INTERNAL CORRESPONDENCE
GULF 973

FROM	R. T. Cheng	AT	San Diego	IN REPLY REFER TO	RTC 4:071
TO	R. L. Gibson, M. D.	AT	Pittsburgh	DATE	4/30/74
SUBJECT	Industrial Hygiene Survey Report, China Gulf Plastics Corporation				

Attached are 6 copies of the industrial hygiene survey report conducted at China Gulf Plastics Corporation in Taiwan during February and March, 1974.

Please note there are only two sets of the Industrial Hygiene Standard attachments as I assume most of the distribution list will already have them in their possession.

If I can be of further assistance, please let me know.

Bob

R. T. Cheng

RTC:mm
Attachments
cc: H. E. Runion

File

INDUSTRIAL HYGIENE SURVEY

Conducted at

CHINA GULF PLASTICS CORPORATION

February 28 - March 15, 1974

By

Robert Ta-Chun Cheng

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I. GENERAL

The subject survey was conducted during the period of February 28 through March 15, 1974. The purpose of the survey was to evaluate the industrial hygiene status of China Gulf Plastics Corporation. Extensive attention was given to the evaluation of the work area vinyl chloride monomer concentrations and workmen's occupational vinyl chloride exposure. Other problems studied in detail included workmen's exposure to dusts of lead, cadmium, and barium, mercury vapors in the chlor-alkali works, and industrial solvents at the fabrication plants. Also reviewed were chemical hazards in the plating room, DOP fumes and exhaust ventilation, plant noise levels, industrial lighting levels, personal protective equipment, housekeeping and general sanitation conditions.

China Gulf Plastics Corporation (CGPC) has its main plant at Toufen, which employs some 1,300 workers, and a fabrication plant at Taoyuan with about 100 employees. In addition, CGPC is a minority owner of Taiwan Vinyl Chloride Monomer Company (TVCM). TVCM has one plant at Kaohsiung and one plant at Toufen near the CGPC's Toufen Main Plant. The TVCM Toufen Plant was very new and was not in operation due to technical problems during the time of this survey. I visited TVCM Kaohsiung Plant which employs some 50 workers.

Preliminary results of this survey have been reported to Mr. G. M. Hale, CGPC President, and other CGPC executives during two debriefing sessions. The survey was terminated with a two-hour long meeting with Mr. Wilbur T. C. Shyeh and forty other plant management staff at Toufen Main Plant. Important findings were presented, obvious hazards were pointed out, and some corrective measures were recommended at this meeting.

I wish to thank Mr. W. Shyeh, Mr. K. Lu and other members of the plant management team for their courtesies and assistance extended to me during my stay in Toufen Main Plant. Also, special thanks to Messrs. K. L. Lu, W. C. Wong and S. T. Huang for their help in carrying out the survey work.

II. SUMMARY

A. Except during the daily drawing of vinyl chloride samples from pipelines, and during process equipment maintenance and repair time, workmen's VC exposure was at a minimum at TVCM Kaohsiung Plant. VC was not detected at CGPC's Taoyuan Plant.

B. VC concentrations up to 10,000 ppm were measured at Toufen Main Plant's Polymerization Plant during reactor vessel bleeding time. This huge escape of VC into the work environment was brought into control by keeping the reactor vessel covered with a specially designed hatch opening lid. Workmen's time weighted VC exposure was estimated at above 200 ppm before the control measure was adopted, and under 5 ppm after the control measure.

C. Exposure to about 500 ppm of VC during the two minutes of water flushing operation could be eliminated by installing some type of automatic water jet flushing system, or prevented by protecting workers with full-face supplied air breathing apparatus.

At the present time, with the special reactor hatch opening lid in service, and with workers protected during water flushing operation, Toufen Main Plant should have no difficulty in meeting the current U. S. Emergency Temporary Standard of 50 ppm maximum VC exposure.

