the "bees wings" from grain will "float" through centrifugal collectors due to their velocity of fall being slower than much smaller spherical particles of the same specific gravity. Combustible nature of many finely divided materials will influence selection of safe types of collectors for such products.

5. Methods of Disposal. Methods of removal and disposal of collected materials will vary with the material, plant process, quantity involved and collector design. Dry collectors can be unloaded continuously or in batches through dump gates, trickle valves and rotary locks to conveyors or containers. Dry materials can create a secondary dust problem where careful thought is not given to dust-free material disposal or to collector dust-bin locations suited to convenient material removal. See Figures 11-1, 11-2 and 11-3 for some typical discharge arrangements and valves.

Wet collectors can be arranged for batch removal or continual ejection of dewatered material by flight conveyors or draining as a slurry. Secondary dust problems are eliminated although disposal of wet sludge can be a material handling problem. Solids carry-over in waste water can create a sewer or stream pollution problem if waste water is not properly clarified.

Material characteristics can influence disposal problems. Packing and bridging of dry materials in dust hoppers, floating or slurry forming characteristics in wet collectors are examples of problems that can be encountered.

Dust Collector Types

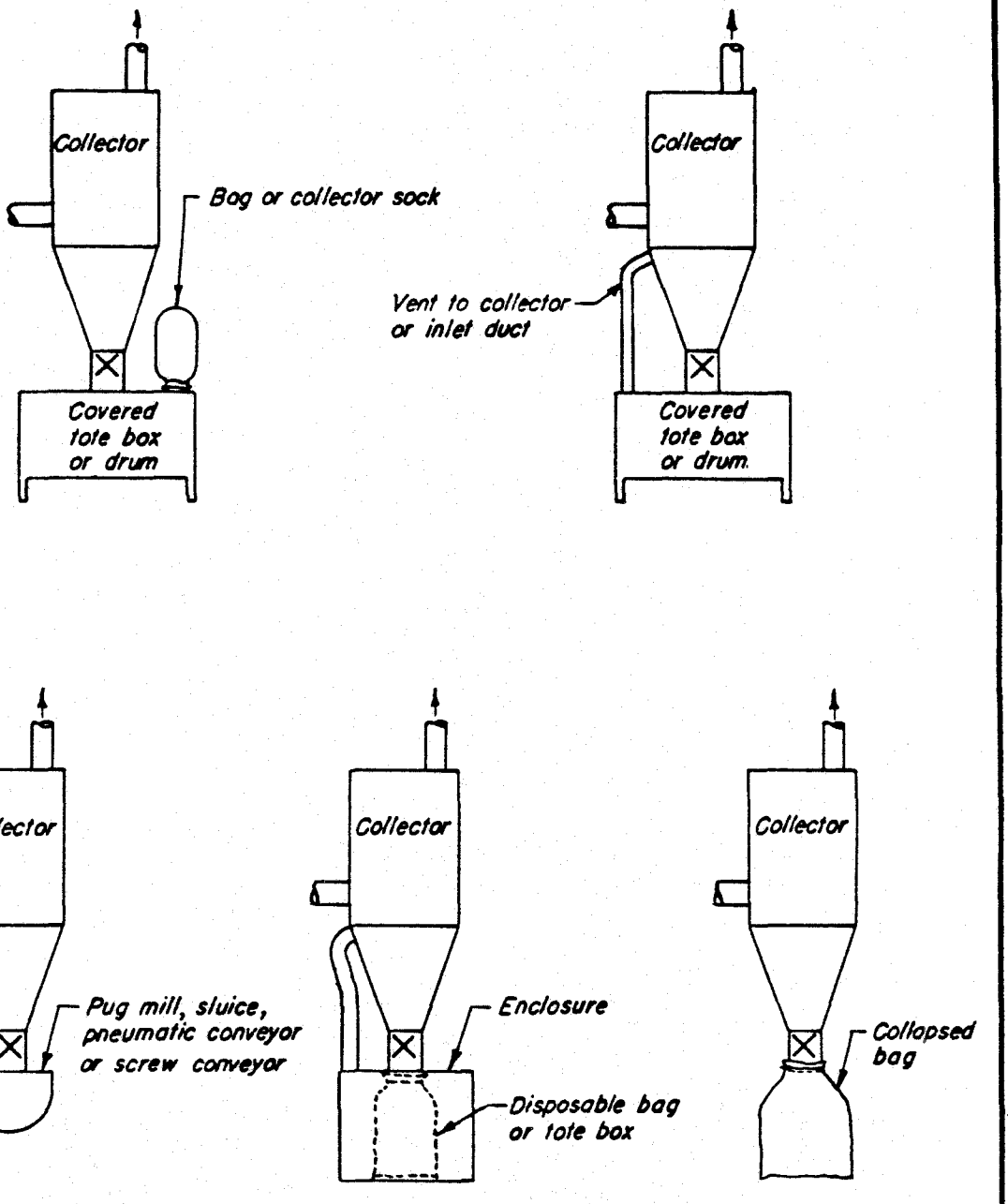
Electrostatic Precipitators

The high voltage electrostatic precipitator, Figure 11-4, is the predominant collector in the high efficiency, high cost group. It should not be confused with the low voltage, small dust holding designs used for filtration in air conditioning systems.

The principle of collection relies on the ability to impart a negative charge to particles in the gas stream causing them to move and adhere to the grounded or positively charged collector plates. Most precipitators are made for horizontal air flow with velocities of 100 to 600 fpm. The collecting plates or electrodes are parallel elements, usually on 9-inch centers, and constructed in various ways including corrugated or perforated plates or rod curtains. The electrode rods are centered between the collector plates. Voltage difference between electrode and plate is 60,000 to 75,000 volts in most designs. Collector plates of cylindrical shapes surrounding the electrode rod are provided where water is used to wash off collected material and where the gas stream is under high pressure or vacuum.

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DRY TYPE DUST COLLECTORS
DUST DISPOSAL

DATE 1-68 | Fig. 11-1

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Removal of the collected material is obtained by rapping or vibrating the elements either continuously or at predetermined intervals. Vibration or unloading usually takes place without stopping air flow through the precipitator, although some loss to the effluent air can be expected in most applications during the cleaning cycle.

Pressure drop is negligible. Collection efficiency is high and nearly uniform regardless of particle size including sub-micron particles (see Figure 11-14). Space is relatively large and cost is high where small gas volumes (below 50,000 cfm) are involved due to the cost of high voltage electrical equipment. Efficiency is improved with increased humidity of the air stream as a change takes place in the dielectric properties of the dust. Heavy concentrations, on the other hand, cause a reduction in collection as the space charge on numerous particles blankets the corona effect from the electrode.

Electrostatic precipitators have been extensively used in high temperature gas cleaning from equipment such as blast furnaces, open hearth furnaces and central station pulverized fuel boilers. The chemical industry has many applications including sulfuric acid plants, carbon black, cement kilns and soda ash from paper mill black liquor furnaces. As voltage setting is close to the spark-over potential, application is limited to materials that are not explosive or combustible in nature unless the carrier gas stream is an inert gas.

Fabric Collectors

Fabric arresters are high efficiency, medium cost collectors. The effectiveness of passing air or gas through a fabric at low velocity has been recognized and used for many years in air cleaning devices. Fabric is arranged in envelope or tubular (stocking) shapes as illustrated in Figure 11-5. While removal appears to take place by a straining action of the media, in reality collection is obtained by building up a mat of the material on the dirty air side of the media. This mat provides the actual filtering or straining bed. By means of this bed a high degree of removal is obtained even on sub-micron size particles. Where new fabric is placed in service, visible escapement will often occur during initial operation until the buildup of the dust mat occurs. Escapement may also occur through sealing devices used to fasten and support the fabric.

These collectors are used extensively in industry for a wide range of applications. They require more space than most other types of air cleaning devices, necessitating outdoor installation in most cases. Erection cost is high due to prevailing practice of completely knocked-down construction when shipped by the manufacturer. The problem of dry dust removal often introduces a secondary dust condition.

The usual fabric is a specially woven cotton, although wool, paper, glass cloth and synthetic fabrics may be used in certain applications. In recent years glass cloth has come into wide use because of silicone treatment of the glass fibers and employment of reverse flow techniques for cleaning. Silicone treatment provides a lubricant between fibers and increases fabric life. Glass cloth is generally used in reverse flow collectors for high temperature gas streams and special applications where conventional fabrics are unsatisfactory.

Fabric collectors are limited to air conditions dry enough to prevent condensation or free moisture deposition on the fabric. With hygroscopic materials, there will be a bonding tendency between particles and fabric under high relative humidity even though no condensation takes place. Maximum recommended temperature for cotton fabric is 180 F, for wool 200 F. Higher temperatures can be handled by using synthetic materials including nylon or orlon fabrics as well as glass cloth and, occasionally, fine metallic mesh. The synthetic fabrics may be used up to 275 F while glass cloth is acceptable to 550 F. Equipment cost is increased considerably with these special media.

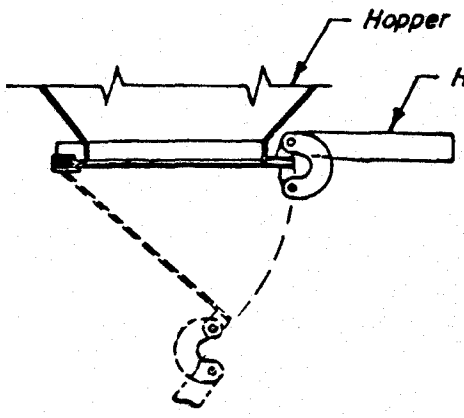
Considerable data has been presented to show variation in rate of resistance rise during the initial cycle of loading of clean fabric. Such investigations are largely academic as the pressure drop of different fabrics for the same application and rating will be comparable after the dust mat has been formed.

As dust is collected on the fabric, resistance to air flow increases. Periodically the fabric must be reconditioned by shaking, vibrating, reverse jet or reverse-flow collapse which agitates sufficiently to remove the bulk of adhering material allowing it to drop into the dust hopper. In most collectors air flow must be stopped during reconditioning, otherwise released material will be re-entrained and redeposited on the fabric. Sufficient dust must adhere to the fabric to maintain the dust mat needed for maximum efficiency; therefore, after reconditioning the pressure drop will be considerably higher than loss through new fabric.

Rate of flow through the media varies with collector type, application and dust concentration. Ratings are usually selected so pressure drop will not exceed 5" wg. The smaller the particle, the more rapid the resistance rise for a given loading. For the same air flow rate and dust loading, resistance rise increases directly in proportion to time. Air flow is in the laminar range where resistance through the fabric at any stage of loading will vary directly with change in air flow. Influence of higher air flow rates or longer intervals between reconditioning can be calculated from these relationships.

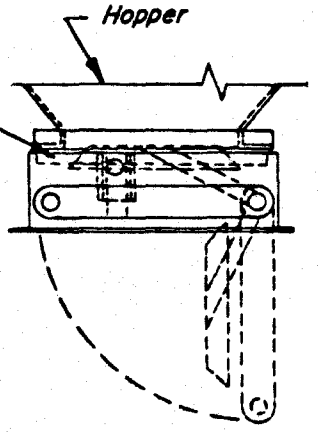
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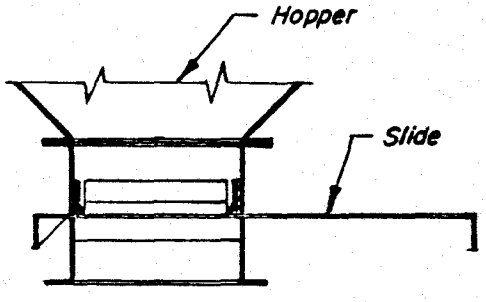
For intermittent, manual dumping where dust loads are light.

DUST DOOR



Similar to dust door but designed for direct attachment to dust chute, external pipe or canvas connection.

DUST GATE



For intermittent, manual dumping where dust loads are light. Flange for connection to dust disposal chute.

SLIDE GATE

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DRY TYPE DUST COLLECTORS DISCHARGE VALVES

DATE 1-68 | Fig. 11-2

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Figure 11-6 illustrates these relationships. Line A indicates that for one application the pressure drop across the arrester would drop to 1-inch after vibration and increase as the first power to 2.5-inches at the end of 4 hours operation; 4-inches, if the vibration cycle was delayed until 8 hours of operation. By keeping the same air flow rate but doubling the dust loading (dust to be same material and to have same median particle size), resistance after vibration would still be 1-inch, although resistance would increase to 4-inches at the end of 4 hours operation. Line C illustrates the problem of trying to increase air flow rate. Doubling the air flow rate through the fabric will double the resistance after vibration. With the same dust loading per cubic foot as in condition A, resistance rise will increase as the square or four times as fast as in condition A. The second power relationship is the combination of increased dust loading rate and increased air flows (twice as many pounds of dust must be collected on a square foot of fabric when the air flow rate through the cloth is doubled).

Intermittent-Duty Fabric Collectors. These types may use either envelope or stocking arrangement of the fabric but will generally employ shaking or vibrating as a means of reconditioning. Periodically (usually at 4 to 6 hour intervals) the air flow must be stopped to effect reconditioning—thus the classification "Intermittent".

Rate of flow through the media seldom exceeds 4 fpm and often is as low as 2 fpm. Ratings are usually selected so pressure drop will be in the 2" to 5" wg range between start and end of a cycle.

Figure 11-7 illustrates the system air flow characteristics where an intermittent-duty fabric collector is employed. As dust is accumulated on the media, resistance to flow increases and air flow decreases until the fan is stopped and the media reconditioned. Variation in air flow due to changing pressure losses is sometimes a disadvantage and when coupled with requirement to periodically stop flow may preclude use of the intermittent collectors.

Multiple-Section, Continuous-Duty, Automatic Fabric Collectors. The disadvantages of stopping the air flow to permit vibration and variations in air flow can be overcome in several ways. Use of sectional arresters, as indicated in Figure 11-5, allows continuous operation of the exhaust system as automatic dampers periodically take one section out of service for reconditioning the fabric while the remaining sections handle the entire gas volume. The larger the number of sections, the nearer the pressure loss will remain constant. The use of reverse air flow to increase effectiveness of removing adhering material is sometimes incorporated in such designs. Reverse-flow collapse type and occasionally reverse-jet type collectors utilize the multiple-section principle.

Figure 11-7 also shows air flow versus time for multiple-section collectors. Each individual section or compartment has an air flow versus time characteristic like that of the intermittent collector but the variation is reduced as a result of the multiple compartments. Note the more constant air flow characteristic of the five-compartment unit as opposed to the three-compartment design. Since an individual section is out of service only 3 to 5 minutes for reconditioning and remaining sections handle the entire gas volume at this time, it is possible to clean the media more frequently than with the intermittent type. Thus the multiple-section collectors can handle higher dust concentrations. Compartments are reconditioned in fixed sequence with allowance for adjustment of time lapse between cleaning of individual compartments.

When employing shakers as a means of reconditioning, rate of flow through the media (air to cloth ratio) will range from 2 to 4 fpm as with the intermittent type. Generally this air to cloth ratio is based on net cloth area available when one compartment is out of service for reconditioning.

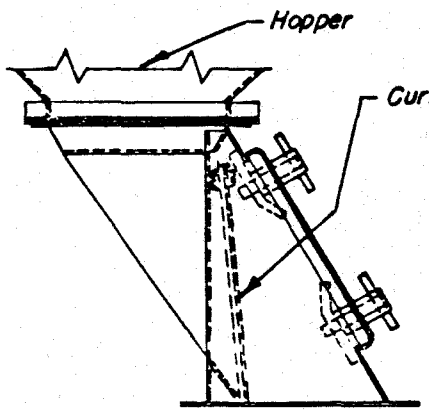
Reverse-Jet, Continuous-Duty, Fabric Collectors. There are several types of reverse-jet cloth collectors. The reverse-jet type differs from the conventional arresters in its use of high pressure air to clean the fabric (see Figure 11-8).

1. One type uses high pressure air (30-40" wg) from a traveling "blow ring" to dislodge the collected cake from inside the fabric tube. Since dust laden air enters the top of the fabric tube, air flow within the stocking is downward to the hopper allowing the fabric to be cleaned without stopping air flow. Multiple sections or compartmentation is not required for continuous duty. The "blow ring" is normally operated continuously.
2. Another type uses high pressure compressed air (100 psi) to break the dust cake from the exterior of the fabric tube or envelope by the intermittent application of the reverse-jet compressed air. In some collectors of this type multiple sections are utilized. Other collectors apply the compressed air on only one or very few tubes or envelopes at a time while preventing air flow in adjacent tubes or envelopes and decreasing the possibility of re-entrainment and redeposition.

Cleaning or reconditioning by the reverse-jet method is more complete than that obtained by vibrating or shaking. Higher air flow rates are possible due to the short reconditioning cycle. Air flow rates of 6 to 12

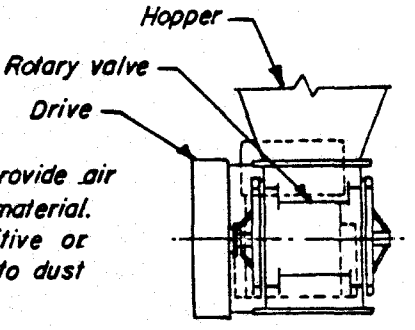
1220 REPRODUCED JM - 83

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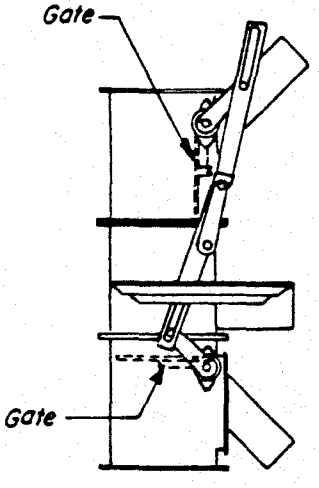
For continuous removal of collected dust where hopper is under negative pressure. Curtain is kept closed by pressure differential until collected material builds up sufficient height to overcome pressure.

TRICKLE VALVE



Motor driven multiple blade rotary valve provide air lock while continuously dumping collected material. Can be used with hoppers under either positive or negative pressure. Flanged for connection to dust disposal chute.

ROTARY LOCK



Motor driven, double gate valve for continuous removal of collected dust. Gates are sequenced so only one is open at a time in order to provide air seal. Flanged for connection to dust disposal chute.

DOUBLE DUMP VALVE

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DRY TYPE DUST COLLECTORS DISCHARGE VALVES

DATE 1-68 | Fig. 11-3

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fpm are usual. For light duty applications rates of 20 fpm and higher have been reported. Pressure loss will be more nearly uniform (generally 4" to 6" wg if properly rated) and exhaust air volume will be more nearly constant. Fabric collectors of this type may be more expensive and require added maintenance for the cleaning mechanism.

Reverse-flow Collapse, Continuous-Duty Collectors. Reverse-flow collapse cleaning is generally used with glass cloth media which is fragile and requires a gentle cleaning technique. Reverse-flow glass cloth collectors have been widely used for collection of dust from cement kilns, rotary furnaces in the chemical industry and other special applications. Reversing the gas flow provides a gentle collapse of the fabric usually in a "four point star" breaking the dust cake which falls by gravity into the hopper.

Compartmentation is required for continuous service. Rate of flow through the media is from 1 to 2 fpm based on net cloth area.

Wet Collectors

Wet collectors are commercially available in many different designs. There are more types of wet collectors than there are differing devices in the other three groups.

Wet type collectors have the ability to handle high temperature and moisture-laden gases. The collection of dust in a wetted form eliminates a secondary dust problem in disposal of collected material.

Some dusts represent explosion or fire hazards when dry and wet collectors eliminate or at least reduce the hazard. However, the use of water may introduce corrosive conditions within the collector and freeze protection may be necessary if collectors are located outside in cold climates. Space requirements are nominal; pressure losses and collection efficiency vary widely with the design.

Wet collectors show a wide range of performance. Several investigators have attempted to define the parameters of cleaning efficiency for wet collectors. As a result it is generally accepted that—for well-designed equipment—the efficiency depends on the energy input per cfm of air only and is independent of operating principle. Efficiency is a function of total energy input per cfm whether the energy is supplied to the air or the water. This relationship applies only when the energy is expended in the gas-liquid contacting process. Well-designed collectors by different manufacturers with equivalent power requirements will demonstrate comparable efficiencies.

Wet collectors (particularly the high energy-high efficiency types) are being used more frequently as the solution of air pollution problems. It should be realized that disposal of collected material in water without clarification or treatment may create water pollution problems.

Wet collectors have one distinct characteristic not found in other collectors—their inherent ability to humidify. Humidification, the process of adding water vapor to the air stream through evaporation, may be either advantageous or disadvantageous depending on the situation. Where the initial air stream is at an elevated temperature and not saturated, the process of evaporation reduces the temperature and the volume of the gas stream leaving the collector. Assuming the fan is to be selected for operation behind or on the clean air side of the collector it may be smaller and will definitely require less power than if there had been no cooling through the collector. This is one of the obvious advantages of humidification.

The user should be aware of humidification and should consider its effects before finalizing design of the entire system. While all wet collectors humidify, the amount of humidification varies between designs. Most manufacturers publish the humidifying efficiency for their equipment and will assist in evaluating the effects.

Chamber or Spray Tower. Chamber or spray tower collectors consist of a round or rectangular chamber into which water is introduced via spray nozzles. There are many variations of design but the principal mechanism is impaction of dust particles on the liquid droplets created by the nozzles. These droplets are separated from the air stream by centrifugal force or impingement on water eliminators.

Pressure drop is relatively low, on the order of 1/2" to 1-1/2" wg, but water pressures range from 10 to 400 psi. The high pressure devices are the exception rather than the rule. In general this type of collector utilizes low pressure supply water and operates in the lower efficiency range of wet collectors. Where water is supplied under high pressure, as with fog towers, collection efficiency reaches the upper range of wet collectors.

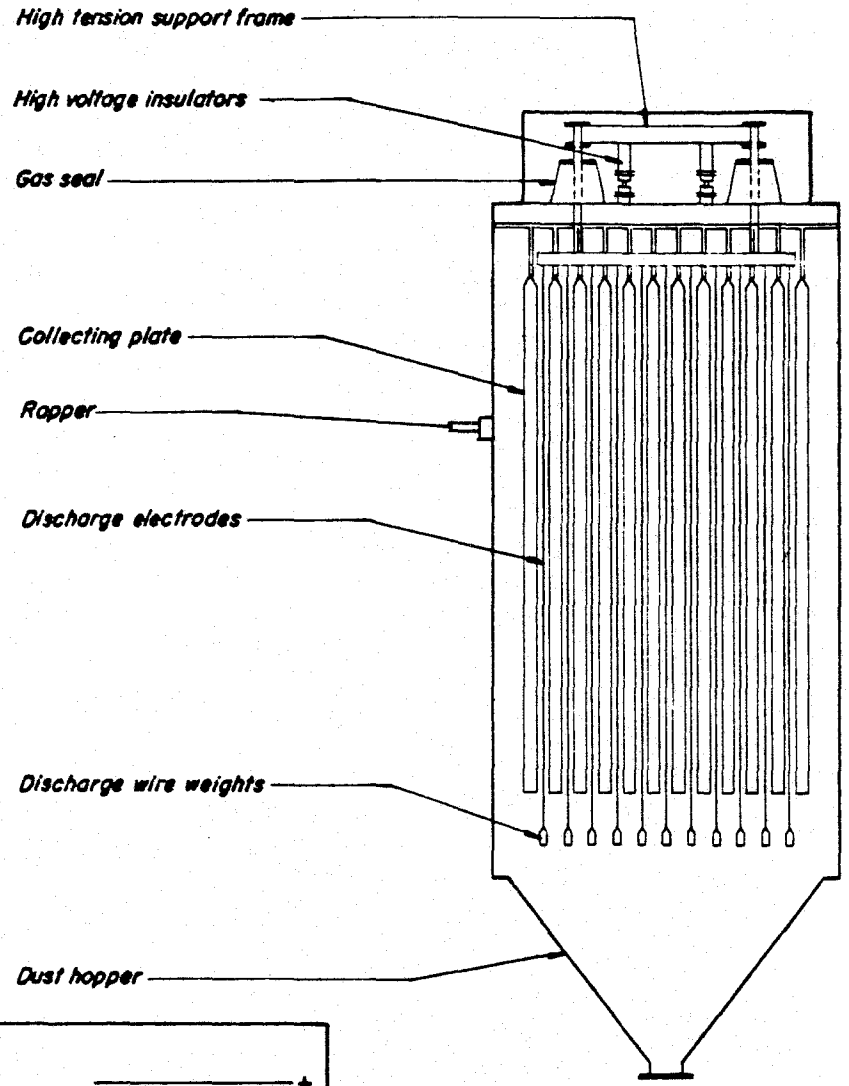
For conventional equipment, water requirements are reasonable with a maximum of about 5 gpm per 1,000 SCFM of gas. Fogging types using high water pressure may require as much as 10 gpm per 1,000 SCFM of gas.

