

by equipment heat and vapor release. Such equipment consists of electric, steam or combustion heating devices, motors, electronic equipment and special apparatus. The evaluation of equipment heat gains to establish design loads requires equipment nameplate ratings, applicable load and use factors and the determination of overall diversity factors. Load factors relate actual equipment heat dissipation to nameplate rating. For motors, it is the ratio of maximum power input to the motor rating. For heating devices such as ovens, furnaces and burners, it represents the ratio of the energy required to elevate the temperature of a mass to the energy required to maintain it at that temperature. Thus a Bunsen burner may operate at partial capacity once a solution reaches its boiling point. Values of 50 to 75 percent of rated capacity are applicable to Bunsen burners. Values for ovens and furnaces may be obtained from manufacturers' data or computed from surface area and temperature data. Load factors for electronic equipment are generally 100 percent. Those for special apparatus should be obtained from manufacturers. Heat release from equipment located in fume hoods may be fully discounted, and equipment under canopy hoods or ventilated by special exhaust devices discounted 50 percent.

Use factors relate to the portion of an hour during which equipment may be in use to the time it is actually operative. Many pieces of laboratory apparatus such as vacuum pumps are not in continuous use, and when operative, cycle frequently. The diversity factor is the percentage of all heat-releasing equipment in a laboratory in simultaneous use. Use factors and diversity factors are best obtained from technical personnel engaged in the particular laboratory work.

The procedure for determining the simultaneous probable equipment heat release is to: (1) obtain nameplate ratings of all apparatus, (2) apply load and use factors to each, and (3) apply overall diversity factors.

Because of equipment thermal gains, laboratory cooling loads are characteristically highly variable. Equipment loads often range up to 75 percent of total heat gains. For this reason, individual space control is required for comfort conditioning and restricted ambient conditions.

AIR FLOW RATES

Supply air quantities are established by room cooling requirements and load characteristics. Supply rates thus derived may be designated primary air rates. Supplemental supply required to make up deficiencies between room exhaust requirements and primary supply may be designated: (1) infiltrated supply if induced indirectly from other spaces, or (2) secondary supply if conducted to the room directly.

Exhaust air rates are established by requirements for the removal of heat odor and airborne contaminants. Contaminants generated or present within research facilities are fumes, gases, pathogens, vapors, and radioactive particulates or ions. Many devices are employed to control the spread of airborne contaminants in laboratories and all require controlled flow of large air quantities to entrain the pollutants and ultimately discharge them to the atmosphere. The most commonly employed general purpose enclosure is the fume hood. Air requirements for fume hoods range from 600 to 2000 cfm. Other special enclosures for the containment of highly toxic contaminants are also available. One variety is a small volume completely enclosed unit called a glove or dry box. Air requirements for these units are low and in the order of 5 to 10 cfm. Another is the massively shielded specially constructed enclosure employed for high level radioactive work called the hot cell or cask wherein handling of substances is done with externally operated mechanical manipulators. Design rates for these units are in the order of 1 air change per minute.

Generally the entrainment of contaminants with air entails substantial exhaust volumes. These are consequently critical in establishing supply air rates, air flow patterns, and air systems design. Explicit and detailed qualitative and quantitative data pertaining to exhaust requirements is, therefore, essential for the design of air conditioning and ventilating systems for laboratory and test facilities.

AIR BALANCE AND FLOW PATTERN

Control of the direction of air flow in many laboratory buildings is a necessary consideration for preventing the spread of airborne contaminants and protecting personnel from exposure to toxic and hazardous substances. In facilities involving work of such nature, the once-through principle of air flow is applicable. This method is based on the assumptions that: (1) 100 percent outdoor air is supplied and exhausted with no recirculation, (2) constant volume air flow is maintained with all exhaust facilities simultaneously operating at full capacity, and (3) any cross transfer of air between spaces is from areas of least contamination to those of highest contamination. In facilities where contamination isolation is not critical, such as electronics laboratories, air can be recirculated and control of interspace air patterns is not essential. Determinants for air pattern control are: (1) the type of contaminants handled or generated in each space, (2) the type, size and number of ventilated enclosures and auxiliary exhaust facilities in each space, and (3) permissibility of air transfer into or out of spaces.

Flow and air balance patterns applicable to various conditions of air transfer are:

1. No transfer to or from a space is permitted. The exhaust rate must be matched by the primary air rate or by a combination of primary and secondary air.
2. Only transfer into a space is permitted, with no outflow.
 - a. Exhaust rate must equal the primary air rate.
 - b. If the exhaust exceeds the primary air rate, then air may be infiltrated from adjoining spaces to make up the deficiency, providing the air is suitable in quality and psychrometric condition.
3. Only transfer out of a space is permitted with no inflow. The primary air rate may exceed the exhaust rate, and the excess supply air may be exhausted providing its quality and condition permit. Otherwise, the room must be kept in balance.

For highly critical air balance conditions, an air lock provides a positive means of control. An air lock is an anteroom between a controlled and uncontrolled space with airtight doors electrically interlocked to prevent simultaneous operation. The air pattern in the air lock is designed to suit any of the foregoing laboratory space air balance requirements.