D. Powders of lead, cadmium, and barium stearates were used as stabilizers. Dust levels were very high at the Compounding Ingredient Mixing Room and at two locations downstairs in the Extrusion Plant. Work area lead dust concentrations went as high as 2 $^{mg}/_{M^3}$. Dust levels could be reduced by employing isolation, confinement, and local exhaust ventilation techniques.

E. Solvent vapors were excessively high at the Flexible Products Fabrication Plant. Concentrations of total solvent vapors around printers and surface treating machines ranged from 200 ppm to over 1,000 ppm. Most machines were without exhaust ventilation, and workers attending

those machines were over-exposed to solvent vapors. Solvent exposure conditions were much worse last summer when the weather was hot and when the fabrication plant was in full production. Local exhaust ventilation should be installed on each and every printer and surface treating machine. The selection and design of an efficient and economical local exhaust system can be time-consuming and requires professional expertise.

F. Mercury vapor concentrations were around 0.04 mg/M^3 at the side aisle, and 0.25 mg/M^3 at the center aisle of the mercury cell room. Employee's mercury vapor exposures were moderately high, and should be reduced by improving general ventilation conditions. Wall fans should be installed on both sides of the new expansion section of the mercury cell room.

G. The work environment of the Flake Soda Operation downstairs in the Mercury Cell Room was very unpleasant, and workers there were over-exposed to mercury vapor. Preferably, this operation should be moved out of the basement to a better environment. Otherwise, this basement work station should be maintained in clean and healthy conditions through improved ventilation control and stringent housekeeping practices.

H. The metal cleaning and plating operations in the plating room should have better local exhaust systems. Eye goggles should be provided and the wearing of them enforced when working inside the plating room. Emergency shower and eye wash fountains are absolutely required.

I. Dioctyl phthalate (DOP) fumes present nuisance problems at Toufen Main Plant and Taoyuan Plant. The fumes can be controlled with properly designed canopy hoods.

J. There were a few locations where plant noise levels over 90 dBA were recorded. However, because workmen's noise exposure times were considerably less than 8 hours per shift, none of the workers surveyed by noise dosimeter study showed excessive noise exposure.

K. Plant lighting levels were inadequate at many locations occupied during the night shift. Better illumination should be provided to reduce accident and increase work efficiency.

L. A strong educational program and a tough policy should be established to encourage and to enforce the wearing of personal protective equipment. The selection of respiratory protective equipment should be based on a thorough evaluation of the hazards involved. A centralized inspection and maintenance program is advisable to assume control of the use, cleanliness, repair, and inventory of respirators and accessory parts.

M. For employees who work in especially hazardous environment, for example, the flake soda workers, the polymerization reactor vessel cleaners, and the compounding ingredient mixing room workers, showers and change of clothing at the termination of an eight-hour work shift should be required.

N. The plant city water distribution system should be thoroughly checked for back siphonage and possible cross-connection with utility and process water.

O. Consumption of food and beverages should be prohibited in any area exposed to toxic materials or substances that may be injurious to health. Drinking water stations should be in clean areas. Common drinking cups and other common utensils should be probihited.

III. VINYL CHLORIDE

A. Observations and Results of Measurements:

Monitoring of vinyl chloride concentrations in production work areas of China Gulf Plastics Corporation's Toufen Main Plant, Taoyuan Plant, and TVCM Kaohsiung Plant was conducted with a portable Century Organic Vapor Analyzer which functions on the principle of flame ionization. This instrument, although nonspecific for vinyl chloride, has good sensitivity (to 1 ppm vinyl chloride), almost instantaneous response, and great reproducibility. Because vinyl chloride is the principle air contaminant at the polymerization plant, the presence of minute amounts of other types of combustible gases and vapors would not significantly contribute interference in the final monitoring result.