Packed Towers (See Figure 11-9). Collectors in this group are essentially contact beds through which gases and liquid pass either concurrently, counter-currently or in cross-flow and are used primarily for

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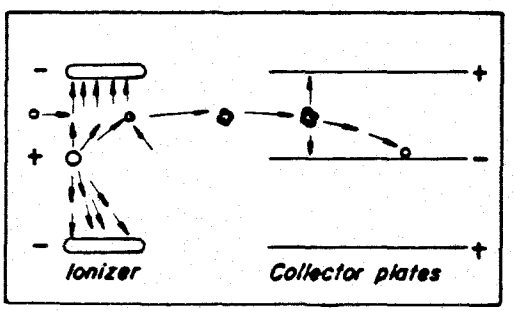
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HIGH VOLTAGE DESIGN

Discharge electrode (normally negative) 30,000 to 75,000 volts. Collecting plates are usually grounded.



LOW VOLTAGE DESIGN

12,000 to 13,000 volts on ionizer
6,000 to 7,000 volts on collector plates

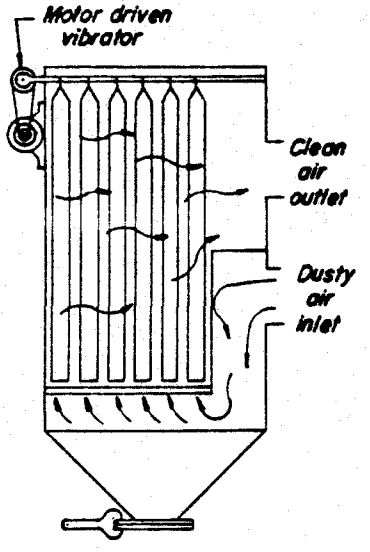
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ELECTROSTATIC PRECIPITATOR

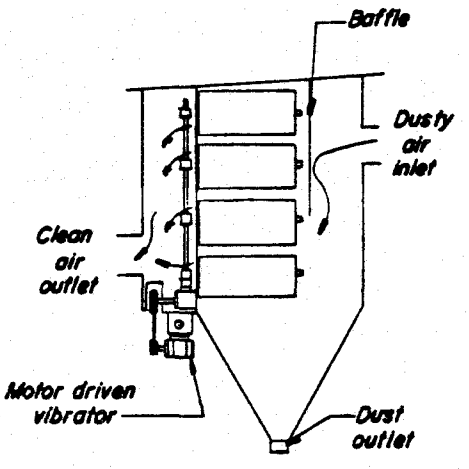
DATE 1-68 | Fig. 11-4

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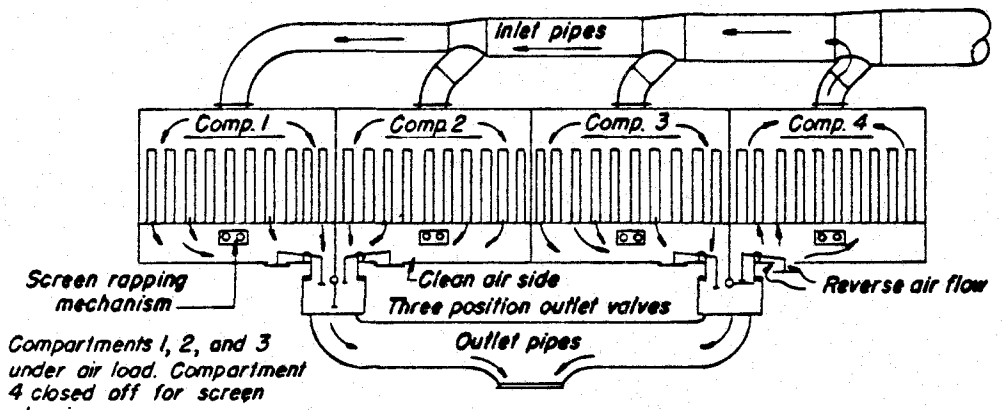
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CLOTH TUBE OR STOCKING TYPE



ENVELOPE OR BAG TYPE



MULTIPLE SECTION CONTINUOUS AUTOMATIC

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FABRIC COLLECTORS	
DATE 1-68	Fig. 11-5

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applications involving gas, vapor and mist removal. These collectors will capture solid particulate matter but are not used because dust will plug the packing requiring unreasonable maintenance.

Water flow rates of 5 to 10 gpm per 1,000 SCFM are frequent. Water is distributed over V-notched ceramic or plastic weirs. High temperature deterioration is avoided by use of brick linings permitting 1600 F gases direct from furnace flues.

Air flow pressure loss for 4' beds of packing such as ceramic saddles or coke range from 1-1/2" to 3-1/2" wg with respective face area velocities of approximately 200 to 300 fpm.

Wet Centrifugal (See Figure 11-10). Wet centrifugal collectors comprise a large portion of the commercially available designs. This type utilizes centrifugal force to accelerate the dust particle and impinge it upon a wetted collector surface.

Water rates are usually 2 to 5 gpm per 1,000 SCFM of gas cleaned. Water distribution can be from nozzles, gravity flow or induced water pickup. Pressure drop is on the order of 2" to 6" wg.

As a group, these collectors are more efficient than the chamber type. Some are available with different numbers of impingement sections. Fewer sections offer lower efficiency, lower cost, less pressure drop and smaller space requirements. Others contain multiple collecting tubes. These relatively small tubes provide higher collection efficiency in the same manner as the multi-tube small diameter cyclones and are more efficient than large diameter cyclones of the dry mechanical group.

Wet Dynamic Precipitator (See Figure 11-11). This type uses water sprays within a fan housing and obtains precipitation of the dust particles on the wetted surfaces of an impeller with special fan blade shape. No internal pressure drop is involved although mechanical efficiency is somewhat lower than the mechanical efficiency of standard exhaust fans.

Orifice Type (See Figure 11-11). In this group of wet dust collector designs, the air flow through the collector is brought in contact with a sheet of water in a restricted passage. Water flow may be induced by the velocity of the air stream or maintained by pumps and weirs. Pressure losses vary from 1" or less in water wall spray booth collector designs to from 3" to 6" in most industrial collector arrangements. Pressure losses as high as 20" are used with some collectors designed to collect very small particles.

Venturi (See Figure 11-10). This collector uses a venturi-shaped constriction to establish throat velocities considerably higher than those experienced with the orifice type. Gas velocities through venturi throats may range from 12,000 to 24,000 fpm. Water is supplied at or ahead of the throat through piping or jets and will range from 5 to 15 gpm per 1,000 SCFM of gas.

The collection mechanism of the venturi is impaction. As with wet collectors in general, the collection efficiency of the venturi increases with higher pressure drops. Different pressure drops are achieved by designing for selected gas velocities in the throat. Some venturi collectors are manufactured with adjustable throats allowing a range of pressure drops for a given volume or for conditions where the volume is variable and a constant pressure drop is desired. Systems are available with throat pressure drops as low as 5" and as high as 100" wg.

The venturi itself is a gas conditioner causing intimate contact between the particulates in the gas and the multiple jet streams of scrubbing water. The resulting mixture of gases, fume-dust agglomerates and dirty water must be channeled through a separation section for the elimination of entrained droplets as shown in Figure 11-10.

Dry Centrifugal Collectors

The use of centrifugal force to throw a dust particle to the periphery of an air stream has been used in the cyclone collector for many years.

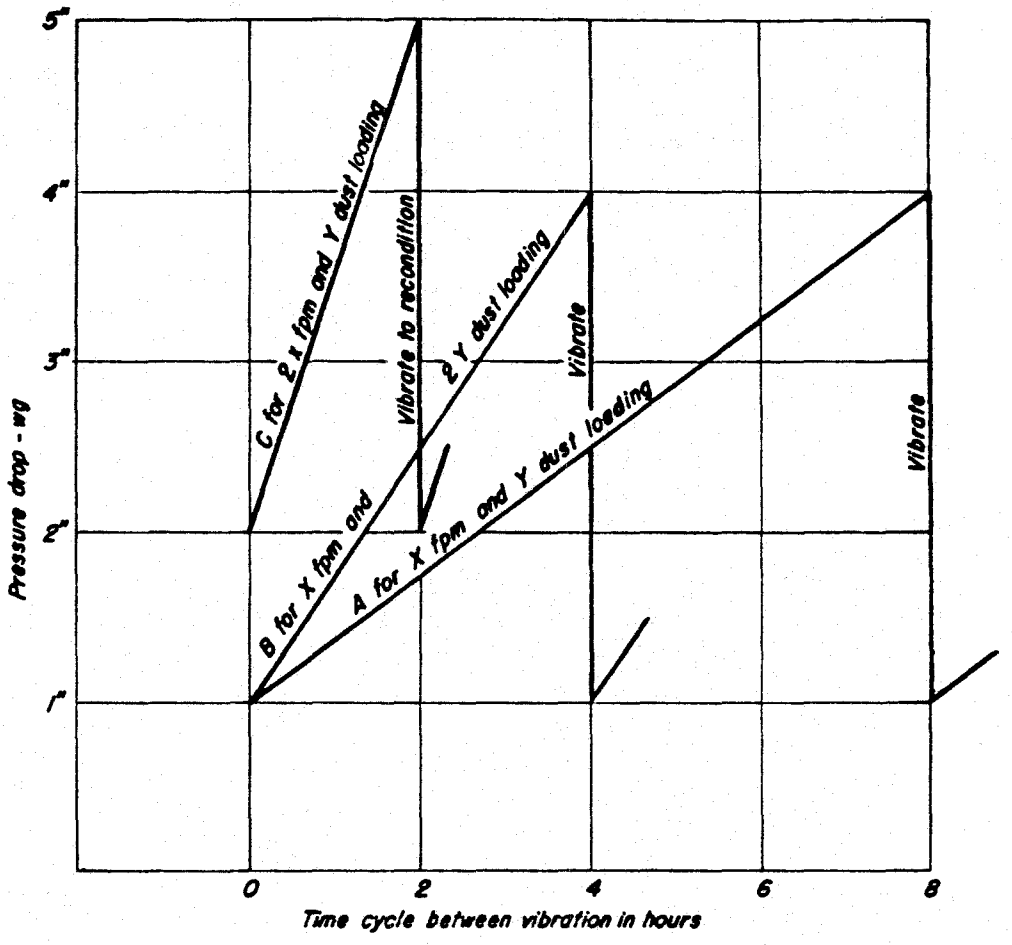
Dry centrifugal collector design can be divided into two basic groups cataloged by their effectiveness in removal of smaller dust particles.

The Cyclone Collector (See Figure 11-12) - is commonly applied for the removal of coarse dusts from an air stream, as a pre-cleaner to more efficient dry or wet dust collectors and/or as a separator in product conveying systems using an air stream to transport material. Principal advantages are low cost, low maintenance and low pressure drop (in order of 3/4 to 1-1/2"), but cannot be used for collection of fine particles.

High Efficiency Centrifugals (See Figure 11-12) - have been developed whereby higher centrifugal forces are exerted on dust particles in a gas stream. Centrifugal force is a function of peripheral velocities and angular acceleration and improvement in dust separation efficiency has been obtained by (a) increasing

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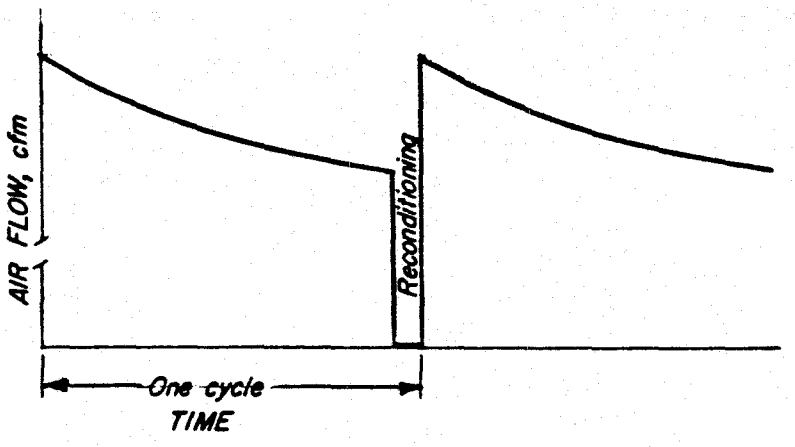


INFLUENCE OF AIR FLOW RATE AND DUST LOADING IN FABRIC ARRESTER RESISTANCE TO AIR FLOW.

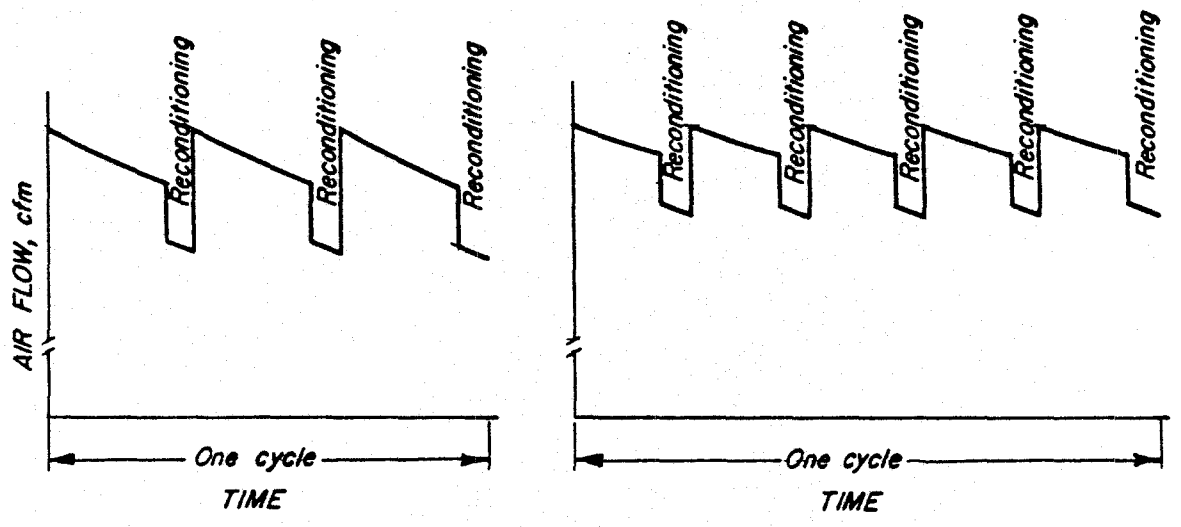
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PRESSURE DROP THROUGH FABRIC COLLECTORS	
DATE 1-68	Fig. 11-6

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INTERMITTENT DUTY FABRIC COLLECTOR



3 Compartment

5 Compartment

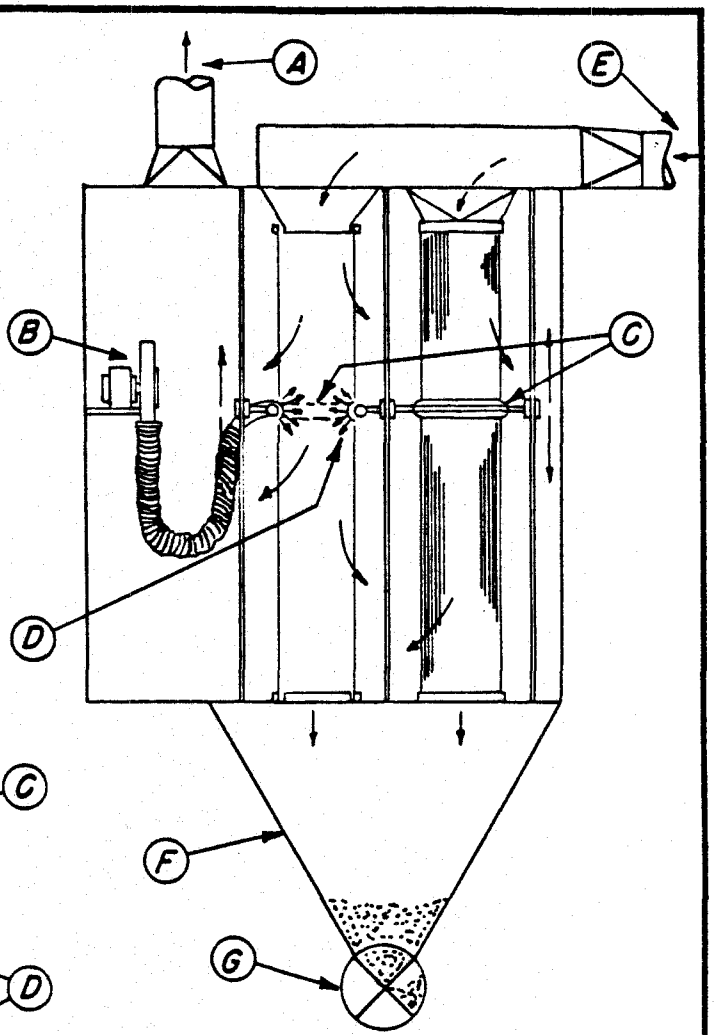
MULTIPLE SECTION, CONTINUOUS DUTY FABRIC COLLECTOR

Note:
The flow variation has been exaggerated and does not represent the percentage change which would be smaller.

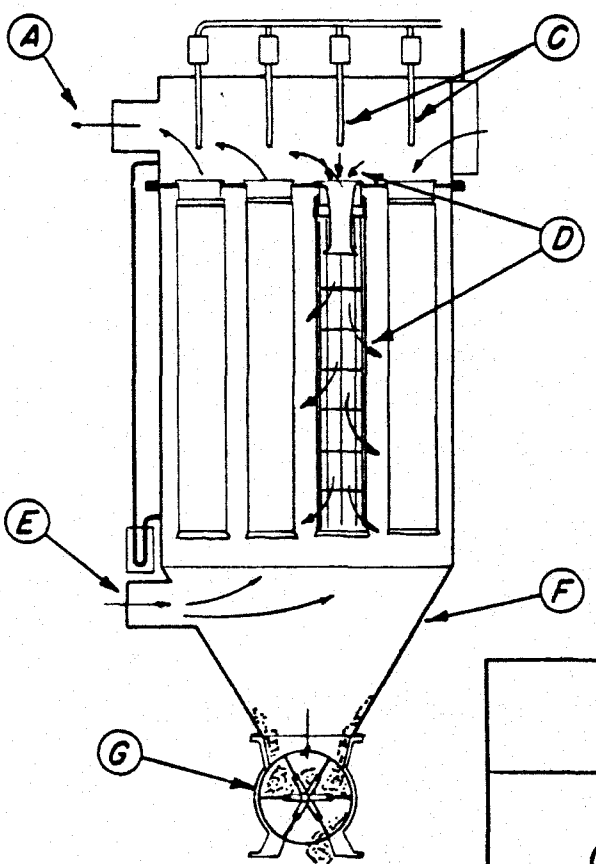
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AIR FLOW THROUGH FABRIC COLLECTORS	
DATE 1-68	Fig. 11-7

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Symbols	Parts
A	Clean air outlet
B	Reverse air blower
C	Reverse air nozzle (jet)
D	Reverse air cleaning action
E	Dirty air inlet
F	Dust hopper
G	Hopper valve and/or dust feeder



TRAVELING RING TYPE



PRESSURE JET TYPE

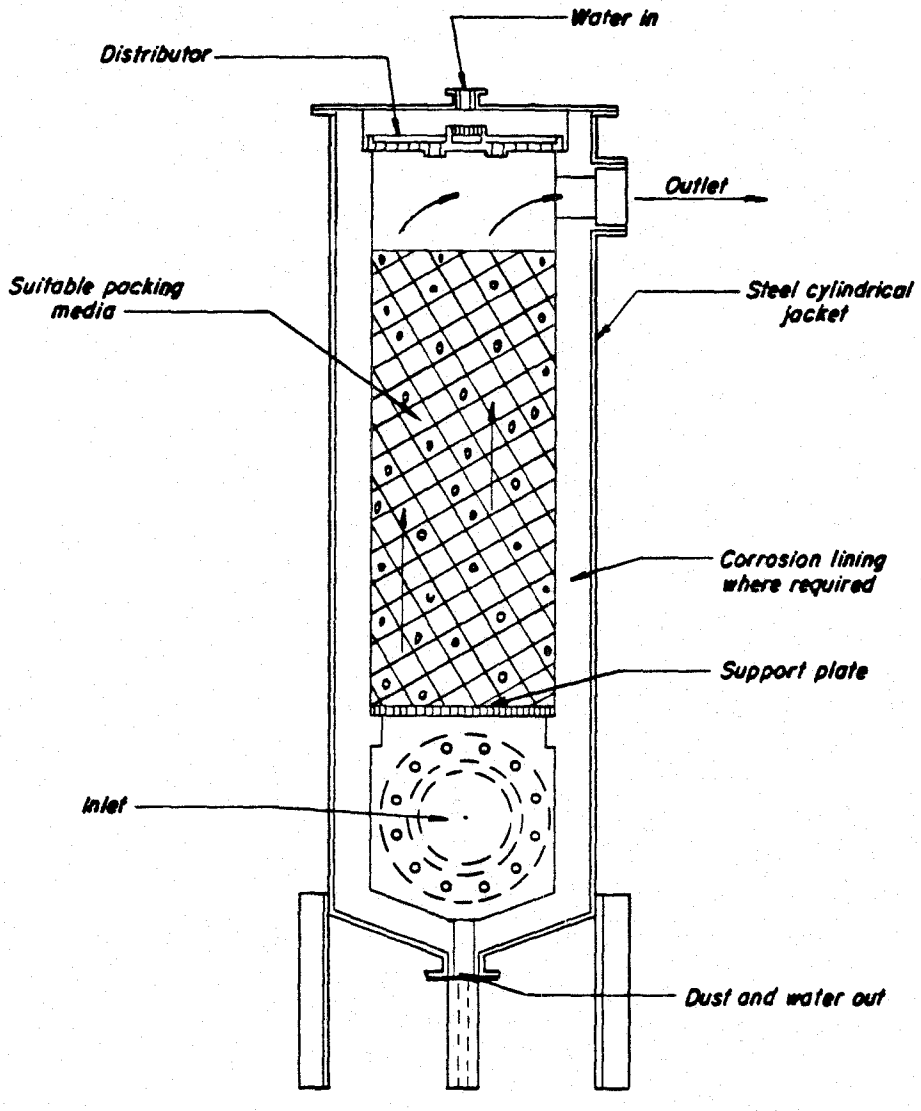
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FABRIC COLLECTORS
CONTINUOUS CLEANING TYPES

DATE 1-68 | Fig. 11-8

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PACKED TOWER

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
WET TYPE DUST COLLECTOR	
DATE 1-68	Fig. 11-9

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velocities through a cyclone shaped collector; (b) utilizing a skimmer or other design feature; (c) using a number of small diameter cyclones in parallel and (d) placing units in series in some unusual applications.