FUME HOODS

A laboratory fume hood is a ventilated enclosed work space consisting of side, back and top enclosure panels, a work surface or deck, a work opening called the face, and an exhaust plenum equipped with horizontal adjustable slots for the regulation of air flow distribution. The work opening may be unrestricted or may be equipped with operable glass doors for observation and shielding purposes. Doors may be: (1) vertically operable, (2) horizontally operable, or (3) vertically and horizontally operable. The combination door, which employs horizontally sliding sash within a vertical uplift frame, provides maximum access for setting up apparatus, reduced operating opening for the conservation of air, and horizontally moveable protective shielding. Hoods are equipped with a variety of accessories including filters, internal lights, service outlets, sinks, air bypass openings and airflow entry devices. The location of the exhaust port distinguishes hoods either as up-draft hoods, if the connection

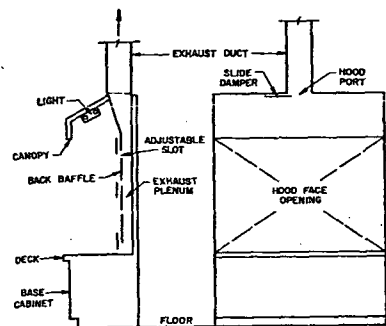


Fig. 1 Typical Laboratory Fume Hood

is at the top of the exhaust plenum, or down-draft hoods, if located at the bottom. The up-draft design is most generally employed. The down-draft hood is applicable to work involving condensable contaminants, exhaust ductwork requiring wash-down facilities, or for radioactive work wherein the exhaust air must be discharged through high stacks remote from the building. Fig. 1 illustrates the basic elements of a hood.

Supplementary air hoods are hoods designed for direct supply air connections to supplement and thereby reduce induced air volumes. They are designed to either introduce supplementary air directly into the hood or as a face air curtain.

Hood Air Requirements

Air requirements for hoods are a function of (1) operating face area and (2) design face velocity.

Operating Face Area. The operating face area of a hood is the opening area employed under operating conditions. It may be equal to or less than the maximum available face opening. For a hood equipped with a single uplift door or a pair of horizontally sliding doors, the operating face is equal to the maximum operable opening. For a combination horizontal-vertical door arrangement, the operating face can be considerably less than the maximum face opening depending on the number of sliding panels and the track arrangement. A door with three sliding panels on separate tracks provides an operating area which is two-thirds the face area, whereas a three panel door with two tracks provides an operating area equal to one-third the face area. Definition of a hood's operating face area is requisite for the determination of its air requirements.

Design Face Velocity. Air velocity across the operating face opening of a hood varies from point to point depending on the hood's air distribution characteristics. The average face velocity is the quotient of the total air passing across the face measured at the exhaust port or by the fan operating point, and the operating face area. Minimum design face velocity is the minimum acceptable velocity at any point on the operating opening. Values range from 50 to 75 fpm for work involving innocuous contaminants, 80 to 100 fpm for toxic and hazardous fumes, and 100 fpm for low level radioisotope work. Minimum values are prescribed in many states under Labor Codes. Maximum design face velocity is the maximum

acceptable velocity at any point of the operating opening for any intermediate position of the hood door. Maximum velocities of 100 to 150 fpm will avoid disturbance to screened flames and most test materials. Velocities up to 300 fpm are used for evaporation purposes.

Design air quantities for hoods are the product of the minimum face velocity and maximum operating area divided by the air distribution efficiency. Efficiency values depend on particular hood designs but generally range from 90 to 95 percent.

Hood Performance

Performance criteria for fume hoods are flow control, outfall and face velocity control.

Flow Control. Regulation of flow over the face opening of a hood is obtained by adjustment of the horizontal slots on the face of the hood plenum. One is provided at the bottom of the plenum to sweep the working surface. Another is located at the top to exhaust the canopy and a third is frequently located midway on the plenum. These adjustable openings permit regulation of exhaust distribution for specific operations. Adjustment may be made for the collection of heavy fumes at the deck surface, for the capture of light fumes and hot gases at the canopy or for uniform flow best suited to general purpose operations.

Outfall. Excluding external disturbances, outfall of fumes from hoods can be caused by: (1) eddy currents generated at hood opening edges, surface projections and depressions, and (2) thermal heads.

Eddy Currents. Corner and intermediate posts, deep deck lip depressions, sinks and projecting service fittings near the face produce air turbulence and potential outfall conditions. Plain entrance edges produce a vena contracta within 1 in. of the surface and up to a depth of 6 in. Fumes generated in this area will be disturbed and possibly escape the hood enclosure. Air foil shapes at the entry edges correct this condition and eliminate outfall possibilities. Sinks and service fitting should be located at least 6 in. beyond the hood face and deck lips should have minimal projections.

Air currents external to a hood can influence the air pattern of hoods and produce fume outfall.

Cross currents are generated by body movements, thermal convection, supply air movement and rapid operation of room doors and windows. Air motion at the hood face in excess of the hood face velocity disturbs face air flow and causes outfall. Terminal supply air velocity in the vicinity of hoods should be limited to 35 fpm. Location of hoods near heating elements or doors and windows which are frequently operated should be avoided.

Thermal Head is the pressure difference between the interior of the hood and the room due to the difference in densities of gases at elevated temperatures in the hood and air at room temperature outside the hood. If the thermal head exceeds the suction head at hood openings, outward leakage will occur. The suction pressure at a hood face operating at 100 fpm is 0.000624 in. of water. Thermal heads generated by two columns of air ranging from 6 to 12 in. in height and temperature differentials of 30 to 100 F (room temperature 70 F and hood temperature 100 to 170 F) range between 0.0004 to 0.0023 in. of water. The critical condition for development of thermal heads is when the hood door is closed coincident with high heat release. Hot gases accumulate near the top of the hood and leak through panel, lighting fixture and door frame joints. Effective control measures are: (1) bypass provisions arranged for continuous flow through the hood, (2) high face velocities (80 to 100 fpm) for optimum thermal dilution, (3) airtight construction of the canopy,