1. TVCM Kaohsiung Plant:

TVCM Plant at Kaohsiung is located within a large industrial complex of Taiwan Alkali Works. TVCM produces vinyl chloride monomer by reacting ethylene and chlorine to form ethylene dichloride, and subsequent dehydrochloronation of ethylene dichloride to form VC and HCl. The process units are in the outdoors. Unit operators spend most of their 8-hour shift inside a modern control room well separated from the process area. Vinyl chloride can be present at the dehydrochloronation unit (Pyrolysis Unit) and separation towers through leaks in pipings and vessels. However, no leaks of vinyl chloride were detected from the process equipment when surveyed with Century Organic Vapor Analyzer.

The only significant sources of VC exposures were from the daily routine VC sampling program, and during process equipment maintenance and repair time. The purity of vinyl chloride is checked by sampling the VC pipeline twice per each eight hour shift. Before catching VC into sampling containers, the sampling line is bled for a few minutes in order to obtain a truly representative sample. During the time of bleeding, VC concentration downwind from the

sampling point can be very high (1000 to 10,000 ppm three feet downwind from the sampling point). But the sample collector knows to stay upwind from the sampling point and gets very little exposure.

Overall, it was determined that occupational exposure to vinyl chloride at TVCM Kaohsuing Plant was at minimal levels considering that workers usually spend less than one hour per 8-hour shift at the process area. Mr. C. L. Chow, Plant Manager at TVCM Kaohsiung, was advised to pay extra attention to providing workers with breathing apparatus and protective clothing during routine sample collection and at process equipment maintenance and repair time.

2. Taoyuan Plant:

China Gulf Plastic Corporation's Taoyuan Plant is strictly a fabrication plant which manufacturers PVC films and fabrics from PVC powders and compounding ingredients supplied by Toufen Main Plant. Presently, it has two large calendering machines for sheeting. There is neither vinyl chloride nor polyvinyl chloride resin production at this plant. Vinyl chloride monomer could be present at this plant only as entrained or adsorbed gas molecules on the PVC powders; and escaped to the work environment through evaporation and seepage. However, a careful survey with Century Organic Vapor Analyzer on the PVC powder and at calendering machines detected no trace of vinyl chloride monomer or any other type of combustible organic vapor.

3. Toufen Main Plant:

Toufen Main Plant obtains part of its vinyl chloride monomer from TVCM Kaohsiung Plant through railroad pressurized tank cars. Additionally, it also manufactures part of its VC monomer requirement at the Toufen Plant Site by an old acetylene process. In the process, calcium carbide rocks react with water in the acetylene generator to produce acetylene (C_2H_2) and calcium hydroxide (lime). The acetylene is next reacted with hydrogen chloride gas to form vinyl

chloride over a catalyst surface in the monomer reaction tower. The monomer reaction process unit is outdoors in the open. A few minor leaks of VC monomer were detected at process pumps and valves. However, occupational VC exposure was at a minimum because workers spent virtually no time at the monomer manufacturing unit.

The calcium carbide process to produce acetylene generates a large quantity of waste calcium hydroxide and causes water pollution problems. Furthermore, the acetylene process to produce vinyl chloride is less efficient compared to the ethylene process. Therefore, it is China Gulf Plastics Corporation's intention to phase out the existing carbide → acetylene → VCM process, and to depend on its monomer supply mainly from the TVCM Toufen Plant once that plant is in full production.

The only significant occupational exposure to vinyl chloride occurred at the polymerization plant of Toufen Main Plant. PVC resin is manufactured at Toufen Main Plant by suspension process. In this technique the reaction vessel is first charged with the required amount of deionized water. Then dispersing agents, buffer, and initiator are added. After the reactor vessel is sealed and evacuated to remove oxygen, the VC monomer is piped into the reactor. Polymerization is conducted at controlled temperature under vigorous agitation. At completion most of the unreacted monomer is evacuated and recovered. The polymer and water mixture is centrifuged to separate the polymer from the water. Next the wet polymer cake is air dried to produce PVC powder. There are twelve (12) polymerization reactors at the polymerization plant which is inside a three-story enclosed building. The polymerization plant control room and the tops of the twelve reactor vessels are located on the third floor. Figure 1 shows a corner of the third floor of the polymerization building.