While such collectors do not generally reach as high an efficiency on small particles as do the electrostatic, fabric or some wet type units, their effective collection range is appreciably extended beyond that of the conventional low-pressure cyclone. Pressure losses of collectors in this group range from 3 to 8" wg.

The Dry Type Dynamic Precipitator (See Figure 11-12) - can be placed in the high efficiency group. In this collector, dust is precipitated by centrifugal force on to specially shaped blades on an exhauster wheel and then conveyed through a dust circuit in the fan casing to the dust storage hopper.

Louver Type - Centrifugal forces can be applied to a particle by a rapid change in direction of air flow by series of plates set at an angle to the air stream. Coarser particles traverse the air stream and will project back to the dirty air side by the forces that can be produced from such an impact. Efficiency will be essentially a function of louver spacing. The closer the spacing, the higher the efficiency but also the greater the probability of plugging of the air passages—plugging due to both buildup on the front and back of the louver and mechanical obstruction by larger particles. For a louver spacing practical for industrial air cleaning applications, efficiency will drop off the same as in other dry type centrifugals.

Settling Chambers

While theoretically it would be possible to settle out dust in a large chamber when conveying velocities are reduced to the point where the particles would no longer be conveyed, such devices have little practical application in dust collecting equipment. Extreme space requirements and the presence of eddy currents to nullify the effective velocity mean that settling chamber type of collectors can be used only for removal of extremely coarse particles.

Unit Collectors

To fill the need for dust collection from isolated, portable or frequently relocated dust producing operations, a number of unit collector designs are available having capacities in the range of 200 to 1,000 cfm. Featuring small space and designed to recirculate the air, collectors of this type have been used extensively, especially in the metal working industry.

Most of the criticism leveled at this group has been prompted by their misapplication where purchasers have failed to appreciate their limitations. Intended for lighter dust loads and/or intermittent operations, the dust holding and storage capacity, servicing facilities and longer periods between maintenance have all been sacrificed, in many cases, for small space and low first cost. While performance can be completely satisfactory for lighter loads such as tool room grinders, occasionally used cut-off saws or light loadings for package filling, applications should be carefully examined before installation is recommended for continuous dust producing operations which release moderate or heavy quantities of fine dust.

Their use also becomes questionable where a larger number of unit collectors are installed within an area in which a central exhaust system would be practical. The dust removal and servicing requirements from a number of such unit collectors are expensive and are more apt to be slighted than would be the case with a single large collector with its one dust disposal point, its greater dust storage capacity and a construction that could reduce frequency of service and maintenance attention required.

Unit collectors, Figure 11-13, normally fall into two groups. Fabric collectors use cloth envelopes quite closely spaced with some manual means of vibration and with air velocities through the fabric of 8 to 12 fpm. The fan filter group uses an air filter, usually of the viscous impingement type, preceded by some primary collector which may be a simple settling chamber or a more effective centrifugal collector.

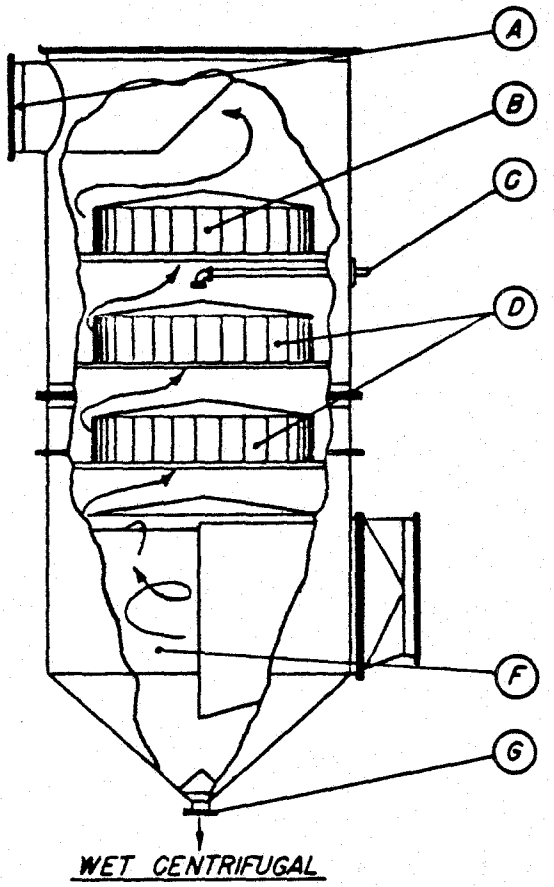
Additional Aids in Dust Collector Selection

The collection efficiencies of the five basic groups of air cleaning devices have been plotted against mass mean particle size (Figure 11-14). The graphs were found through laboratory and field testing and were not compiled mathematically. The number of lines for each group indicates the range that can be expected for the different collectors operating under the same principle. Variables such as type of dust, velocity of the air, water rates, etc., will also account for the range.

Deviation lines shown in the upper right hand corner of the chart are the results of a methematical calculation to enable the prediction of mass mean particle size of material in the effluent of a collector if the inlet mean size is known. Space does not permit a detailed explanation of how the slopes of these lines were determined and it should suffice to illustrate how they are used in the following example. It should also be pointed

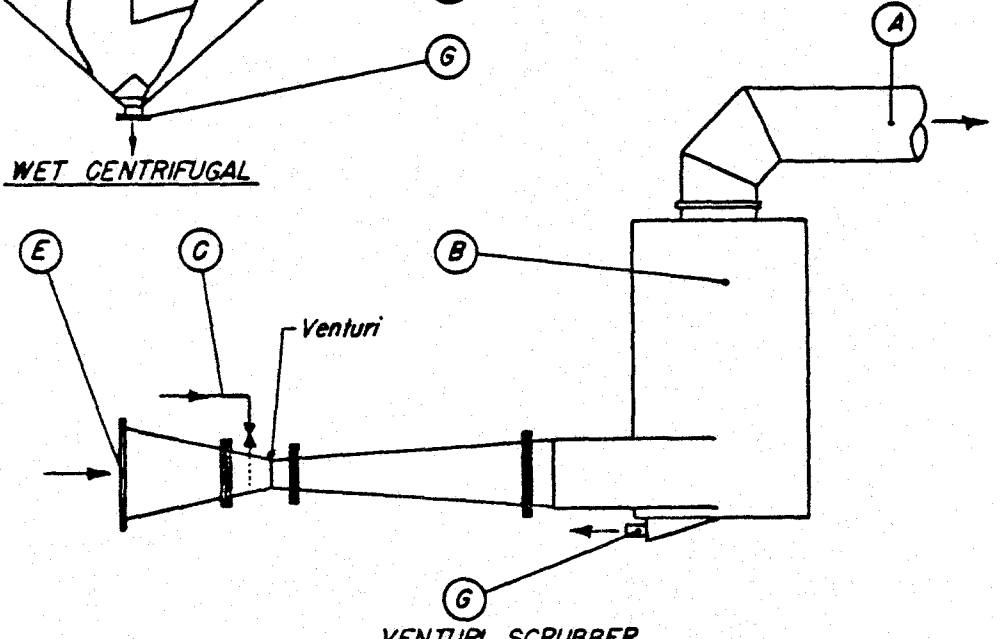
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WET CENTRIFUGAL

Symbols	Ports
A	Clean air outlet.
B	Entrainment separator.
C	Water inlet.
D	Impingement plates.
E	Dirty air inlet.
F	Wet cyclone for collecting heavy material.
G	Water and sludge drain.



VENTURI SCRUBBER

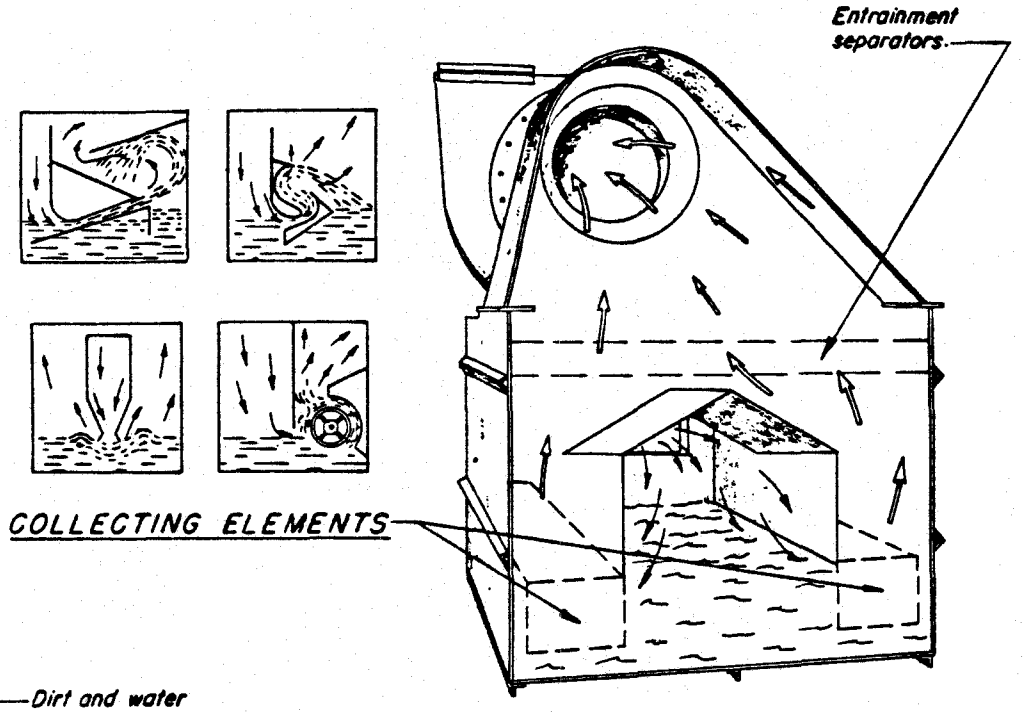
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WET TYPE DUST COLLECTORS

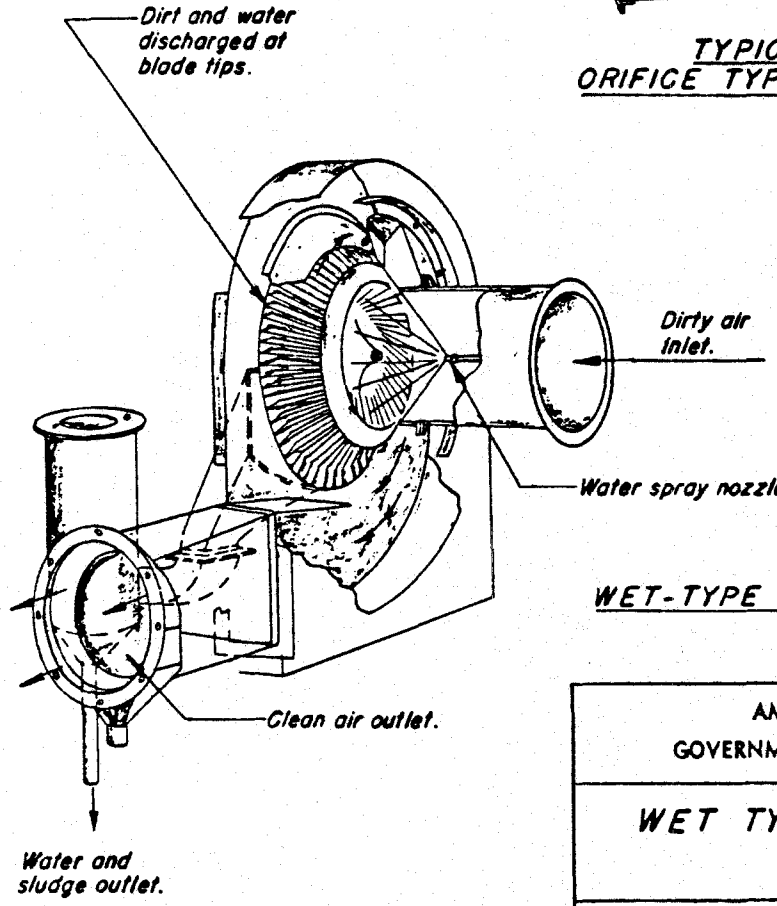
DATE 1-68 | Fig. 11-10

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TYPICAL WET
ORIFICE TYPE COLLECTOR

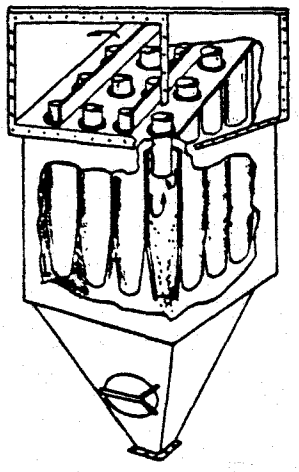


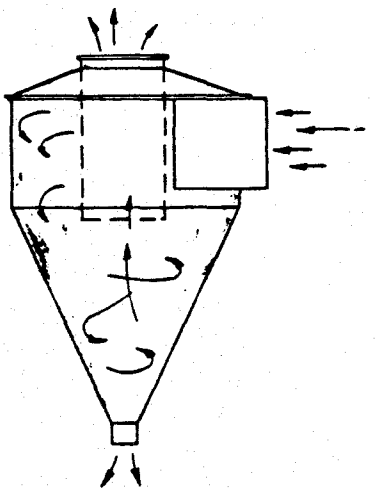
WET-TYPE DYNAMIC PRECIPITATOR

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WET TYPE DUST COLLECTOR	
DATE 1-68	Fig. 11-11

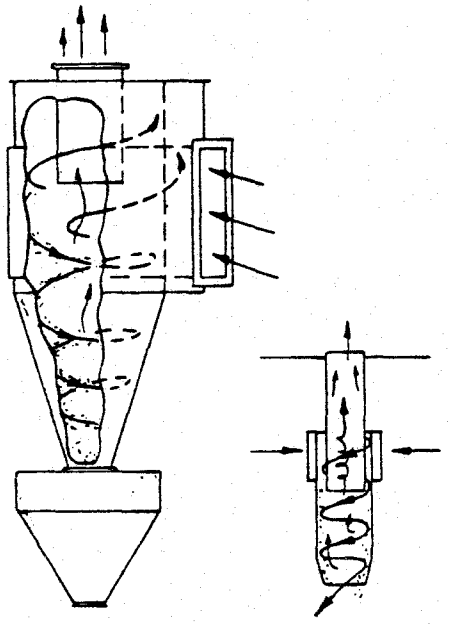
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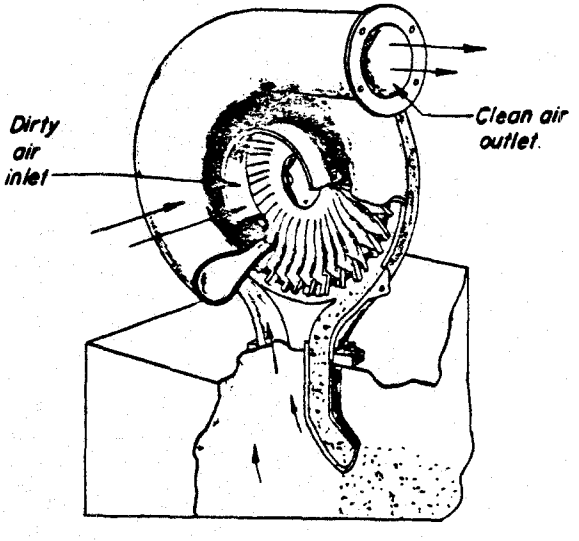




LOW PRESSURE CYCLONE



HIGH EFFICIENCY CENTRIFUGALS



DRY TYPE DYNAMIC PRECIPITATOR

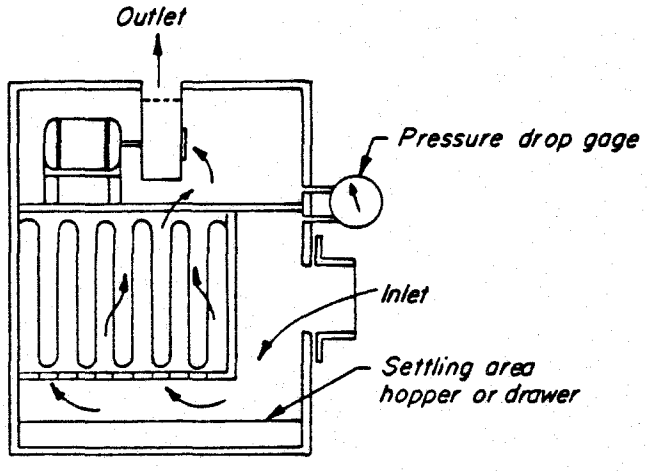
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DRY TYPE CENTRIFUGAL COLLECTORS

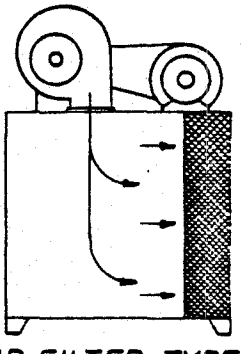
DATE 1-68 | Fig. 11-12

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FABRIC TYPE



AIR FILTER TYPE

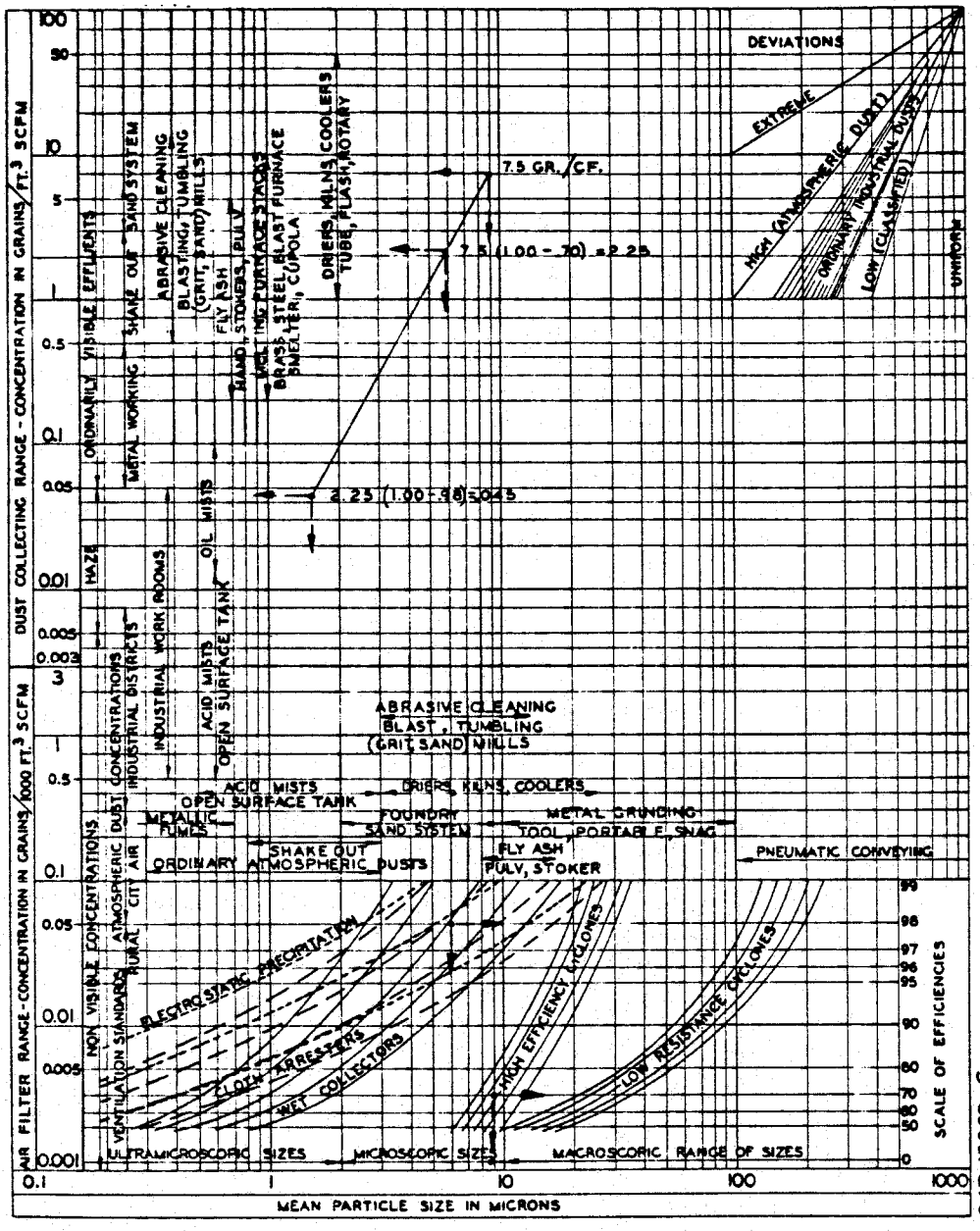
NOTES:

1. These units are not intended for production operations.
2. Install pressure drop gage to indicate need for cleaning or filter replacement.
3. Automatic fabric cleaning is preferred. Manual methods are unreliable without careful scheduling and supervision.
4. Recirculation (return) of air to workroom is not permitted with many materials. Consult State and Local Codes.

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UNIT COLLECTORS	
DATE 1-72	Fig. 11-13

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RANGE OF PARTICLE SIZES, CONCENTRATION, & COLLECTOR PERFORMANCE

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ACKNOWLEDGEMENTS OF PARTIAL SOURCES OF DATA REPORTED:
FRANK W.G. - AMERICAN AIR FILTER - SIZE AND CHARACTERISTICS OF AIR BORNE SOLIDS - 1931
FIRST AND DRINKER - ARCHIVES OF INDUSTRIAL HYGIENE AND OCCUPATIONAL MEDICINE - APRIL 1952

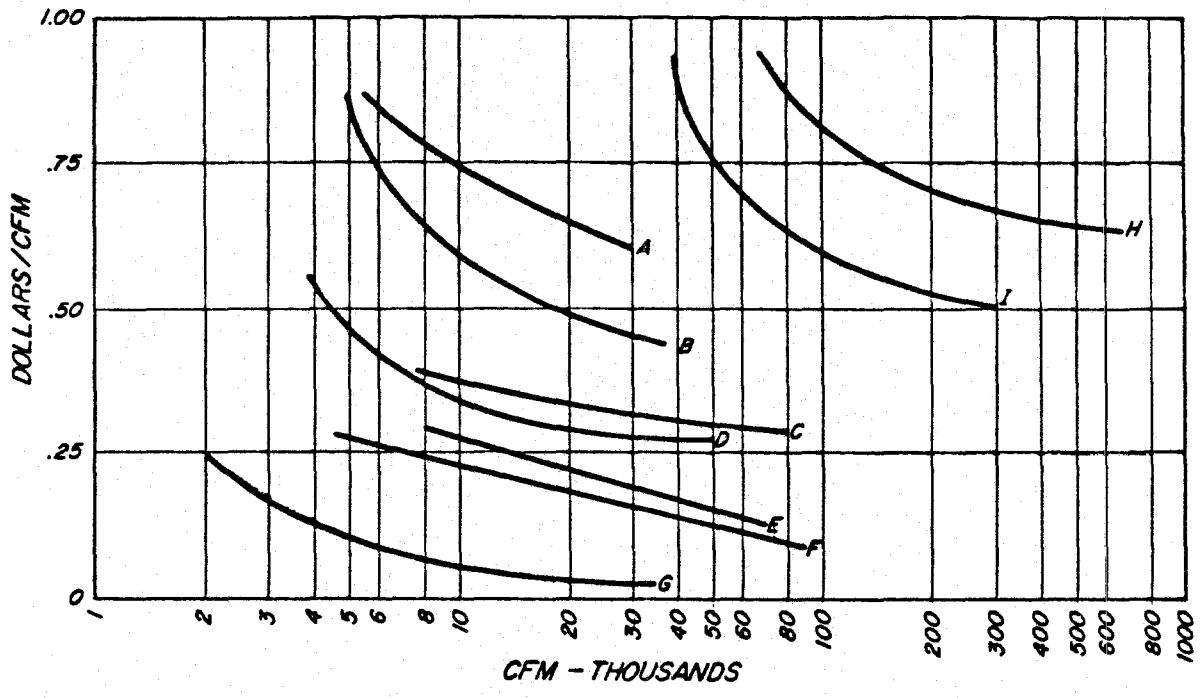
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RANGE OF PARTICLE SIZE

DATE *1-68* | *Fig. 11-14*

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A - High temperature fabric collector (continuous duty)
B - Reverse jet fabric collector (continuous duty)
C - Wet collector (maximum cost range)
D - Intermittant duty fabric collector
E - High efficiency centrifugal collector
F - Wet collector (minimum cost range)
G - Low pressure drop cyclone (maximum cost range)
H - High voltage precipitators
I - High voltage precipitators (minimum cost range)

Note 1: Cost based on collector section only. Cost does not include ducting, water requirement, power requirement or exhausters (unless exhaust is integral part of secondary air circuit.)