At the end of polymerization reaction and after most of the unreacted VC monomer is evacuated for recovery, the reactor hatch

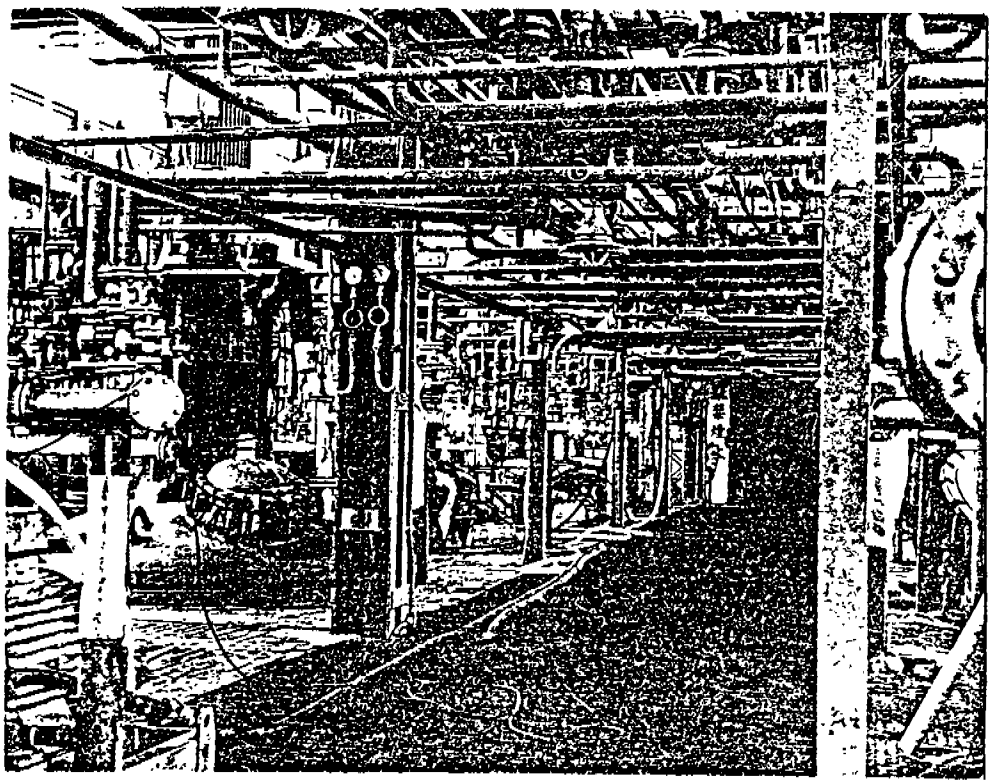


Figure 1 Third Floor of the Polymerization Plant Showing Tops of Reactor Vessels.

cover is opened to bleed the reactor. The remaining unreacted and un-evacuated vinyl chloride monomer bubbles through the PVC and water slurry and escapes to the third floor of the polymerization building through the opened hatch cover.

This bleeding process takes approximately 30 minutes. During this time, vinyl chloride concentrations (as measured with Century Organic Vapor Analyzer 5 minutes after the hatch cover was opened) ranges from 1000 ppm to over 10,000 ppm (1%) at a spot 10 feet away from the opened hatch cover.

During the 30 minute reactor bleeding time water in the form of high pressure jet is used to wet and flush down the PVC scales formed on the upper portion of the reactor walls. This water jet washing process takes approximately 2 minutes. Then the reactor content (PVC and water slurry) is pumped out of the reactor to be centrifuged and dehydrated. The bottom manhole of the reactor vessel is opened, and the empty reactor is purged with large amounts of air for 30 minutes. The purging air is supplied with a big air hose. The air blows into the reactor through the opened top hatch cover and flushes out through the bottom manhole. This air purging of the reactor lasts for about 30 minutes. During this time, vinyl chloride concentration at the hatch cover opening drops from 500 ppm to less than 10 ppm.