Note 2: Cost of continuous duty sectional fabric collector approaches cost of reverse jet continuous duty collector.

Note 3: Price of electrostatic precipitators will vary with the contact time and the electrical equipment required. Price shown are for fly ash installations when high velocities of 300 to 600 fpm are usual. Precipitators for metallurgical fumes, etc, will be considerably higher in cost per cfm.

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COST ESTIMATES OF
DUST COLLECTING EQUIPMENT

DATE 1-68 | Fig. 11-15

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out that the deviation lines should not be used for electrostatic precipitators but can be used for the other groups shown at the bottom of the graph.

Example: A suitable collector will be selected for a lime kiln to illustrate the use of the chart. Referring to the chart, the concentration and mean particle size of the material leaving the kiln can vary between 3 and 10 grains per cubic foot with 5 to 10 microns the range for mass mean particle size. Assume an inlet concentration of 7.5 grains/cu ft and inlet mean particle size of 9 microns. Projection of this point vertically downward to the collection efficiency portion of the chart will indicate that a low resistance cyclone will be less than 50% efficient; a high efficiency centrifugal will be 60 to 80% efficient and a wet collector, fabric arrester and electrostatic precipitator will be 97% plus efficient. The latter three collectors are often preceded by a precleaner so a high efficiency centrifugal will be selected. Using the average line of this group, the efficiency will be 70%. Therefore, the effluent from this collector will have a concentration of 7.5 x (1.00 - 0.70) = 2.25 grains/cu ft. Draw a line through the initial point with a slope parallel to the deviation lines marked "industrial dust". Where deviation is not known, the average of this group of lines will normally be sufficiently accurate to predict the mean particle size in the collector effluent. Where this line intersects the horizontal line marked 2.25 grains/cu ft, a vertical line through the point will indicate the effluent mean particle size of 6.0 microns.

A projection of this point of collector effluent vertically downward shows that a second high efficiency centrifugal will be less than 50% efficient. A wet collector, fabric arrester and electrostatic precipitator will be not less than 94% efficient. Selection of a good wet collector will show an efficiency of 98%. The effluent leaving this collector will have a concentration of 2.25 x (1.00 - 0.98) = 0.045 grains/cu ft. Using the line initially drawn, at the point where it intersects the line of 0.045 grains/cu ft, will indicate a mean particle size in the effluent of 1.6 microns.

In Figure 11-17, an effort has been made to report types of dust collectors encountered for a wide range of industrial processes. While many of the ratings are purely arbitrary, they may serve as a guide in selecting the type of dust collector most frequently used.

Control of Mist, Gas and Vapor Contaminants

Previous discussion has centered on the collection of dust and fume or particulate existing in the solid state. Only the Packed Tower was singled out as being used primarily to collect mist, gas or vapor. It should be realized that the character of a mist aerosol is very similar to that of a dust or fume aerosol and that mist can be removed from an air stream by applying the same principles which are used to remove solid particulate.

Many of the devices previously described, or equipment quite similar, are used to collect mist. Standard wet collectors are used to collect many types of mists. Specially designed electrostatic precipitators are frequently employed to collect sulfuric acid or oil mist. Even fabric and centrifugal collectors, although none of the types specifically described earlier, are widely used to collect oil mist generated by high speed machining.

Equipment designed specifically to control gas or vapor contaminants can be classified as:

1. Absorbers
2. Adsorbers
3. Thermal Oxidizers
4. Direct Combustors
5. Catalytic Oxidizers

Absorbers: Absorbers remove soluble or chemically reactive gases from an air stream by contacting them with a suitable liquid. The equipment provides intimate contact between the gaseous contaminant and absorbent but may vary widely in design and performance. Removal may be by absorption if the gas solubility and vapor pressure promote absorption or chemical reaction. Water is the most frequently used absorbent, but additives are frequently required and occasionally other chemical solutions must be used. Packed towers (Figure 11-9) are typical absorbers.

Adsorbers: Adsorbers remove contaminants by collection on a solid. No chemical reaction is involved as adsorption is a physical process where molecules of a gas adhere to surfaces of the solid adsorbent. Activated carbon or molecular sieves are popular adsorbents.

Thermal Oxidizers: Thermal oxidizers or afterburners may be used where the contaminant is combustible. The contaminated air stream is introduced to an open flame or heating device followed by a residence chamber where combustibles are oxidized producing carbon dioxide and water vapor. Most combustible contaminants can be oxidized at temperatures between 1000 and 1500 F. The residence chamber must provide sufficient dwell time and turbulence to allow complete oxidation.

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Direct Combustors: Direct combustors differ from thermal oxidizers by introducing the contaminated gases and auxiliary air into the burner itself as fuel. Auxiliary fuel, usually natural gas or oil, is generally required for ignition and may or may not be required to sustain burning.

Catalytic Oxidizers: Catalytic oxidizers may be used where the contaminant is combustible. The contaminated gas stream is preheated and then passed through a catalyst bed which promotes oxidation of the combustibles to carbon dioxide and water vapor. Metals of the platinum family are commonly used catalysts which will promote oxidation at temperatures between 700 and 900 F.

To use either thermal or catalytic oxidation, the combustible contaminant concentration must be below the lower explosive limit. Equipment specifically designed for control of gaseous or vapor contaminants should be applied with caution when the air stream also contains solid particles. Solid particulate can plug absorbers, adsorbers and catalysts and, if non-combustible, will not be converted in thermal oxidizers and direct combustors.

Air streams containing both solid particles and gaseous contaminants may require appropriate control devices in series.

Dust Collection Equipment Cost

The variation in equipment cost, especially on an installed basis is difficult to estimate and any figures to use for comparisons are complicated unless a thorough knowledge of the factors included or the items not included are carefully evaluated. Factors which make useful cost estimates difficult to furnish include:

Price Versus Capacity - All dust collector prices per cfm of gas handled will vary with the volume involved. The smaller the volume, the higher the cost per cfm. The break point, where price per cfm cleaned tends to level off, will vary with the design, as can be noted from a few typical curves shown on Figure 11-15.

Accessories Included - Careful analysis of components of equipment included is very important. Some collector designs include exhaust fan, motor, drive and starter. In other designs, these items and their supporting structure must be secured from other sources by the purchaser. Likewise, while dust storage hoppers are integral parts of some dust collector designs, they are not provided in other types. Duct connections between elements may be included or omitted. Recirculating water pumps and/or settling tanks may be required and may not be included in the equipment price.

Installation Cost - Installation cost can equal or exceed the cost of the collector, depending on method of shipment (completely assembled, sub-assemblies or completely knocked down), on location which may require expensive rigging to put in place and on expensive supporting steel and access platforms. The cost picture can be measurably influenced by the need for water and drain supply, special or extensive electrical work and expensive material handling equipment for collection material disposal. Items in the latter group will often also be a variable decreasing in cost per cfm as the volume of gas to be cleaned increases.

Special Construction - Prices shown in any tabulation must necessarily assume standard or basic construction. Increase in cost for corrosion resisting material, special high temperature fabrics, insultation and/or weather protection for outdoor installations, can introduce a multiplier one to four times standard construction cost.

With all the reservations mentioned, some idea of dust collector costs is provided in Figure 11-15. The additional notes and explanations included in this data should also be carefully examined before data is used for estimating cost of specific installations. In the final analysis, it will be safer for management to call in the equipment manufacturer or installer and to get estimates for his specific problem unless a past history record for similar control problems is available. Figure 11-16 lists other characteristics that must be evaluated along with equipment cost.

Price estimates included in Figure 11-15 are for equipment of standard construction in more usual arrangement. Estimates for exhausters and dust storage hoppers have been included as indicated in Notes 1 and 2 where they are normally furnished by others. Prices can be multiplied by factors of 1 to 4 where special metals and/or special fabrics are indicated to resist corrosion and/or high temperatures. Installed costs are subject to even wider variations due to assembly work required on location, rigging costs based on actual location selected for equipment, supporting structures and foundations, variation in electrical, plumbing, connecting duct work that may be involved. Installed dust collecting cost estimates can range from 120 to 200% or more of the cost of collector as shipped by the manufacturer.

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FIGURE 11-16 – COMPARISON OF SOME IMPORTANT DUST COLLECTOR CHARACTERISTICS

Type	Higher Efficiency Range on Particles Greater than Mean size in Microns	Pressure Loss Inches	H_2O Gal per 1,000 CFM	Space	Sensitivity to CFM Change		Humid Air Influence	Max. Temp., F. Standard Construction
					Pressure	Efficiency		
Electrostatic	0.25	1/2	-	Large	Negligible	Yes	Improves Efficiency	500
Fabric:								
Conventional	0.25	3-6	-	Large	As cfm	Negligible	May Make Recondi-	180 Note 1
Reverse Jet	0.25	3-8	-	Moderate	As cfm	Negligible	tioning difficult	180
Glass, Reverse flow	0.25	3-8	-	Large	As cfm	Negligible		550
Wet:								
Packed Tower	1-5	1.5-3.5	5-10	Large	As cfm	Yes		
Wet Centrifugal	1-5	2.5-6	3-5	Moderate	As $(cfm)^2$	Yes		
Wet Dynamic	1-2	Note 2	1/2 to 1	Small	Note 2	No	None	Unlimited
Orifice Types	1-5	2 1/2-6	10-40	Small	As cfm or less	Varies with design		
Higher Efficiency:								
Fog Tower	0.5-5	2-4	5-10	Moderate	As $(cfm)^2$	Slightly	None	Note 3
Venturi	0.5-2	10-100	5-15	Moderate	As $(cfm)^2$	Yes		Unlimited
Dry Centrifugal:								
Low Pressure Cyclone	20-40	0.75-1.5	-	Large	As $(cfm)^2$	Yes		750
High Eff. Centrifugal	10-30	3-6	-	Moderate	As $(cfm)^2$	Yes	May cause condensation and plugging	750
Dry Dynamic	10-20	Note 2	-	Small	Note 2	No		750

Note 1: 180 F based on cotton fabric. Synthetic fabrics may be used to 275 F.
Note 2: A function of the mechanical efficiency of these combined exhausters and dust collectors.
Note 3: Precooling of high temperature gases will be necessary to prevent rapid evaporation of fine droplets.

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Operation	Concentration Note 1	Particle Sizes Note 2	COLLECTOR TYPES USED IN INDUSTRY: Cyclone	High Eff. Centrifugal	Wet Collector	Fabric Arrester	Hi-Volt. Electrostatic	See Remark No.
CERAMICS								
a. Raw product handling	light	fine	rare	seldom	frequent	frequent	no	1
b. Fettling	light	fine to medium	rare	occasional	frequent	frequent	no	2
c. Refractory sizing	heavy	coarse	seldom	occasional	frequent	frequent	no	3
d. Glaze & vitr. enamel spray	moderate	medium	no	no	usual	occasional	no	
CHEMICALS								
a. Material handling	light to moderate	fine to medium	occasional	frequent	frequent	frequent	rare	4
b. Crushing, grinding	moderate to heavy	fine to coarse	often	frequent	frequent	frequent	no	5
c. Pneumatic conveying	very heavy	fine to coarse	usual	occasional	rare	usual	no	6
d. Roasters, kilns, coolers	heavy	med-coarse	occasional	usual	usual	rare	often	7
COAL MINING AND POWER PLANT								
a. Material handling	moderate	medium	rare	occasional	frequent	frequent	no	8
b. Bunker ventilation	moderate	fine	occasional	frequent	occasional	frequent	no	9
c. Dedusting, air cleaning	heavy	med-coarse	frequent	frequent	occasional	often	no	10
d. Drying	moderate	fine	rare	occasional	frequent	no	no	11
FLY ASH								
a. Coal burning—chain grate	light	fine	no	rare	no	no	no	12
b. Coal burning—stoker fired	moderate	fine to coarse	rare	usual	no	no	rare	
c. Coal burning—pulverized fuel	heavy	fine	rare	frequent	no	no	frequent	13
d. Wood burning	varies	coarse	occasional	occasional	no	no	no	14
FOUNDRY								
a. Shakeout	light to moderate	fine	rare	rare	usual	occasional	no	15
b. Sand handling	moderate	fine to medium	rare	rare	usual	rare	no	16
c. Tumbling mills	heavy	med-coarse	no	no	frequent	frequent	no	17
d. Abrasive cleaning	moderate to heavy	fine to medium	no	occasional	frequent	frequent	no	18
GRAIN ELEVATOR, FLOUR AND FEED MILLS								
a. Grain handling	light	medium	usual	occasional	rare	frequent	no	19
b. Grain dryers	light	coarse	no	no	no	no	no	20
c. Flour dust	moderate	medium	usual	often	occasional	frequent	no	21
d. Feed mill	moderate	medium	usual	often	occasional	frequent	no	22
METAL MELTING								
a. Steel blast furnace	heavy	varied	frequent	rare	frequent	no	frequent	23
b. Steel open hearth	moderate	fine to coarse	no	no	doubtful	possible	usual	24
c. Steel electric furnace	light	fine	no	no	considerable	frequent	rare	25
d. Ferrous cupola	moderate	varied	occasional	occasional	frequent	frequent	rare	26
e. Non-ferrous reverberatory	varied	fine	no	no	rare	?	?	27
f. Non-ferrous crucible	light	fine	no	no	rare	occasional	?	28
METAL MINING AND ROCK PRODUCTS								
a. Material handling	moderate	fine to medium	rare	occasional	usual	considerable	?	29
b. Dryers, kilns	moderate	med-coarse	frequent	frequent	frequent	rare	occasional	30
c. Cement rock dryer	moderate	fine to medium	rare	frequent	occasional	no	occasional	31
d. Cement kiln	heavy	fine to medium	rare	frequent	rare	considerable	considerable	32
e. Cement grinding	moderate	fine	rare	rare	no	frequent	rare	33
f. Cement clinker cooler	moderate	coarse	occasional	occasional	?	?	?	34
METAL WORKING								
a. Production grinding, scratch brushing, abrasive cut off	light	coarse	frequent	frequent	considerable	considerable	no	35
b. Portable and swing frame	light	medium	rare	frequent	frequent	considerable	no	
c. Buffing	light	varied	frequent	rare	frequent	rare	no	36
d. Tool room	light	fine	frequent	frequent	frequent	frequent	no	37
e. Cast iron machining	moderate	varied	rare	frequent	considerable	considerable	no	38
PHARMACEUTICAL AND FOOD PRODUCTS								
a. Mixers, grinders, weighing, blending, bagging, packaging	light	medium	rare	frequent	frequent	frequent	?	39
b. Coating pans	varied	fine to medium	rare	rare	frequent	frequent	no	40
PLASTICS								
a. Raw material processing	(See comments under Chemicals)							41
b. Plastic finishing	light to moderate	varied	frequent	frequent	frequent	frequent	no	42
RUBBER PRODUCTS								
a. Mixers	moderate	fine	no	no	frequent	usual	no	43
b. Batchout rolls	light	fine	no	no	usual	frequent	no	44
c. Talc dusting and dedusting	moderate	medium	no	no	frequent	usual	no	45
d. Grinding	moderate	coarse	often	often	frequent	often	no	46
WOODWORKING								
a. Woodworking machines	moderate	varied	usual	occasional	rare	frequent	no	47
b. Sanding	moderate	fine	frequent	occasional	occasional	frequent	no	48
c. Waste conveying, hogs	heavy	varied	usual	rare	occasional	occasional	no	49

Note 1: Light: less than 2 gr/ft³; Moderate: 2 to 5 gr/ft³; Heavy: 5 gr/ft³ and up.
Note 2: Fine: 50% less than 5 microns; Medium: 50% 5 to 15 microns; Coarse: 50% 15 microns and larger.

Fig. 11-17

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REMARKS REFERRED TO IN FIG. 11-17

1. Dust released from bin filling, conveying, weighing, mixing, pressing, forming. Refractory products, dry pan and screening operations more severe.
2. Operations found in vitreous enameling, wall and floor tile, pottery.
3. Grinding wheel or abrasive cut-off operation. Dust abrasive.
4. Operations include conveying, elevating, mixing, screening, weighing, packaging. Category covers so many different materials that recommendation will vary widely.
5. Cyclone and high efficiency centrifugals often act as primary collectors followed by fabric or wet type.
6. Cyclones used as product collector followed by fabric arrester for high over-all collection efficiency.
7. Dust concentration determines need for dry centrifugal; plant location, product value determines need for final collectors. High temperatures are usual and corrosive gases not unusual.
8. Conveying, screening, crushing, unloading.
9. Remote from other dust producing points. Separate collector usually.
10. Heavy loading suggests final high efficiency collector for all except very remote locations.
11. Difficult problem but collectors will be used more frequently with air pollution emphasis.
12. Public nuisance from boiler blow-down indicates collectors are needed.
13. Large installations in residential areas require electrostatic in addition to dry centrifugal.
14. Public nuisance from settled wood char indicates collectors are needed.
15. Hot gases and steam usually involved.
16. Steam from hot sand, adhesive clay bond involved.
17. Concentration very heavy at start of cycle.
18. Heaviest load from airless blasting due to higher cleaning speed. Abrasive shattering greater with sand than with grit or shot. Amounts removed greater with sand castings, less with forging scale removal, least when welding scale is removed.
19. Operations such as car unloading, conveying, weighing, storing.
20. Collection equipment expensive but public nuisance complaints becoming more frequent.
21. Operations include conveyors, cleaning rolls, sifters, purifiers, bins and packaging.
22. Operations include conveyors, bins, hammer mills, mixers, feeders, and baggers.
23. Primary dry trap and wet scrubbing usual. Electrostatic is added where maximum cleaning required.
24. Collectors seldom installed in past. Air pollution emphasis indicates collector usage to increase.
25. Air pollution standards will probably require increased usage of fabric arresters.
26. Collectors not usually provided but air pollution emphasis creating greater interest.
27. Zinc oxide loading heavy during zinc additions. Stack temperatures high.
28. Zinc oxide plume can be troublesome in certain plant locations.
29. Crushing, screening, conveying involved. Wet ores often introduce water vapor in exhaust air.
30. Dry centrifugals used as primary collectors, followed by final cleaner.
31. Collection equipment installed primarily to prevent public nuisance.
32. Collectors usually permit salvage of material and also reduce nuisance from settled dust in plant area.
33. Salvage value of collected material high. Same equipment used on raw grinding before calcining.
34. Coarse abrasive particles readily removed in primary collector types.
35. Roof discoloration, deposition on autos can occur with cyclones and less frequently with high efficiency dry centrifugal. Heavy duty air filters sometimes used as final cleaners.
36. Linty particles and sticky buffing compounds can cause pluggage and fire hazard in dry collectors.
37. Unit collectors extensively used, especially for isolated machine tools.
38. Dust ranges from chips to fine floats including graphitic carbon.
39. Materials vary widely. Collector selection depends on salvage value, toxicity, sanitation yardsticks.
40. Controlled temperature and humidity of supply air to coating pans makes recirculation desirable.
41. Plastic manufacture allied to chemical industry and vary with operations involved.
42. Operations and collector selection similar to woodworking. See Item 13.
43. Concentration is heavy during feed operation. Carbon black and other fine additions make collection and dust-free disposal difficult.
44. Often no collector used where dispersion from or location of exhaust stack favorable.
45. Salvage of collected material often dictates type of high efficiency collector.
46. Fire hazard from some operations must be considered.
47. Bulking material. Collected material storage and bridging from splinters and chips can be a problem.
48. Dry centrifugals not too effective on heavy concentration of fine particles from production sanding.
49. Primary collector invariably indicated with concentration and particle size range involved, wet or fabric collectors when used are employed as final collectors.

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FIGURE 11-18--COMPARISON OF SOME IMPORTANT AIR FILTER CHARACTERISTICS

Air filters should be used only for supply air systems or other applications where dust loading does not exceed 4 grains per 1000 cubic feet of air.

TYPE	Pressure Drop in wg		Average Efficiency		Face Velocity fpm	Maintenance	
	Initial	Final	AFI	NBS		Labor	Cost
Glass Throwaway (2" Deep)	0.1	0.5	77%	Note 5	300	Medium	High
High Velocity (Permanent Units) (2" Deep)	0.1	0.5	73%	Note 5	432	High	Low
Low Velocity (Permanent Units) (2" Deep)	0.1	0.5	68%	Note 5	300	High	Low
Automatic (Viscous)	0.37-0.5	Note 2	80%	Note 5	500	Low	Low
Automatic (Semi-Dry)	0.25-0.40	Note 2	85%	Note 5	500	Low	Low
Replaceable Media (Permanent Units)	0.03-0.13	0.5-1.0	86-93%	Note 5	250	Medium	Low
Electrostatic (Replaceable Media)	0.06-0.1	0.5	Note 4	64%	250	Medium	Low
Electrostatic (Manual Cleaning)	0.18-0.29	Note 2	Note 4	85-90%	300-450	High	High
Electrostatic (Automatic Cleaning)	0.092-0.32	Note 2	Note 4	85-90%	400-500	Low	Low
Ultra High Efficiency (Asbestos or glass fibre media)	0.8-1.0	2.0-3.0	Note 3	Note 3	250	Medium	High

Note 1: Values shown constitute a range or average, whichever is applicable.
Note 2: Final pressure drop indicates point at which filter or filter media is removed and the media is either cleaned or replaced. All others are cleaned in place, automatically, manually or media renewed automatically. Therefore, pressure drop remains approximately constant.
Note 3: 99.97% by particle count, DOP.
Note 4: AFI is the Air Filter Institute test based on efficiency by weight. Test is not applicable where results approach 100%, therefore, not appropriate for comparison.
Note 5: NBS is the National Bureau of Standards test by discoloration using atmospheric dust. Test is not applicable where results are unreliable due to comparatively low order of efficiency of the filter.

Air Cleaning Equipment for Radioactive and High Toxicity Operations

There are three major requirements for air cleaning equipment involving radioactive or high toxicity applications. High efficiency is required due to the extremely low tolerances for the amount and concentration of stack effluents; the valuable nature of the materials handled and the accountability in some instances of radioactive materials.

The problem of low maintenance is of special importance when exhausting these hazardous materials. When it is realized that the operation of changing the bags in a conventional fabric arrester may expend the daily radiation tolerances of 20 or more men, the importance of low frequency, speed and ease of maintenance is evident. Also important is the factor of low residual buildup of material in the collector since excessive amounts will increase the amount of radiation and reduce the allowable working time.

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The third major problem is due to the inability to dispose of appreciable amounts of radioactive or toxic materials either by air, water or land; for example, scalping filters loaded with radioactive dust usually have to be incinerated to reduce quantity of material disposal in special burial grounds. The incineration in turn will require a fume scrubber or wet collector. This same factor sometimes complicates the use of wet collectors where they might otherwise be applicable because the contaminated water effluent would require further chemical treatment to avoid stream pollution.

With these factors involved, it is necessary to select a dust collecting device that will meet the requirements efficiency-wise without causing too much difficulty from a standpoint of maintenance and methods of disposal of the collected material.

Air-Cleaning Equipment Used:

Dry centrifugal type collectors are usually eliminated immediately because of lack of collection efficiency.

In fabric arresters, the reverse jet type collector with wool felt media has become almost a standard because:

1. Efficiency has been constantly demonstrated to be superior to the conventional fabric where shaking or rapping the media is required for reconditioning.
2. Higher filter velocities mean less exposure to personnel when bags are removed or servicing required.
3. Residual material on the media is less primarily because of the smaller area of bag surface.

In wet collector designs, the orifice type is usually selected because of fewer internal elements for possible accumulations, maintained efficiency with changes in air volume and recycling of water without the need of auxiliary equipment such as pump or nozzles. Wet collectors will usually be selected because:

1. Temperature and moisture prevent the use of fabric arresters.
2. Water may offer the more convenient method of disposal of collected material either due to plant facilities or prevention of creating a secondary dust hazard if collected material is handled dry.
3. Exhaust air contains corrosive gases or vapors requiring special materials of construction.

In the electrostatic group, the low voltage type is not used too frequently because of comparatively high service factor. The high voltage group will normally only be used when temperature prevents fabric arresters and required collection efficiency eliminates wet collectors.

Filters are frequently used as an integral part of laboratory hoods (VS-203 and 204) or dry boxes (VS-202). They are primarily scalping filters to prevent excessive concentration of contaminated material in the exhaust piping. Depending on the concentration, they will be backed up by an ultra high-efficiency filter or dust collector. Due to limited dust holding capacity, these filters may require frequent replacement, resulting in excessive exposure to radioactive or toxic dusts.

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APPENDIX

THRESHOLD LIMIT VALUES FOR 1970

Threshold limit values refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. Because of wide variation in individual susceptibility, however, a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit, a smaller percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness.

Simple tests are now available (J. Occup. Med. 9, 537, 1967; Ann. N.Y. Acad. Sci. 151 Art. 2, p. 968, 1968) that may be used to detect those individuals hypersusceptible to a variety of industrial chemicals (respiratory irritants, hemolytic chemicals, organic isocyanates, carbon disulfide). These tests may be used to screen out by appropriate job placement the hyperreactive worker and thus in effect improve this "coverage" of the TLV's.

Threshold limit values refer to time-weighted concentrations for a 7 or 8-hour workday and 40-hour workweek. They should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations. (Exceptions are the substances listed in Appendices A and E and those substances designated with a "C" or Ceiling value, Appendix C.

Time-weighted averages permit excursions above the limit provided they are compensated by equivalent excursions below the limit during the workday. In some instances it may be permissible to calculate the average concentration for a workweek rather than for a workday. The degree of permissible excursion is related to the magnitude of the threshold limit value of a particular substance as given in Appendix C. The relationship between threshold limit and permissible excursion is a rule of thumb and in certain cases may not apply. The amount by which threshold limits may be exceeded for short periods without injury to health depends upon a number of factors such as the nature of the contaminant, whether very high concentrations—even for short periods—produce acute poisoning, whether the effects are cumulative, the frequency with which high concentrations occur, and the duration of such periods. All factors must be taken into consideration in arriving at a decision as to whether a hazardous condition exists.

Threshold limits are based on the best available information from industrial experience, from experimental human and animal studies, and, when possible, from a combination of the three. The basis on which the values are established may differ from substance to substance; protection against impairment of health may be a guiding factor for some, whereas reasonable freedom from irritation, narcosis, nuisance or other forms of stress may form the basis for others.

The committee holds to the opinion that limits based on physical irritation should be considered no less binding than those based on physical impairment. There is increasing evidence that physical irritation may initiate, promote or accelerate physical impairment through interaction with other chemical or biologic agents.

In spite of the fact that serious injury is not believed likely as a result of exposure to the threshold limit concentrations, the best practice is to maintain concentrations of all atmospheric contaminants as low as is practical.

These limits are intended for use in the practice of industrial hygiene and should be interpreted and applied only by a person trained in this discipline. They are not intended for use, or for modification for use, (1) as a relative index of hazard or toxicity (2) in the evaluation or control of community air pollution or air pollution nuisances, (3) in estimating the toxic potential of continuous uninterrupted exposures, (4) as proof or disproof of an existing disease or physical conditions, or (5) for adoption by countries whose working conditions differ from those in the United States of America and where substances and processes differ.

Ceiling vs Time-Weighted Average Limits. Although the time-weighted average concentration provides the most satisfactory, practical way of monitoring airborne agents for compliance with the limits, there are certain substances for which it is inappropriate. In the latter group are substances which are predominantly fast acting and whose threshold limit is more appropriately based on this particular response. Substances with this type of response are best controlled by a ceiling "C" limit that should not be exceeded. It is implicit in these definitions that the manner of sampling to determine compliance with the limits for each group must differ; a single brief sample, that is applicable to a "C" limit, is not appropriate to the time-weighted limit: here, a sufficient number of samples are needed to permit a time-weighted average concentration throughout a complete cycle of operations or throughout the work shift.

Whereas the ceiling limit places a definite boundary which concentrations should not be permitted to exceed, the time-weighted average limit requires an explicit limit to the excursions that are permissible above the listed values. The magnitude of these excursions may be pegged to the magnitude of the threshold limit by an appropriate factor shown in Appendix C. It should be noted that the same factors are used by the Committee in making a judgment whether to include or exclude a substance for a "C" listing.

"Skin" Notation. Listed substances followed by the designation "Skin" refer to the potential contribution to the over-all exposure by the cutaneous route including mucous membranes and eye, either by air-borne, or more particularly, by direct contact with the substance. Vehicles can alter skin absorption. This attention-calling designa-

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tion is intended to suggest appropriate measures for the prevention of cutaneous absorption so that the threshold limit is not invalidated.

Mixtures. Special consideration should be given also to the application of the TLV's in assessing the health hazards which may be associated with exposure to mixtures of two or more substances. A brief discussion of basic considerations involved in developing threshold limit values for mixtures, and methods for their development, amplified by specific examples are given in Appendix B.

Nuisance Dusts. In contrast to fibrogenic dusts which cause scar tissue to be formed in lungs when inhaled in excessive amounts, so-called "nuisance" dusts have a long history of little adverse effect on lungs and do not produce significant organic disease or toxic effect when exposures are kept under reasonable control. The nuisance dusts have also been called (biologically) "inert" dusts, but the latter term is inappropriate to the extent that there is no dust which does not evoke some cellular response in the lung when inhaled in sufficient amounts. However, the lung-tissue reaction caused by inhalation of nuisance dusts has the following characteristics: 1) The architecture of the air spaces remains intact. 2) Collagen (scar tissue) is not formed to a significant extent. 3) The tissue reaction is potentially reversible.

Excessive concentrations of nuisance dusts in the workroom air may seriously reduce visibility (iron oxide), may cause unpleasant deposits in the eyes, ears and nasal passages (Portland Cement dust), or cause injury to the skin or mucous membranes by chemical or mechanical action per se or by the rigorous skin cleansing procedures necessary for their removal.

A threshold limit of 10 mg/M^3, or 30 mppcf, of total dust <1% SiO_2, whichever is less, is recommended for substances in these categories and for which no specific threshold limits have been assigned. This limit, for a normal workday, does not apply to brief exposures at higher concentrations. Neither does it apply to those substances which may cause physiologic impairment at lower concentrations but for which a threshold limit has not yet been adopted. Some "inert" particulates are given in Appendix D.

Simple Asphyxiants—"Inert" Gases or Vapors. A number of gases and vapors, when present in high concentrations in air, act primarily as simple asphyxiants without other significant physiologic effects. A TLV may not be recommended for each simple asphyxiant because the limiting factor is the available oxygen. The minimal oxygen content should be 18 percent by volume under normal atmospheric pressure (equivalent to a partial pressure, pO_2 of 135 mm Hg). Atmospheres deficient in O_2 do not provide adequate warning and most simple asphyxiants present an explosion hazard. Account should be taken of this factor in limiting the concentration of the asphyxiant. Specific examples are listed in Appendix E.

Physical Factors. It is recognized that such physical factors as heat, ultraviolet and ionizing radiation, humidity, abnormal pressure (altitude) and the like may place added stress on the body so that the effects from exposure at a threshold limit may be altered. Most of these stresses act adversely to increase the toxic response of a substance. Although most threshold limits have built-in safety factors to guard against adverse effects to moderate deviations from normal environments, the safety factors of most substances are not of such a magnitude as to take care of gross deviations. For example, continuous work at temperatures above 90 F or over-time extending the workweek more than 25% might be considered gross deviations. In such instances judgment must be exercised in the proper adjustments of the threshold limit values.

"Notice of Intent". At the beginning of each year, proposed actions of the Committee for the forthcoming year are issued in the form of a "Notice of Intent." This Notice provides not only an opportunity for comment, but solicits suggestions of substances to be added to the list. The suggestions should be accompanied by substantiating evidence. This list of Intended Changes follows the Adopted Values.

As Legislative Code. The Conference recognizes that the TLV's may be adopted in legislative codes and regulations. If so used, the intent of the concepts contained in the Preface should be maintained and provisions should be made to keep the list current. These values are reviewed annually by the Committee on Threshold Limits for revisions or additions, as further information becomes available.

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Documentation of Threshold Limit Values. A separate companion piece to the TLV's is issued by ACGIH under this title. This publication gives the pertinent scientific information and data with reference to literature sources that were used to base each limit. Each documentation also contains a statement defining the type of response against which the limit is safeguarding the worker. For a better understanding of the TLV's it is essential that the Documentation be consulted when the TLV's are being used.

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APPENDIX A

A[1] Because of the high incidence of cancer, either in man or in animals, no exposure or contact by any route, respiratory, oral or skin should be permitted for the compounds:

2-Acetylaminofluorene	beta-Naphthylamine
4-Aminodiphenyl	4-Nitrodiphenyl
Benzidine & its salts	N-Nitrosodimethylamine
Dichlorobenzidine	beta-Propiolactone
4-Dimethylaminoazobenzene	

Because of the extremely high incidence of bladder tumors in workers handling beta-naphthylamine and the potential carcinogenic activity of the other compounds, the State of Pennsylvania prohibits the manufacture, use and other activities that involve human exposure without express approval by the Department of Health.

A[2] Polytetrafluoroethylene* decomposition products. Thermal decomposition of the fluorocarbon chain in air leads to the formation of oxidized products containing carbon, fluorine and oxygen. Because these products decompose in part by hydrolysis in alkaline solution, they can be quantitatively determined in air as fluoride to provide an index of exposure. No TLV is recommended pending determination of the toxicity of the products, but air concentrations should be minimal.

A[3] Gasoline and/or Petroleum Distillates. The composition of these materials varies greatly and thus a single TLV for all types of these materials is no longer applicable. In general, the aromatic hydrocarbon content will determine what TLV applies. Consequently the content of benzene, other aromatics and additives should be determined to arrive at the appropriate TLV (Elkins, et al. A.I.H.A.J. 24, 99, 1963).

* Trade Names: Algoflon, Fluon, Halon, Teflon, Tetran.

APPENDIX B

Threshold Limit Values for Mixtures

When two or more hazardous substances are present, their combined effect, rather than that of either individually, should be given primary consideration. In the absence of information to the contrary, the effects of the different hazards should be considered as additive.

A complete discussion of the effects of mixtures is a part of the TLV booklet published by and available from the Secretary-Treasurer, ACGIH.

APPENDIX C

Permissible Excursions for Time-Weighted Average (TWA) Limits

The Excursion TLV Factor in the Table automatically defines the magnitude of the permissible excursion above the limit for those substances not given a "C" designation; i.e., the TWA limits. Examples in the Table show that nitrobenzene, the TLV for which is 1 ppm, should never be allowed to exceed 3 ppm. Similarly, carbon tetrachloride, TLV 10 ppm, should never be allowed to exceed 20 ppm. By contrast, those substances with a "C" designation are not subject to the excursion factor and must be kept below the TLV.

These limiting excursions are to be considered to provide a 'rule-of-thumb' guidance for listed substances generally, and may not provide the most appropriate excursion for a particular substance. Efforts are being made to develop such specific excursions, when indicated to be significantly different from that recommended by the present excursion factors.

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APPENDIX

Bases for Assigning Limiting "C" Values

By definition in the Preface, a listed value bearing a "C" designation refers to a 'ceiling' value that should not be exceeded; all values should fluctuate below the listed value. This, in effect, makes the "C" designation a maximal allowable concentration (MAC). In general, the bases for assigning or not assigning a "C" value rest on whether excursions of concentration above a proposed limit for periods up to 15 minutes may result in a) intolerable irritation, b) chronic, or irreversible tissue change, or c) narcosis of sufficient degree to increase accident proneness, impair self-rescue or materially reduce work efficiency.

Substance	TLV	Excursion Factor	Max. Conc. Permitted for short time
Nitrobenzene	1 ppm	3	3 ppm
Carbon tetrachloride	10 ppm	2	20 ppm
Carbon monoxide	50 ppm	1.5	75 ppm
Acetone	1000 ppm	1.25	1250 ppm
Boron trifluoride	C 1 ppm	—	1 ppm
Butylamine	C 5 ppm	—	5 ppm
Styrene monomer	C 100 ppm	—	100 ppm

For all substances:

TLV = 0-1 (ppm or mg/M^3), Excursion Factor = 3
TLV = 1-10 (ppm or mg/M^3), Excursion Factor = 2
TLV = 10-100 (ppm or mg/M^3), Excursion Factor = 1.5
TLV = 100-1000 (ppm or mg/M^3), Excursion Factor = 1.25

APPENDIX D

Some "Inert" or Nuisance Particulates*

Alundum (Al_2O_3)
Calcium carbonate
Cellulose (Paper Fiber)
Portland Cement
Corundum (Al_2O_3)
Emery
Glass, fibrous** or dust
Glycerine Mist
Graphite (synthetic)
Gypsum
Vegetable oil mists
(except castor, cashew nut, or similar irritant oils)
Kaolin
Limestone
Magnesite
Marble
Pentaerythritol
Plaster of Paris
Rouge
Silicon Carbide
Starch
Sucrose
Tin Oxide
Titanium Dioxide

* When toxic impurities are not present, e.g. quartz < 1%. See page 13-2.
** < 5-7μ in diameter.

APPENDIX E

Some Simple Asphyxiants—"Inert" Gases and Vapors***

Acetylene
Argon
†Butane
Ethane
Ethylene
Helium
Hydrogen
Methane
Neon
Nitrogen
Nitrous Oxide
Propane

*** As defined on page 13-2.
† See Notice of Intended Changes.

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MT-PWHD-004789

Threshold Limit Values for Toxic Dusts, Fumes and Mists

Substance	ppm*	Mg/M³**
Abate	—	10
† Acetaldehyde	200	360
Acetic acid	10	25
† Acetic anhydride	5	20
Acetone	1000	2400
Acetonitrile	40	70
+ 2-Acetylaminofluorene—Skin	—	A1
Acetylene	E	—
Acetylene dichloride, see 1,2 Dichloroethylene		
Acetylene tetrabromide	1	14
Acrolein	0.1	0.25
Acrylamide—Skin	—	0.3
Acrylonitrile—Skin	20	45
Aldrin—Skin	—	0.25
Allyl alcohol—Skin	2	5
Allyl chloride	1	3
†C Allyl glycidyl ether (AGE)	10	45
Allyl propyl disulfide	2	12
Alundum (Al_2O_3)	—	D
+ 4-Aminodiphenyl—Skin	—	A1
2-Aminoethanol, see Ethanolamine		
2-Aminopyridine	0.5	2
† Ammonia	50	35
Ammonium sulfamate (Ammate)	—	10
n-Amyl acetate	100	525
sec-Amyl acetate	125	650
Aniline—Skin	5	19
Anisidine (o, p-isomers)—Skin	—	0.5
Antimony & compounds (as Sb)	—	0.5
ANTU (alpha naphthyl thiourea)	—	0.3
Argon	E	—
Arsenic & compounds (as As)	—	0.5
Arsine	0.05	0.2
+ Asphalt (petroleum) fumes	—	5
Azinphos-methyl—Skin	—	0.2
Barium (soluble compounds)	—	0.5
C Benzene (benzol)—Skin	25	80
Benzidine—Skin	—	A1
p-Benzoquinone, see Quinone		
Benzoyl peroxide	—	5
Benzyl chloride	1	5
Beryllium	—	0.002
Biphenyl, see Diphenyl		
Boron oxide	—	10
Boron tribromide	1	10
C Boron trifluoride	1	3
Bromine	0.1	0.7
Bromine pentafluoride	0.1	0.7
Bromoform—Skin	0.5	5
Butadiene (1,3-butadiene)	1000	2200
Butanethiol, see Butyl mercaptan		
2-Butanone	200	590
2-Butoxy ethanol (Butyl Cellosolve)—Skin	50	240
Butyl acetate (n-butyl acetate)	150	710
sec-Butyl acetate	200	950
tert-Butyl acetate	200	950
Butyl alcohol	100	300
sec-Butyl alcohol	150	450
tert. Butyl Alcohol	100	300
C Butylamine—Skin	5	15
C tert. Butyl Chromate (as CrO_3)—Skin	—	0.1
n-Butyl glycidyl ether (BGE)	50	270
Butyl mercaptan	0.5	1.5
p-tert. Butyltoluene	10	60
Cadmium (Metal dust and soluble salts)	—	0.2
C Cadmium oxide fume (as Cd)	—	0.1
Calcium arsenate	—	1
Calcium carbonate	—	D
Calcium oxide	—	5
† Camphor (Synthetic)	2	—
Carbaryl (Sevin) (R)	—	5
Carbon black	—	3.5
Carbon dioxide	5000	9000
Carbon disulfide—Skin	20	60
Carbon monoxide	50	55
Carbon tetrachloride—Skin	10	65
Cellulose (paper fiber)	—	D
Chlordane—Skin	—	0.5
Chlorinated camphene—Skin	—	0.5
Chlorinated diphenyl oxide	—	0.5
Chlorine	1	3
Chlorine dioxide	0.1	0.3
C Chlorine trifluoride	0.1	0.4
C Chloroacetaldehyde	1	3
α-Chloroacetophenone (phenacylchloride)	0.05	0.3
Chlorobenzene (monochlorobenzene)	75	350
o-Chlorobenzylidene malononitrile (OCBM)	0.05	0.4
Chlorobromomethane	200	1050
2-Chloro-1,3 butadiene, see Chloroprene		
Chlorodiphenyl (42% Chlorine)—Skin	—	1
Chlorodiphenyl (54% Chlorine)—Skin	—	0.5

* Parts of vapor or gas per million parts of air by volume at 25 C and 760 mm. Hg pressure.
** Approximate milligrams per cubic meter of air.
+1971 Addition or Revision.
† See Notice of Intended Changes.
Capitals A, C, D, E refer to Appendices.

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Substance	ppm*	Mg/M³**
1,Chloro,2,3 epoxypropane, see Epichlorhydrin		
2,Chloroethanol, see Ethylene chlorohydrin		
Chloroethylene, see Vinyl chloride		
†C Chloroform (trichloro-methane)	50	240
1-Chloro-1-nitropropane	20	100
Chloropicrin	0.1	0.7
Chloroprene (2-chloro-1,3-butadiene)—Skin	25	90
Chromic acid and chromates (as CrO_3)	—	0.1
Chromium, sol. chromic, chromous salts as Cr	—	0.5
metal and insol. salts	—	1
Coal tar pitch volatiles (benzene soluble fraction) (anthracene, BaP, phen-anthrene, acridine, chrysene, pyrene)	—	0.2
Cobalt, metal fume & dust	—	0.1
Copper Fume	—	0.1
Dusts & Mists	—	1
Corundum (Al_2O_3)	—	D
Cotton dust (raw)	—	1
Crag (R) herbicide	—	10
Cresol (all isomers)—Skin	5	22
Crotonaldehyde	2	6
Cumene—Skin	50	245
Cyanide (as CN)—Skin	—	5
Cyanogen	10	—
Cyclohexane	300	1050
Cyclohexanol	50	200
Cyclohexanone	50	200
Cyclohexene	300	1015
Cyclopentadiene	75	200
2,4-D	—	10
DDT—Skin	—	1
DDVP—Skin, see Dichlorvos		
Decaborane—Skin	0.05	0.3
Demeton (R)—Skin	—	0.1
Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone)	50	240
† 1,2 Diaminoethane, see Ethylenediamine		
Diazomethane	0.2	0.4
Diborane	0.1	0.1
C 1,2-Dibromoethane (Ethylene dibromide)—Skin	25	190
Dibrom (R)	—	3
Dibutyl phosphate	1	5
Dibutylphthalate	—	5
C Dichloroacetylene	0.1	0.4
C o-Dichlorobenzene	50	300
p-Dichlorobenzene	75	450
+ Dichlorobenzidine—Skin	—	A1
Dichlorodifluoromethane	1000	4950
1,3-Dichloro-5,5-dimethyl hydantoin	—	0.2
† 1,1-Dichloroethane	100	400
1,2-Dichloroethane	50	200
1,2-Dichloroethylene	200	790
†C Dichloroethyl ether—Skin	15	90
Dichloromethane, see Methylene chloride		
Dichloromonofluoro-methane	1000	4200
C 1,1-Dichloro-1-nitroethane	10	60
1,2-Dichloropropane, see Propylenedichloride		
Dichlorotetrafluoroethane	1000	7000
Dichlorvos (DDVP)—Skin	—	1
Dieldrin—Skin	—	0.25
Diethylamine	25	75
Diethylamino ethanol—Skin	10	50
†C Diethylene triamine—Skin	10	—
Diethylether, see Ethyl ether		
Difluorodibromomethane	100	860
C Diglycidyl ether (DGE)	0.5	2.8
Dihydroxybenzene, see Hydroquinone		
† Diisobutyl ketone	50	290
Diisopropylamine—Skin	5	20
Dimethylamine	10	18
+ 4-Dimethylaminoazobenzene	—	A1
Dimethylaminobenzene, see Methylal		
Dimethyl acetamide—Skin	10	35
Dimethylamine	10	18
Dimethylaminobenzene, see Xylidene		
Dimethylaniline (N-dimethyl-aniline)—Skin	5	25
Dimethylbenzene, see Xylene		
Dimethyl 1,2-dibromo-2,2-dichloroethyl phosphate, (Dibrom)	—	3
Dimethylformamide—Skin	10	30
2,6 Dimethylheptanone, see Diisobutyl ketone		
1,1-Dimethylhydrazine—Skin	0.5	1
Dimethylphthalate	—	5
Dimethylsulfate—Skin	1	5
Dinitrobenzene (all isomers)—Skin	—	1
Dinitro-o-cresol—Skin	—	0.2
Dinitrotoluene—Skin	—	1.5
Dioxane (diethylene dioxide)	100	360
Diphenyl	0.2	1
Diphenyl Amine	—	10
Diphenylmethane diisocyanate (See Methylene bisphenyl isocyanate (MDI))		
Dipropylene glycol methyl ether—Skin	100	600
Di-sec, octyl phthalate (Di-2-ethylhexyl-phthalate	—	5
Emery	—	D
Endosulfan (Thiodan) (R)—Skin	—	0.1
Endrin—Skin	—	0.1
Epichlorhyrin—Skin	5	19

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Substance	ppm*	Mg/M³**
EPN—Skin	—	0.5
1,2-Epoxypropane, see Propyleneoxide		
2,3-Epoxy-1-propanol, see Glycidol		
Ethane	E	—
Ethanethiol, see Ethyl mercaptan		
Ethanolamine	3	6
† 2-Ethoxyethanol—Skin	200	740
2-Ethoxyethylacetate (Cellosolve Acetate)—Skin	100	540
Ethyl acetate	400	1400
Ethyl acrylate—Skin	25	100
Ethyl alcohol (ethanol)	1000	1900
Ethylamine	10	18
Ethyl sec-amyl ketone (5-methyl-3-heptanone)	25	130
Ethyl benzene	100	435
Ethyl bromide	200	890
Ethyl butyl ketone (3-Heptanone)	50	230
Ethyl chloride	1000	2600
Ethyl ether	400	1200
Ethyl formate	100	300
Ethyl mercaptan	0.5	1
Ethyl silicate	100	850
Ethylene	E	—
Ethylene chlorohydrin—Skin	5	16
Ethylenediamine	10	25
Ethylene dibromide, see 1,2-Dibromoethane		
Ethylene dichloride, see 1,2-Dichloroethane		
C Ethylene glycol dinitrate and/or Nitroglycerin—Skin	0.2[d]	—
Ethylene glycol monomethyl ether acetate, (Methyl cellosolve acetate)—Skin	25	120
Ethylene imine—Skin	0.5	1
Ethylene oxide	50	90
Ethylidine chloride, see 1,1-Dichloroethane		
N-Ethylmorpholine—Skin	20	94
Ferbam	—	10
Ferrovanadium dust	—	1
Fluoride (as F)	—	2.5
† Fluorine	0.1	0.2
Fluorotrichloromethane	1000	5600
†C Formaldehyde	5	6
Formic acid	5	9
Furfural—Skin	5	20
† Furfuryl alcohol	50	200
Gasoline	—	A3
Glass, figrous(g) or dust	—	D
Glycerine mist	—	D
Glycidol (2,3-Epoxy-1-propanol)	50	150
Glycol monoethyl ether, see 2-Ethoxyethanol		
Graphite, synthetic	—	D
Guthion (R), see Azinphosmethyl		
Gypsum	—	D
Hafnium	—	0.5
Helium	E	—
Heptachlor—Skin	—	0.5
Heptane (n-heptane)	500	2000
Hexachloroethane—Skin	1	10
Hexachloronaphthalene—Skin	—	0.2
Hexane (n-hexane)	500	1800
2-Hexanone	100	410
Hexone (Methyl isobutyl ketone)	100	410
sec-Hexyl acetate	50	300
Hydrazine—Skin	1	1.3
Hydrogen	E	—
Hydrogen bromide	3	10
C Hydrogen chloride	5	7
Hydrogen cyanide—Skin	10	11
Hydrogen fluoride	3	2
Hydrogen peroxide	1	1.4
Hydrogen selenide	0.05	0.2
Hydrogen sulfide	10	15
Hydroquinone	—	2
Indene	10	45
Indium and compounds, as In	—	0.1
C Iodine	0.1	1
Iron oxide fume	—	10
Iron salts, soluble, as Fe	—	1
Isoamyl acetate	100	525
Isoamyl alcohol	100	360
Isobutyl acetate	150	700
Isobutyl alcohol	100	300
† Isophorone	25	140
Isopropyl acetate	250	950
Isopropyl alcohol	400	980
Isopropylamine	5	12
† Isopropylether	500	2100
Isopropyl glycidyl ether (IGE)	50	240
Kaolin	—	D
Ketene	0.5	0.9
† Lead	—	0.2
Lead arsenate	—	0.15
Limestone	—	D
Lindane—Skin	—	0.5
Lithium hydride	—	0.025
L.P.G. (Liquified petroleum gas)	1000	1800
Magnesite	—	D
Magnesium oxide fume	—	10
Malathion—Skin	—	10
Maleic anhydride	0.25	1
C Manganese and cmpds, as Mn	—	5
Marble	—	D
+ Mercury (Alkyl compounds)—Skin	—	0.01

(g): < 5-7μ Diameter. No TLV for coarse fibrous glass has yet been set.

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MT-PWHD-004792

Substance	ppm*	Mg/M3**
+ Mercury (All forms except alkyl)	—	0.05
Mesityl oxide	25	100
Methane	E	—
Methanethiol, see Methyl mercaptan		
Methoxychlor	—	10
2-Methoxyethanol, (Methyl cellosolve)—Skin	25	80
Methyl acetate	200	610
Methyl acetylene (propyne)	1000	1650
Methyl acetylene-propadiene mixture (MAPP)	1000	1800
Methyl acrylate—Skin	10	35
Methylal (dimethoxy-methane)	1000	3100
Methyl alcohol (methanol)	200	260
Methylamine	10	12
Methyl amyl alcohol, see Methyl isobutyl carbinol		
Methyl isoamyl ketone	100	475
Methyl (n-amyl) ketone (2-Heptanone)	100	465
†C Methyl bromide—Skin	20	80
Methyl butyl ketone, see 2-Hexanone		
Methyl cellosolve—Skin	25	80
Methyl cellosolve acetate—Skin	25	120
†C Methyl chloride	100	210
Methyl chloroform	350	1900
Methylcyclohexane	500	2000
† Methylcyclohexanol	100	470
† o-Methylcyclohexanone—Skin	100	460
+ Methylcyclopentadienyl manganese tricarbonyl (as Mn)—Skin	0.1	0.2
+ Methyl demeton—Skin	—	0.5
Methyl ethyl ketone (MEK), see 2-Butanone		
Methyl formate	100	250
Methyl iodide—Skin	5	28
Methyl isobutyl carbinol—Skin	25	100
Methyl isobutyl ketone, see Hexone		
Methyl isocyanate—Skin	0.02	0.05
Methyl mercaptan	0.5	1
Methyl methacrylate	100	410
Methyl propyl ketone, see 2-Pentanone		
C Methyl silicate	5	30
C α Methyl styrene	100	480
C Methylene bisphenyl isocyanate (MDI)	0.02	0.2
Methylene chloride (di-chloromethane)	500	1740
Molybdenum (soluble compounds)	—	5
(insoluble compounds)	—	10
Monomethyl aniline—Skin	2	9
C Monomethyl hydrazine—Skin	0.2	0.35
Morpholine—Skin	20	70
Naphtha (coal tar)	100	400
Napthalene	10	50
β-Naphthylamine	—	A1
Neon	E	—
Nickel carbonyl	0.001	0.007
Nickel, metal and soluble compounds, as Ni	—	1
Nicotine—Skin	—	0.5
Nitric acid	2	5
Nitric oxide	25	30
p-Nitroaniline—Skin	1	6
Nitrobenzene—Skin	1	5
p-Nitrochloro-benzene—Skin	—	1
Nitroethane	100	310
Nitrogen	E	—
C Nitrogen dioxide	5	9
Nitrogen trifluoride	10	29
C Nitroglycerin—Skin	0.2	2
Nitromethane	100	250
1-Nitropropane	25	90
2-Nitropropane	25	90
N-Nitrosodimethylamine (Dimethylnitrosoamine)—Skin	—	A1
Nitrotoluene—Skin	5	30
Nitrotrichloromethane, see Chloropicrin		
Nitrous Oxide	E	—
Octachloronaphthalene—Skin	—	0.1
Octane	400	1900
Oil mist, particulate	—	5[h]
Oil mist, vapor	A3[(i)]	—
Osmium tetroxide	—	0.002
Oxalic acid	—	1
Oxygen difluoride	0.05	0.1
Ozone	0.1	0.2
Paraquat—Skin	—	0.5
Parathion—Skin	—	0.1
Pentaborane	0.005	0.01
Pentachloronaphthalene—Skin	—	0.5
Pentachlorophenol—Skin	—	0.5
Pentaerithritol	—	D
Pentane	500	1500
2-Pentanone	200	700
Perchloroethylene	100	670
Perchloromethyl mercaptan	0.1	0.8
Perchloryl fluoride	3	14
Petroleum Distillates (naphtha)	A3[i]	—
Phenol—Skin	5	19
p-Phenylene diamine—Skin	—	0.1
Phenyl ether (vapor)	1	7
Phenyl ether-Diphenyl mixture (vapor)	1	7
Phenylethylene, see Styrene		

h: as sampled by method that does not collect vapor.
i: according to analytically determined composition.

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Substance	ppm*	Mg/M3**
Phenyl glycidyl ether (PGE)	10	60
Phenylhydrazine—Skin	5	22
+ Phenothiazine—Skin	—	5
Phosdrin (Mevinphos) (R)—Skin	—	0.1
Phosgene (carbonyl chloride)	0.1	0.4
Phosphine	0.3	0.4
Phosphoric acid	—	1
Phosphorus (yellow)	—	0.1
Phosphorus pentachloride	—	1
Phosphorus pentasulfide	—	1
Phosphorus trichloride	0.5	3
Phthalic anhydride	2	12
Picric acid—Skin	—	0.1
Pival (R) (2-Pivalyl-1,3-indandione)	—	0.1
Plaster of Paris	—	D
Platinum (Soluble Salts), as Pt	—	0.002
Polytetrafluoroethylene decomposition products	—	A2
Propane	E	—
β Propiolactone	—	A1
Propargyl alcohol—Skin	1	—
n-Propyl acetate	200	840
Propyl alcohol	200	500
n-Propyl nitrate	25	110
Propylene dichloride	75	350
Propylene imine—Skin	2	5
Propylene oxide	100	240
Propyne, see Methylacetylene		
Pyrethrum	—	5
Pyridine	5	15
Quinone	0.1	0.4
RDX—Skin	—	1.5
Rhodium, Metal fume and dusts, as Rh	—	0.1
Soluble salts	—	0.001
Ronnel	—	10
Rotenone (commercial)	—	5
Rouge	—	D
Selenium compounds (as Se)	—	0.2
Selenium hexafluoride	0.05	0.4
Silicon carbide	—	D
Silver, metal and soluble compounds	—	0.01
Sodium fluoroacetate (1080)—Skin	—	0.05
Sodium hydroxide	—	2
Starch	—	D
Stibine	0.1	0.5
Stoddard solvent	200	1150
Strychnine	—	0.15
+C Styrene (phenylethylene)	100	420
Sucrose	—	D
Sulfur dioxide	5	13
Sulfur hexafluoride	1000	6000
Sulfur monochloride	1	6
Sulfur pentafluoride	0.025	0.25
Sulfuric acid	—	1
Sulfuryl fluoride	5	20
Systox, see Demeton (R)		
2,4,5T	—	10
Tantalum	—	5
TEDP—Skin	—	0.2
Teflon (R) decomposition products	—	A2
Tellurium	—	0.1
Tellurium hexafluoride	0.02	0.2
TEPP—Skin	—	0.05
C Terphenyls	1	9
1,1,1,2-Tetrachloro-2,2-difluoroethane	500	4170
1,1,2,2-Tetrachloro-1,2-difluoroethane	500	4170
1,1,2,2-Tetrachloroethane—Skin	5	35
Tetrachloroethylene, see Perchloroethylene		
Tetrachloromethane, see Carbon tetrachloride		
Tetrachloronaphthalene—Skin	—	2
Tetraethyl lead (as Pb)—Skin	—	0.100[j]
Tetrahydrofuran	200	590
Tetramethyl lead (TML) (as lead)—Skin	—	0.150[j]
Tetramethyl succinonitrile—Skin	0.5	3
Tetranitromethane	1	8
Tetryl (2,4,6-trinitrophenylmethylnitramine)—Skin	—	1.5
Thallium (soluble compounds as Tl)—Skin	—	0.1
Thiram	—	5
Tin (inorganic compounds, except SnH_4 and SnO_2), as Sn	—	2
Tin (organic compounds)—Skin	—	0.1
Tin oxide	—	D
Titanium dioxide	—	D
† Toluene (toluol)	200	750
C Tolulene-2,4-diisocyanate	0.02	0.14
o-Toluidine—Skin	5	22
Toxaphene, see Chlorinated camphene		
+ Tributyl phosphate	—	5
1,1,1-Trichloroethane, see Methyl chloroform		
1,1,2-Trichloroethane—Skin	10	45
Trichloroethylene	100	535
Trichloromethane, see Chloroform		
Trichloronaphthalene—Skin	—	5
1,2,3-Trichloropropane	50	300
1,1,2-Trichloro 1,2,2-trifluoroethane	1000	7600
Triethylamine	25	100

j: For control of general room air. Biologic monitoring is essential for personnel control.

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MT-PWHD-004794

Substance	ppm*	Mg/M³**
Trifluoromonobromomethane	1000	6100
Trimethyl benzene	25	120
2,4,6-Trinitrophenol, see Picric acid		
2,4,6-Trinitrophenylmethylnitramine, see Tetryl		
Trinitrotoluene—Skin	—	1.5
Triorthocresyl phosphate	—	0.1
Triphenyl phosphate	—	3
Tungsten & Compounds, as W		
Soluble	—	1
Insoluble	—	5
Turpentine	100	560
Uranium (natural) sol. & insol. compounds, as U	—	0.2
C Vanadium (V_2O_5 dust)	—	0.5
† (V_2O_5 fume)	—	0.1
+ Vinyl acetate	10	30
Vinyl benzene, see Styrene		
†C Vinyl chloride	500	1300
Vinylcyanide, see Acrylonitrile		
Vinyl toluene	100	480
Warfarin	—	0.1
Xylene (xylol)	100	435
Xylidine—Skin	5	25
Yttrium	—	1
Zinc chloride fume	—	1
Zinc oxide fume	—	5
Zirconium compounds (as Zr)	—	5

Radioactivity: For permissible concentrations of radio-isotopes in air, see U.S. Department of Commerce, National Bureau of Standards, Handbook 69, "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," June 5, 1959. Also, see U.S. Department of Commerce, National Bureau of Standards, Handbook 50, "Permissible Dose from External Sources of Ionizing Radiation," September 24, 1954, and addendum of April 15, 1958. A report, Basic Radiation Protection Criteria, published by the National Committee on Radiation Protection, revises and modernizes the concept of the NCRP Standards of 1954, 1957 and 1958; obtainable as NCRP Report No. 39, PO Box 4867, Washington, D.C. 20008.

Threshold Limit Values for Mineral Dusts

Substance	m.p.p.c.f.*
SILICA	
Crystalline	
† Quartz	$TLV = \frac{250^{**}}{\%SiO_2 + 5}$
† Cristobalite	$TLV = \frac{250^{**}}{\%SiO_2 + 5}$
Amorphous, including natural diatomaceous earth	20
SILICATES (less than 1% crystalline silica)	
† Asbestos, all types	—
Mica	20
+ Perlite	30
Portland Cement	50
Soapstone	20
Talc (non-asbestiform)	20
Talc, (fibrous), use Asbestos limit	
Tremolite, see Talc, fibrous	
Graphite (natural)	15
† Inert or nuisance particulates (when toxic impurities are not present, eg., quartz < 1%)	50 (or 15 mg/m³ whichever is the smaller)

Conversion factors
mppcf × 35.3 = million particles per cubic meter
= particles per c.c.

+1971 Addition or Revision.

* Millions of particles per cubic foot of air, based on impinger samples counted by light-field technics.
** The percentage of crystalline silica in the formula is the amount determined from air-borne samples, except in those instances in which other methods have been shown to be applicable.

PRODUCED 1257 JM - 83

MT-PWHD-004795

NOTICE OF INTENDED CHANGES

These substances, with their corresponding values, comprise those for which either a limit has been proposed for the first time, or for which a change in the "Adopted" listing has been proposed. In both cases, the proposed limits should be considered trial limits that will remain in the listing for a period of at least two years. During this time, the previously Adopted Limit will remain in effect. If, after two years no evidence comes to light that questions the appropriateness of the values herein, the values will be placed in the "Adopted" list. Documentation is available for each of these substances.

Substance	ppm*	mg/M3**
+ Acetaldehyde	100	180
+C Acetic anhydride	5	20
Allyl glycidyl ether	5	22
Ammonia	25	18
Ammonium chloride fume	—	10
+ Bismuth telluride	—	10
+ Bismuth telluride (Se-doped)	—	5
+ Butane	500	1200
Butyl lactate	1	5
Camphor (synthetic)	2	12
+ Caprolactam (2-Oxohexamethyl-enimine)	—	5
+ Chloroform (trichloromethane)	25	120
Diazinon—Skin	—	0.1
+ 1,2-Dibromoethane (ethylene dibromide)—Skin	20	145
2-N Dibutylaminoethanol—Skin	2	14
+ 1,1-Dichloroethane	200	820
+ Dichloroetheyl ether—Skin	5	30
Diethylene triamine—Skin	1	4
+ Diisobutyl ketone	25	150
+ Diquat	—	0.5
+ Ethylene glycol, particulate	—	10
+ Ethylene glycol, vapor	100	260
+ 2-Ethoxyethanol—Skin	100	370
+ Fluorine	1	2
C Formaldehyde	2	3
+ Furfuryl alcohol	5	20
+ Hexachlorocyclopentadiene	0.1	1
+ Hexafluoroacetone	0.1	0.7
Iron pentacarbonyl	0.01	0.08
+ Isophorone	10	55
+ Isopropyl ether	250	1050
+ Lead, inorganic compounds, fumes & dusts	—	0.15
+ Methylacrylonitrile—Skin	1	3
+ Methyl bromide—Skin	15	60
Methyl chloride	100	210
+ Methyl cyclohexanol	50	235
+ o-Methyl cyclohexanone—Skin	50	230
Methylcyclopentadienyl manganese tricarbonyl (as Mn)—Skin	0.1	0.2
+ Mineral wool fiber	—	D
+ Paraffin wax fume	—	1
+ Perlite	—	30mppcf
+C Phenylphosphine	0.05	0.25
Propylene glycol monomethyl ether	100	360
Rosin Core Solder, pyrolysis products (as formaldehyde)	—	0.1
+ Silicon	—	10
C Subtilisins (Proteolytic enzymes) (as 100% pure crystalline enzyme)	—	0.0003
+ Sulfur tetrafluoride	0.1	0.4
+ Toluene	100	375
Vanadium (V_2O_5 Fume) as V	—	0.05
Vinyl bromide	250	1100
Vinyl chloride	200	770
Wood dust (nonallergenic)	—	5

* Parts of vapor or gas per million parts of contaminated air by volume at 25 C and 760 mm. Hg pressure.
** Approximate milligrams of particulate per cubic meter of air.

MINERAL DUSTS

Substance	TLV
+ Asbestos (all types)	5 fibers/ml > 5μ in length(k)
+ Coal dust (bituminous)	2 mg/M3 (respirable dust)(m)
Cristobalite	Use one-half the value calculated from the count or mass formulae for quartz
+ "Inert" or nuisance particulates	10 mg/M3 or 30 mppcf (whichever is the smaller) of total dust < 1% SiO_2
+ Quartz	TLV in mppcf = $\frac{300(n)}{\%SiO_2 + 10}$ TLV for respirable dust in mg/M3(p) = $\frac{10\ mg/M^3}{\%\ Respirable\ Quartz + 2}$ TLV for 'total dust', respirable and non-respirable = $\frac{30\ mg/M}{\%\ Quartz + 3}$
Silica, fused	Use quartz formulae
Tridymite	Use one-half the value calculated from the count or mass formulae for quartz

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Substance

+ 1971 Revision or Addition.

(k) As determined by the membrane filter method at 400-450X magnification (4 mm objective) phase contrast illumination. Concentrations 5 fibers/ml but not to exceed 10, may be permitted for 15-minute periods each hour up to five times daily.

(m) Respirable dust as defined by the British Medical Research Council Criteria[1] and as sampled by a device producing equivalent results.[2]

(1) Hatch, T. E. and Gross, P., Pulmonary Deposition and Retention of Inhaled Aerosols, p. 149. Academic Press, New York, N.Y. 1964.

(2) Interim Guide for Respirable Mass Sampling, AIHA Aerosol Technology Committee, AIHA J. 31, 2, 1970 p. 133.

(n) The percentage of crystalline silica in the formula is the amount determined from airborne samples, except in those instances in which other methods have been shown to be applicable.

(p) Both concentration and percent quartz for the application of this limit are to be determined from the Fraction passing a size-selector with the following characteristics:

Aerodynamic Diameter (μ) (unit density sphere)	% passing selector
≤ 2	90
2.5	75
3.5	50
5.0	25
10.0	0

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APPENDIX

COMPARISON OF COMFORT LIMITS AND THRESHOLD LIMIT VALUES
(Expressed in Parts per Million)

SOLVENT	IRRITATING CONCENTRATION (8 hr. Exposure)	IRRITATING CONCENTRATION			TLV
		Eyes	Nose	Throat	
HYDROCARBONS					
n-Hexane	500				500
Stoddard's Solvent	400	400	400	400	200
Turpentine	100	175	175	175	100
Toluene (Toluol)	200	300	...	300	200*
Xylene (Xylol)	100	200	200	200	100
ALCOHOLS					
Isopropyl	200	800	800	800	400
Butyl	25	50	25	25	100
Isoamyl	100	150	150	100	100
Cyclohexanol	100	100	100	100	50
Methyl Isobutyl Carbinol	25	50	50	50	25
Di-isobutyl Carbinol	5	5	10	10	
Methyl Vinyl Carbinol	25	50	50	50	
Hexylene Glycol	50	50	50	50	
KETONES					
Acetone	200	500	500	500	1000
2-Butanone (MEK)	200	350	350	350	200
Cyclohexanone	25	75	75	75	50
Methyl Isobutyl Ketone (Hexone)	100	200	200	200	100
Di-acetone Alcohol	50	100	100	100	50
Di-isobutyl Ketone	25	50	50	50	50*
Isophorone	10	25	25	25	25*
Mesityl Oxide	25	25	50	50	25
ESTERS					
Ethyl Acetate	100	400	400	400	400
n-Butyl Acetate	100	300	300	200	150
n-Amyl Acetate	100	300	300	200	100
Methyl Amyl Acetate	100	100	100	100	
Isopropyl Acetate	100	200	200	200	250
ETHERS					
Ethyl Ether	100		200		400
n-Butyl Ether	100	200	200	200	
Isopropyl Ether	300	300	300	300	500*
Dioxane	200	200	200	200	100
MISCELLANEOUS SOLVENTS					
1,2,3-Trichlorpropane	50	100	100	100	50
1-Nitropropane	100	150	150	150	25
Acetaldehyde	50	50	200	200	200*
Styrene monomer	100				100

*See Threshold Limit Values for 1971 in Appendix.

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PHYSICAL CONSTANTS OF SELECTED MATERIALS

Substance	Formula	Molecular Weight	Specific Gravity	Flash Point F		Explosive Limits (Volume Per Cent)	
				Closed Cup	Open Cup	Lower	Upper
Acetaldehyde	CH_3CHO	44.05	0.821	-17	-	3.97	57.
Acetic Acid	CH_3COOH	60.05	1.049	104	110	5.40	-
Acetic Anhydride	$(CH_3CO)_2O$	102.09	1.082	121	130	2.67	10.13
Acetone	CH_3COCH_3	58.08	0.792	0	15	2.55	12.80
Acrolein	CH_2:CHCHO	56.06	0.841	Gas		Unstable	
Acrylonitrile	CH_2:CHCN	53.06	0.806	-	32	3.05	17.0
Ammonia	NH_3	17.03	0.597	Gas		15.50	27.0
Amyl Acetate	$CH_3CO_2C_5H_{11}$	130.18	0.879	76	80	1.10	-
Iso-Amyl Alcohol	$(CH_3)_2CHCH_2CH_2OH$	88.15	0.812	109	115	1.20	-
Aniline	$C_6H_5NH_2$	93.12	1.022	168	-	-	-
Arsine	AsH_3	77.93	2.695 (A)	Gas		-	-
Benzene	C_6H_6	78.11	0.879	12	-	1.40	7.10
Bromine	Br_2	159.83	3.119	-	-	-	-
Butane	$CH_3(CH_2)_2CH_3$	58.12	2.085	Gas		1.86	8.41
1,3 Butadiene	$(CH_2$:$CH)_2$	54.09	0.621	Gas		2.00	11.50
n-Butanol	$C_2H_5CH_2CH_2OH$	74.12	0.810	84	110	1.45	11.25
2, Butanone (Methyl Ethyl Ketone)	$CH_3COC_2H_5$	72.10	0.805	30	-	1.81	9.50
n-Butyl Acetate	$CH_3CO_2C_4H_9$	116.16	0.882	72	90	1.39	7.55
Butyl "cellosolve"	$C_4H_9OCH_2CH_2OH$	118.17	0.903	141	165	-	-
Carbon Dioxide	CO_2	44.01	1.53	-	-	-	-
Carbon Disulphide	CS_2	76.13	1.263	-22	-	1.25	50.0
Carbon Monoxide	CO	28.10	0.968	Gas		12.5	74.2
Carbon Tetrachloride	CCl_4	153.84	1.595	Nonflammable			
Cellosolve	$C_2H_5O(CH_2)_2OH$	90.12	0.931	104	120	2.6	15.7
Cellosolve Acetate	$CH_3CO_2C_4H_9O$	132.16	0.975	124	135	1.71	-
Chlorine	Cl_2	70.91	3.214	Gas		-	-
2-Chlorobutadiene	CH_2:$CClCHCH_2$	88.54	0.958	-	-	-	-
Chloroform	$CHCl_3$	119.39	1.478	Nonflammable			
1-Chloro-1-Nitropropane	$NO_2ClC_3H_6$	139.54	1.209	144	-	-	-
Cyclohexane	C_6H_{12}	84.16	0.779	1	-	1.26	7.75
Cyclohexanol	$CH_2(CH_2)_4CHOH$	100.16	0.962	154	-	-	-
Cyclohexanone	$CH_2(CH_2)_4CO$	98.14	0.948	147	-	-	-
Cyclohexene	$CH_2(CH_2)_3CH$:CH	82.14	0.810	-	-	-	-
Cyclopropane	$CH_2CH_2CH_2$	42.08	0.720	Gas		2.40	10.40
o-Dichlorobenzene	$Cl_2C_6H_4$	147.01	1.305	151	165	-	-
Dichlorodifluoromethane	CCl_2F_2	120.92	1.486	Nonflammable			
1,1 Dichloroethane	CH_3CHCl_2	98.97	1.175	-	-	-	-
1,2 Dichloroethane (Ethylene Dichloride)	$ClCH_2CH_2Cl$	98.97	1.257	56	65	6.2	15.9
1,2 Dichloroethylene	ClCHCHCl	96.95	1.291	43	-	9.7	12.8
Dichloroethylether	$ClCH_2CHClOC_2H_5$	143.02	1.222	131	180	-	-
Dichloromethane	H_2CCl_2	84.94	1.336	-	-	-	-
Dichloromonofluoromethane	$HCCl_2F$	102.93	1.426	-	-	-	-
1,1 Dichloro-1-nitroethane	$H_3C_2Cl_2NO_2$	143.97	1.692	-	168	-	-
1,2 Dichloropropane	$CH_3CHClCH_2Cl$	112.99	1.159	59	65	3.4	14.5
Dichlorotetrafluoroethane	$CClF_2CClF_2$	170.93	1.433	Nonflammable			
Dimethylaniline	$(CH_3)_2NC_6H_5$	121.18	0.956	145	170	-	-
Dimethylsulfate	$(CH_3)_2SO_4$	126.13	1.332	182	240	-	-
Dioxane	$O(CH_2)_4O$	88.10	1.034	-	35	-	-
Ethyl Acetate	$CH_3CO_2C_2H_5$	88.10	0.901	24	30	2.18	11.4
Ethyl Alcohol	C_2H_5OH	46.07	0.789	55	-	3.28	18.95
Ethyl Benzene	$C_6H_5C_2H_5$	106.16	0.867	59	75	-	-
Ethyl Bromide	C_2H_5Br	109.98	1.430	-	-	6.75	11.25
Ethyl Chloride	C_2H_5Cl	64.52	0.921	-58	-45	3.6	14.80
Ethylene Chlorohydrin	$ClCH_2CH_2OH$	80.52	1.213	-	140	-	-
Ethylenediamine	$NH_2CH_2CH_2NH_2$	60.10	0.899	-	-	-	-
Ethylene Oxide	CH_2CH_2O	44.05	0.887	-	-	3.0	80.0
Ethyl Ether	$(C_2H_5)_2O$	74.12	0.713	-	-	-	-

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Substance	Formula	Molecular Weight	Specific Gravity	Flash Point F Closed Cup	Flash Point F Open Cup	Explosive Limits (Volume Per Cent) Lower	Explosive Limits (Volume Per Cent) Upper
Ethyl Formate	$HCO_2C_2H_5$	74.08	0.917	-	-	2.75	16.40
Ethyl Silicate	$(C_2H_5)_4SiO_4$	208.30	0.933	-	125	-	-
Formaldehyde	HCHO	30.03	0.815	Gas		7.0	73.0
Gasoline	$C_nH_{(2n+2)}$	86	0.660	-50	-	1.3	6.0
Heptane	$CH_3(CH_2)_5CH_3$	100.20	0.684	25	-	1.1	6.7
Hexane	$CH_3(CH_2)_4CH_3$	86.17	0.660	-7	-	1.18	7.4
Hydrogen Chloride	HCl	36.47	1.268 (A)	-	-	-	-
Hydrogen Cyanide	HCN	27.03	0.688	Gas		5.6	40.0
Hydrogen Fluoride	HF	20.01	0.987	Gas		-	-
Hydrogen Selenide	H_2Se	80.98	2.12	Gas		-	-
Hydrogen Sulfide	H_2S	34.08	1.189 (A)	Gas		4.3	45.5
Iodine	I_2	253.82	4.93	-	-	-	-
Isophorone	$(CH_3)_3C(CH_2)_2CCHCO$	138.20	0.923	-	205	-	-
Mesityl Oxide	$(CH_3)_2$:CHCOCH$_3$	98.14	0.857	87	-	-	-
Methanol	CH_3OH	32.04	0.792	54	60	6.72	36.5
Methyl Acetate	$CH_3CO_2CH_3$	74.08	0.928	15	20	3.15	15.60
Methyl Bromide	CH_3Br	94.95	1.732	-	-	13.5	14.5
Methyl Butanone (iso propyl butane)	$CH_3COCH(CH_3)_2$	86.13	0.803	-	-	-	-
Methyl Cellosolve	$HOCH_2CH_2OCH_3$	76.06	0.965	107	115	-	-
Methyl Cellosolve Acetate	$CH_3OCH_2CH_2OOCCH_3$	118.13	1.007	132	140	-	-
Methyl Chloride	CH_3Cl	50.49	1.785	Gas		8.25	18.70
Methyl Cyclohexane	$CH_3(CHC_5H_{10})$	98.18	0.769	25	-	1.15	-
Methyl Cyclohexanol	$CH_3(CHC_4H_8CHOH)$	114.18	0.934	154	-	-	-
Methyl Cyclohexanone	$CH_3C_5H_9CO$	122.17	0.925	118	-	-	-
Methyl Formate	HCO_2CH_3	60.05	0.974	-2	-	4.5	20
Methyl Isobutyl Ketone	$CH_3COC_4H_9$	100.16	0.801	73	-	-	-
Monochlorobenzene	C_6H_5Cl	112.56	1.107	90	-	-	-
Monofluorotrichloromethane	Cl_3CF	137.38	1.494	Nonflammable			
Mononitrotoluene	$CH_3C_6H_4NO_2$	137.13	1.163	223	-	-	-
Naphtha (coal tar)	$C_6H_4(CH_3)_2$	106.16	0.85	100-110	-	-	-
Nickel Carbonyl	$Ni(CO)_4$	170.73	1.31	-	-	-	-
Nitrobenzene	$C_6H_5NO_2$	123.11	1.205	190	-	1.8 (200°F)	-
Nitroethane	$CH_3CH_2NO_2$	75.07	1.052	82	106	-	-
Nitrogen Oxides	NO	30.0	1.0367 (A)	-	-	-	-
	N_2O	44.02	1.53	-	-	-	-
	N_2O_3	76.02	1.447	-	-	-	-
	NO_2	46.01	1.448	-	-	-	-
	N_2O_4	108.02	1.642	-	-	-	-
Nitroglycerine	$C_3H_5(ONO_2)_3$	227.09	1.601	-	-	-	-
Nitromethane	CH_3NO_2	61.04	1.130	95	112	-	-
2-Nitropropane	$CH_3CHNO_2CH_3$	89.09	1.003	-	103	-	-
Octane	$CH_3(CH_2)_6CH_3$	114.22	0.703	56	-	.95	3.2
Ozone	O_3	48	1.658 (A)	-	-	-	-
Pentane	$CH_3(CH_2)_3CH_3$	72.15	0.626	<-40	-	1.4	7.8
Pentanone (Methylpropanone)	$CH_3COCH_2C_2H_5$	86.13	0.816	45	60	1.55	8.15
Phosgene	O:C:Cl_2	98.92	1.392	-	-	-	-
Phosphine	PH_3	34.0	1.146 (A)	-	205	-	-
Phosphorus Trichloride	PCl_3	137.35	1.574	-	-	-	-
iso-Propanol	$(CH_3)_2CHOH$	60.09	0.785	53	60	2.02	11.80
Propane	$CH_3CH_2CH_3$	44.09	1.554	Gas		2.12	9.35
Propyl Acetate	$CH_3CO_2CH_2C_2H_5$	102.13	0.886	43	60	1.77	8.0
iso-Propyl Ether	$(CH_3)_4(CH)_2O$	102.17	0.725	-18	-15	-	-
Stibine	SbH_3	124.78	4.344 (A)	-	-	-	-
Styrene Monomer	C_6H_5HC:CH_2	104.14	0.903	90	-	1.1	6.1
Sulfur Chloride, Mono	S_2Cl_2	135.03	1.678	245	None	-	-
Di	SCl_2	102.97	1.621	-	-	-	-
Tetra	SCl_4	173.89		-	-	-	-
Sulfur Dioxide	SO_2	64.07	2.264 (A)	Gas		-	-
1,1,2,2 Tetrachloroethane	$Cl_2CHCHCl_2$	167.86	1.588	-	-	-	-

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Substance	Formula	Molecular Weight	Specific Gravity	Flash Point F		Explosive Limits (Volume Per Cent)	
				Closed Cup	Open Cup	Lower	Upper
Tetrachloroethylene	$Cl_2C:CCl_2$	165.85	1.624	Nonflammable			
Toluene	$C_6H_5CH_3$	92.13	0.866	40	45	1.27	6.75
Toluidine	$CH_3C_6H_4NH_2$	107.15	0.999	188	205	-	-
Trichloroethylene	$ClCHCCl_2$	131.40	1.466	Nonflammable			
Turpentine (Turpene)	$C_{10}H_{16}$	136.23		95	-	0.8	-
Vinyl Chloride (Chloroethane)	C_2H_5Cl	62.50	0.908	Gas		4	21.70
Xylene	$C_6H_4(CH_3)_2$	106.16	0.881	63	75	1.0	6.0

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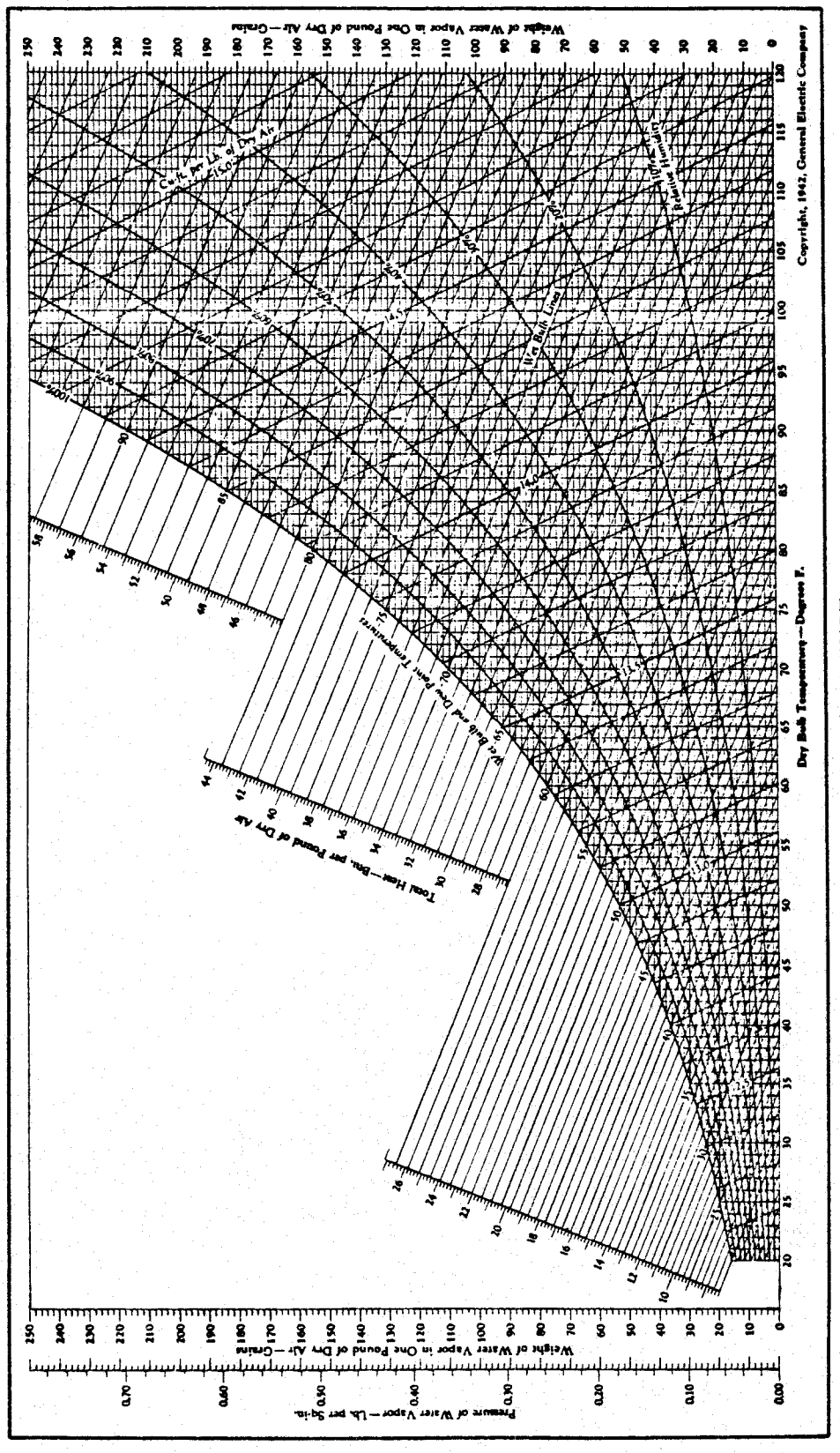
SOLVENT DRYING TIME

SOLVENT	Dry Time Relation	Boiling Range Deg. C.	Boiling Range Deg. F.	Weight per Gal. Lbs.
Ethyl Ether, C. P.	1.0	34-35	93-95	5.98
Petrolene	1.8	61-96	142-205	5.83
Carbon Tetrachloride	1.9	76	169	13.30
Acetone	2.0	56-58	133-136	6.35
Methyl Acetate	2.2	56-62	133-144	7.79
Ethyl Acetate 85-88%	2.5	74-77	165-171	7.37
Trichlorethylene	2.5	87	189	12.20
Benzol (Industrial)	2.6	79-81	174-178	7.38
Methyl Ethyl Ketone	2.7	77-82	171-180	6.95
Isopropyl Acetate 85%	2.7	84-93	183-199	7.26
Ethylene Dichloride	3.0	84	183	10.49
Solvsol 19/27	3.7	86-123	187-254	6.58
Ethylene Chloride	4.0	81-87	178-189	10.49
Propylene Dichloride	4.1	93-97	199-207	9.64
Toluoil	4.1	90-122	194-252	6.17
Methanol	5.0	64-65	147-149	6.63
Toluol (Industrial	5.0	109-111	229-232	7.19
Methyl Propyl Ketone	5.2	101-107	214-225	6.77
V. M. & P.	5.8	95-141	203-286	6.23
Perchlorethylene	6.0	121	250	13.55
Nor. Propyl Acetate	6.1	97-101	207-214	7.50
Sec. Butyl Acetate	6.5	106-135	223-275	7.13
Solox (Anhydrous)	6.5	71.78	160-172	6.80
Isobutyl Acetate 90%	7.0	106-117	223-243	7.28
Apcothinner	7.0	115-143	239-289	6.31
Ethyl Alcohol, Den. No. 1	7.7	78	172	6.64
Solox	8.0	76-78	169-172	6.73
Isopropyl Alcohol 99%	8.6	79-82	174-180	6.75
Nor. Propyl Alcohol	9.1	96-98	205-208	6.73
Solvsol 24/34	9.4	101-168	214-334	6.80
Nor. Butyl Acetate	9.6	110-132	230-270	7.29
Diethyl Carbonate	9.6	100-130	212-266	8.14
Methyl Butyl Ketone	9.7	114-137	237-279	6.84
Xylol (Industrial	9.7	127-144	261-291	7.17
Monochlor Benzol	10.0	130-132	266-270	9.20
Tertiary Butyl Alcohol	11.9	82-83	180-181	6.55
Sec. Butyl Alcohol	14.0	99-100	210-212	6.85
Sec. Amyl Acetate	16.9	121-144	250-291	7.21
Amyl Acetate	17.4	105-142	221-288	7.24
Isobutyl Alcohol	17.7	107-111	225-232	6.70
Methyl Cellosolve	18.0	121-126	250-259	8.07
Butyl Propionate	18.0	124-171	255-340	7.31
Pentacetate	20.0	121-155	250-311	7.19
Turpentine	20.0	155-173	311-343	12.24
Butanol	21.0	116-119	241-246	6.79
Sec. Amyl Alcohol	25.0	105-125	221-257	6.79
2-50-W Hi-Flash Naphtha	27.5	148-187	298-369	7.18
Amyl Alcohol (Fusel Oil)	32.1	126-130	259-266	6.76
Di Isopropyl Ketone	33.9	164-169	327-336	6.75
Ethyl Cellosolve	36.2	133-137	271-279	7.77
Odorless Mineral Spirits	38.6	150-201	302-394	6.52
Ethyl Lactate	40.0	119-176	246-349	8.59
Sec. Hexyl Alcohol	41.7	157	315	6.97
Solvsol 30/40	43.2	142-199	288-390	7.06
Pentasol	45.0	112-140	234-284	6.76
Hi-Solvency Mineral Spirits	46.7	152-200	306-392	6.79
No. 380 Mineral Spirits	47.0	151-196	304-385	6.57
No. 10 Mineral Spirits	55.0	154-196	309-385	6.49
Distilled Water	60.0	100	212	8.32
Apco No. 125	60.5	162-200	324-392	6.52
Cellosolve Acetate	65.0	145-166	293-331	8.15
Sec. Butyl Lactate	73.0	172	342	8.14
Sec. Hexyl Acetate	76.5	129-158	264-316	7.19
Butyl Cellosolve	88.5	163-172	325-342	7.58
Dipentene	89.2	149-215	300-419	7.10
No. 140 Thinner	91.0	185-210	365-410	6.62
Octyl Acetate	152.5	195-203	383-397	7.20
Isobutyl Lactate	156.5	168-200	334-392	8.15
Hexalin	177.5	159-162	318-324	7.89
Solvsol 40/50	270.0	191-248	376-478	7.42
Methyl Hexalin	276.5	170-190	338-374	7.66
Butyl Lactate	339.0	185-195	365-383	8.14
Excellene	384.0	162-260	324-500	6.55
Special Heavy Naphtha	403.0	202-242	396-468	6.73
Dispersol	425.0	193-242	379-468	6.59
No. 50 Kerosene	626.7	178-256	352-493	6.76
Triethylene Glycol	Over 5200.0	276-310	529-590	9.30
Dibutyl Phthalate	Over 5200.0	195-200	383-392	8.73

*Dry Time Relation
Below 5 Fast
5-15 Medium
15-75 Slow
75 over - Nil

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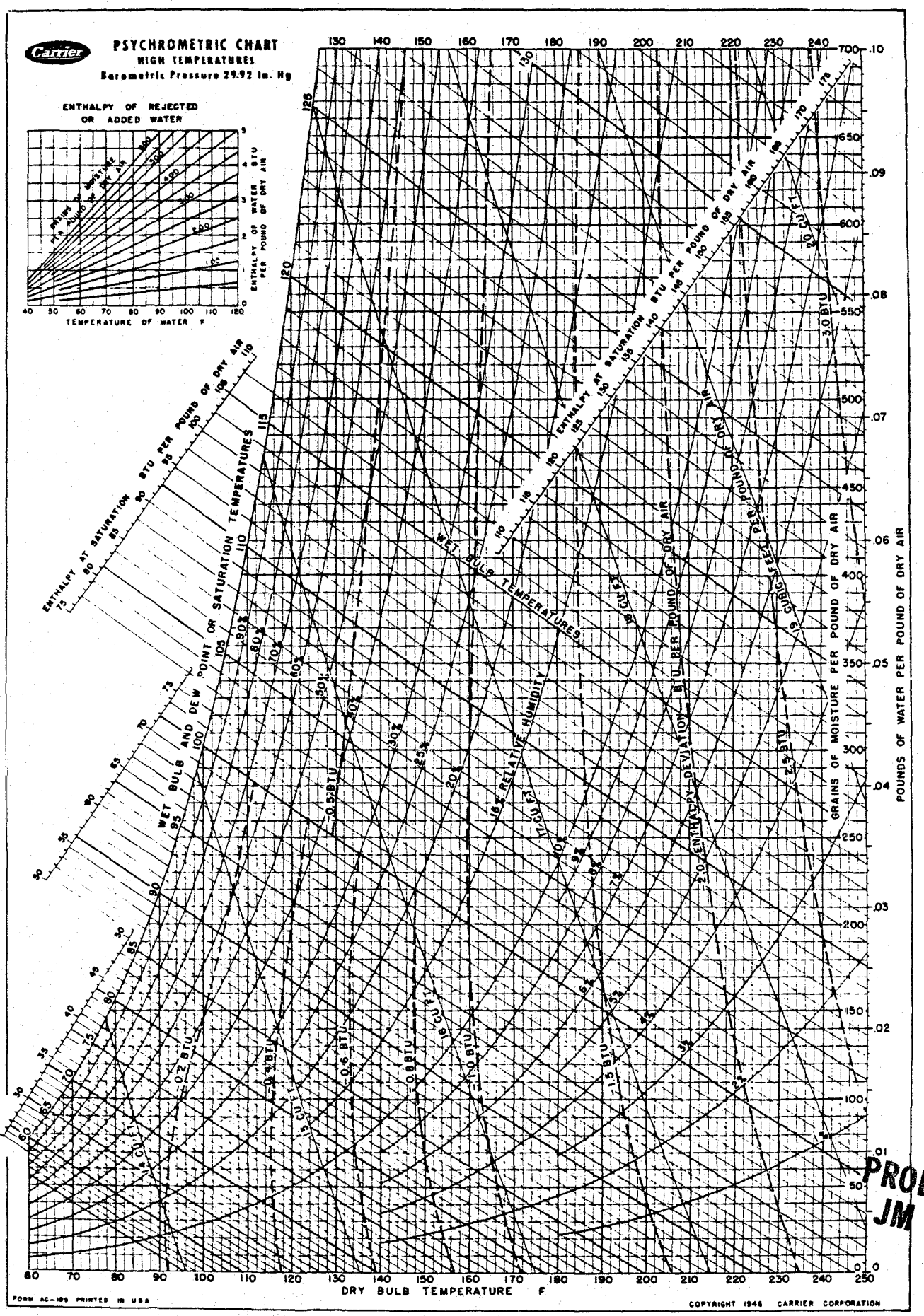


PSYCHROMETRIC CHART

Barometric Pressure 14.696 Lb. per Sq. in.

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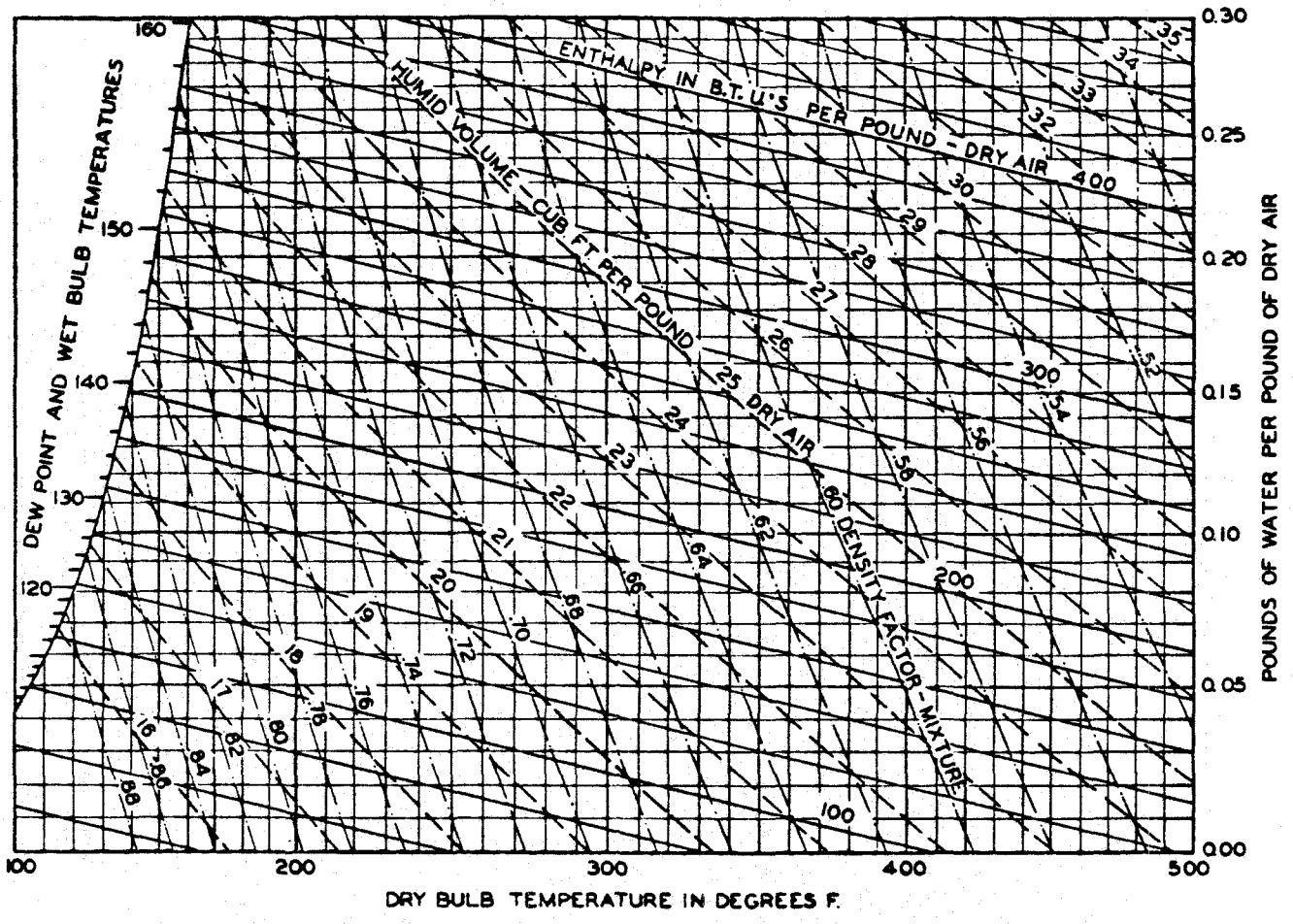
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PSYCHROMETRIC CHART FOR HUMID AIR

BASED ON ONE POUND DRY WEIGHT

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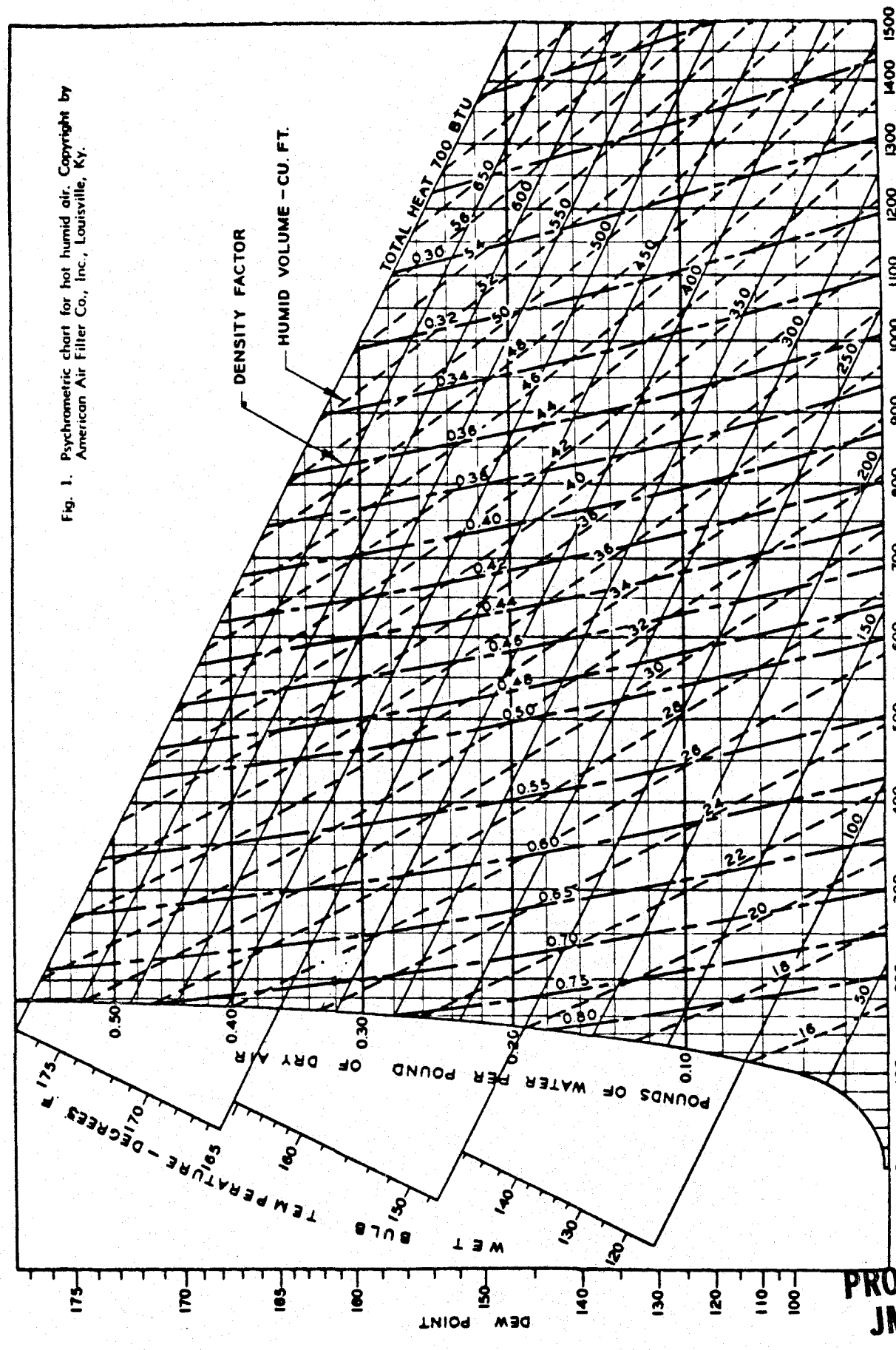


Fig. 1. Psychrometric chart for hot humid air. Copyright by American Air Filter Co., Inc., Louisville, Ky.

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CONVERSION FACTORS

METRIC EQUIVALENTS

Length

Cm = 0.3937 in	In = 2.5400 cm		
Meter = 3.2808 ft	Ft = 0.3048 m		
Meter = 1.0936 yd	Yd = 0.9144 m		
Km = 0.6214 mile	Mile = 1.6093 km		

Volume

Cu cm = 0.0610 cu in	Cu in = 16.3872 cu cm
Cu m = 35.3145 cu ft	Cu ft = 0.0283 cu m
Cu m = 1.3079 cu yd	Cu yd = 0.7647 cu m

Capacity

Liter = 2.2046 lb of pure water at 4C
Liter = 61.0250 cu in
Liter = 0.0353 cu ft
Liter = 0.2642 gal (US)
Cu in = 0.0164 liter
Cu ft = 28.3162 liter
Gal (US) = 3.7853 liter

Weight

Gram = 15.4324 grains	grain/ft^3 = 2288.1 mg/m^3
Gram = 0.0353 oz	lb/1000 ft^3 = 16,017. mg/m^3
Kg = 2.2046 lb	ton/sq mile = 0.35026 gm/m^2
Grain = 0.0648 g	lb/acre = 0.11208 gm/m^2
Oz = 28.3495 g	lb/1000 ft^2 = 4.8807 gm/m^2
Lb = 0.4536 kg	grain/ft^2 = 0.69725 gm/m^2

Concentration

HEAT AND ENERGY UNITS

1 kw-hr=	1 hp-hr=	1 lb water evaporated from and at 212 F
1000 whr	0.7457 kw-hr	0.2844 kw-hr
1.3410 hp-hr	1,980,000 ft-lb	0.3814 hp-hr
2,655,217 ft-lb	2545 Btu	970.2 Btu
3413 Btu		

1 Boiler Hp = 33,475 Btu/hr
1 Ton (refrig) = 12,000 Btu/hr

Btu = 0.2520 kg-cal

TEMPERATURE EQUIVALENTS

Fahrenheit, F = Rankin - 460 = 9/5 C + 32

Centrigrade, C = Kelvin - 273 = 5/9 (F-32)

PRESSURE EQUIVALENTS

1 Atmosphere =
14.696 lbs per sq in = 2116.3 lbs per sq ft
33.96 ft of water = 407.52 in water
29.92 in of mercury = 760 mm mercury
234.54 oz per sq in = 10340 mm water

1 in water =
.0361 lbs per sq in = 5.196 lbs per sq ft
.0735 in mercury = 1.876 mm mercury
.002456 atmospheres = .5774 oz per sq in
25.4 mm water = .08333 ft of water

1 in mercury =
.491 lbs per sq in = 70.70 lbs per sq ft
25.4 mm mercury = 7.86 oz per sq in
.03342 atmospheres = 345.6 mm water
13.61 in water = 1.134 ft water

1 mm mercury =
.01934 lbs per sq in = 2.789 lbs per sq ft
.3094 oz per sq in = .001316 atmospheres
.5357 in water = .04464 ft water
13.61 mm water = .03937 in mercury

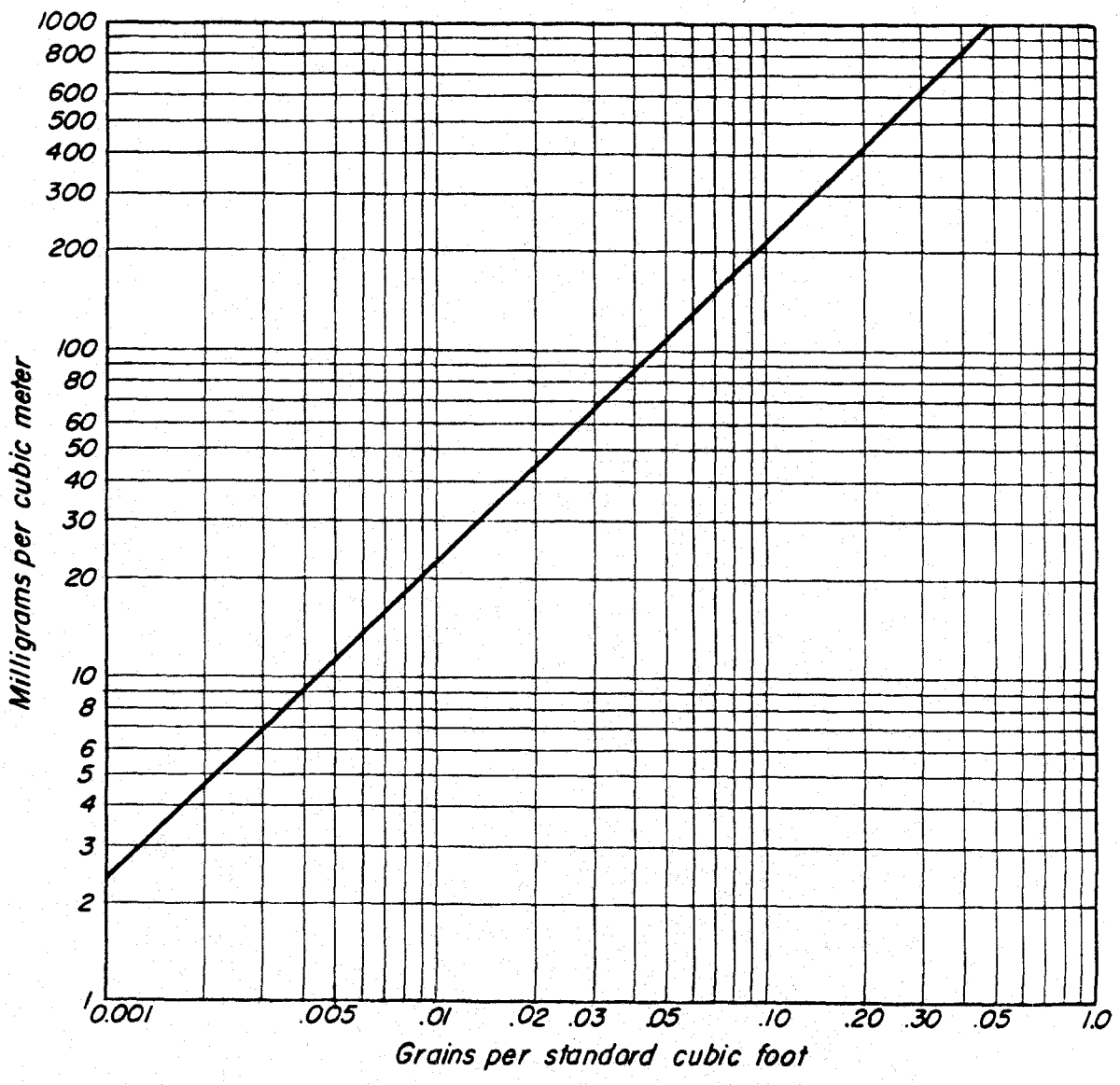
1 lb per sq in =
144 lbs per sq ft = 16 oz per sq in
51.71 mm mercury = 2.036 in mercury
.06804 atmospheres = 703.7 mm water
27.70 in water = 2.309 ft water

1 oz per sq in =
.0625 lbs per sq in = 9.00 lbs per sq ft
1.733 in water = .1441 ft water
.1272 in mercury = 3.23 mm mercury
.00425 atmospheres = 44.02 mm water

1" of water resistance lowers density of air by $\frac{1}{4}$ of 1%.
1" of water represents 66 ft difference in elevation at sea level to 4000 ft altitude.
1" of water represents 74 ft difference in elevation at 4000 to 6000 ft altitude.
1" of mercury represents 900 ft difference in elevation at sea level to 4000 ft altitude.
1" of mercury represents 1000 ft difference in elevation at 4000 to 6000 ft altitude.
1000 ft difference in elevation at sea level represents 1.11" of mercury = 15.2" water.
1000 ft difference in elevation at 4000 ft represents 1" of mercury = 13.6" water.

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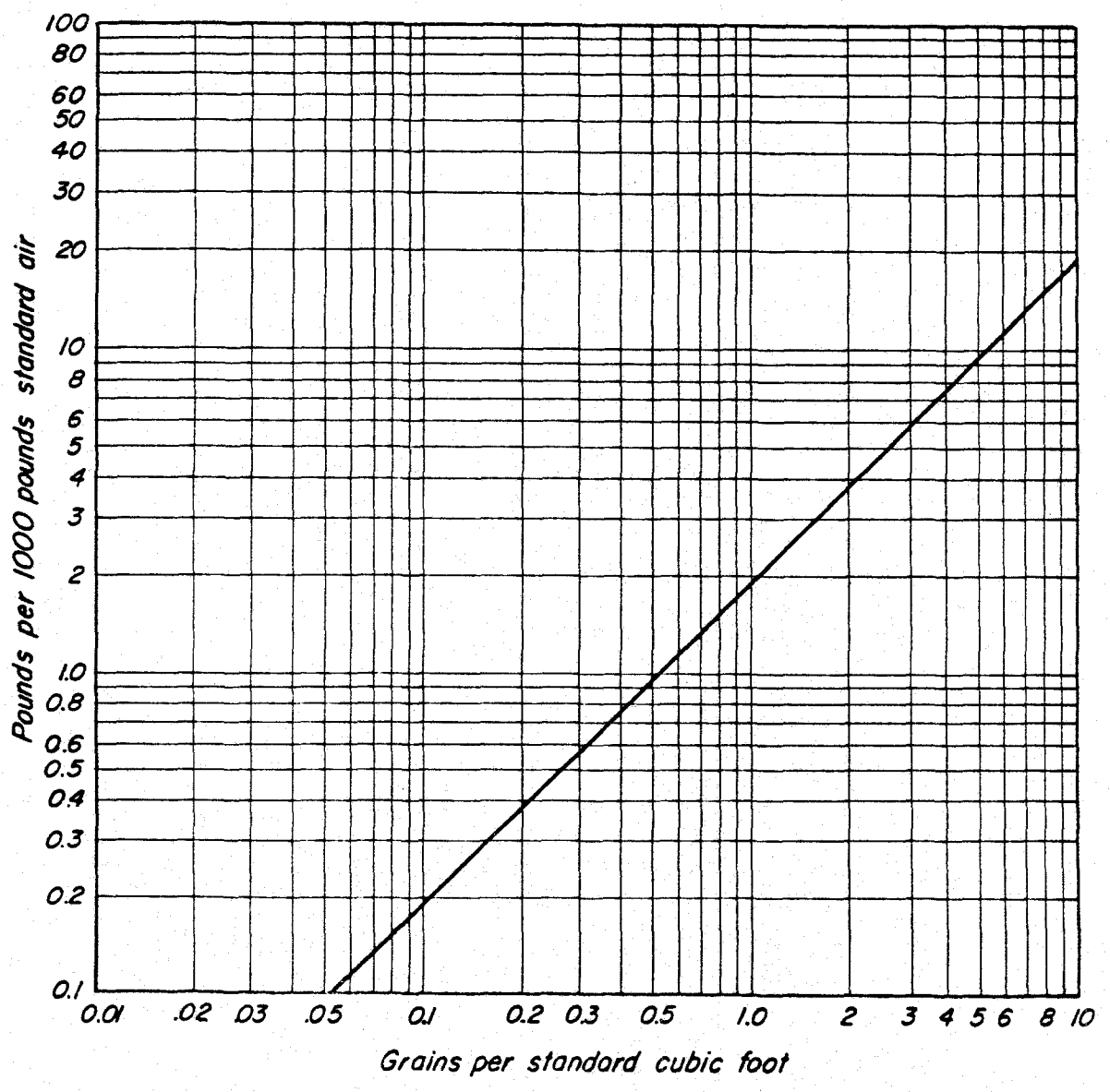
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CONVERSION CHART FOR DUCT EMISSION

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CONVERSION CHART FOR DUCT EMISSION

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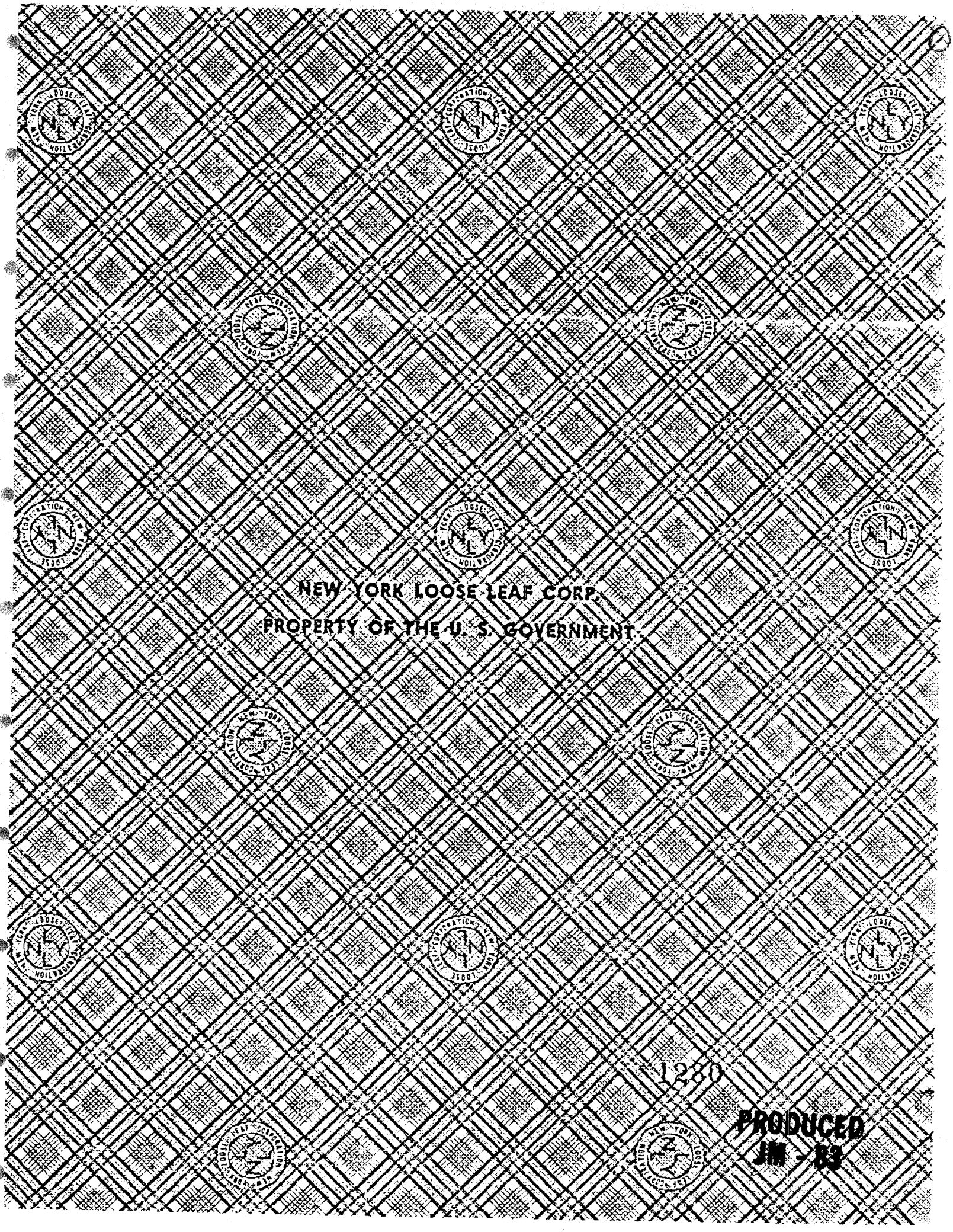
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