Figure 2 shows a reactor in the air purging stage. The reactor hatch cover is open. The larger hose on the left blows air into the reactor vessel while the smaller hose on the right supplies water into the reactor.

After the 30 minutes of air purging, three reactor cleaners are sent into the reactor vessel through the bottom manhole. These three reactor cleaners, equipped with hammer, knives and chissels, and usually wearing nothing but short drawer, hard hat, and a pair of eye goggles, are to manually clean the PVC deposits and scales off the inside reactor walls. The air purging process is kept

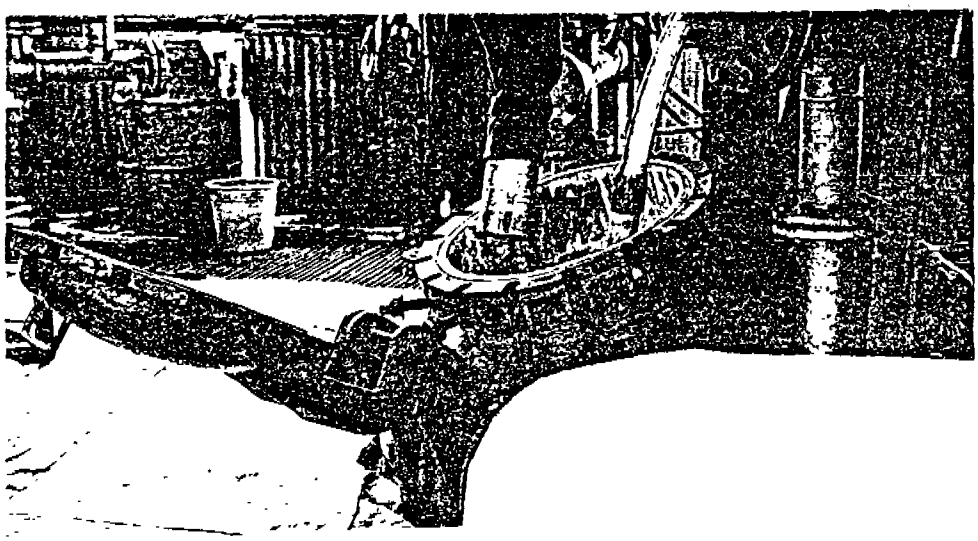


Figure 2 A Polymerization Reactor Vessel During Air Purging.

going during the entire reactor cleaning period. The air purging serves to reduce the vinyl chloride concentrations inside the reactor and to cool the temperature in the reactor. While inside the reactor, the cleaners are exposed to around 10 ppm of vinyl chloride due to the continuous seepage of VC from the PVC scales and reactor walls. It usually takes about 30 minutes for three reactor cleaners to clean a reactor. Figure 3 shows two of the three reactor cleaners, fully dressed, with tools in hands, posing for the picture.

After the built-up PVC scales are removed from the reactor walls through the cleaning process, the bottom manhole is closed and the reactor is ready to reload. Due to shortage of monomer supply, the polymerization plant was operated at less than 50% of full capacity during the month of March, 1974. On the average, only three reactors were cleaned and reloaded per 8 hour shift during the period of this survey.

From the above descriptions of the polymerization process, it is clear that the greatest work area VC concentration and the largest personal VC exposure occurs during the 30 minutes of reactor bleeding time (1000 to over 10,000 ppm measured 10 feet away from the reactor hatch cover). The corrective measure is to bleed the reactor vessel without letting the VC vapors enter the polymerization building. The second largest occupational VC exposure is the reactor cleaning process. However, the presence of around 10 ppm of vinyl chloride inside the reactor vessel due to seepage is more or less uncontrollable, and it appears that the logical solution is to provide the reactor cleaners with proper clothing and respiratory protective apparatus to reduce their VC exposures.

If the polymerization plant were operated at full capacity, there would be 6 to 8 reactors going through the bleeding, cleaning and reloading procedures during every 8 hour work shift. In other words, almost at every hourly interval the vinyl chloride concentration

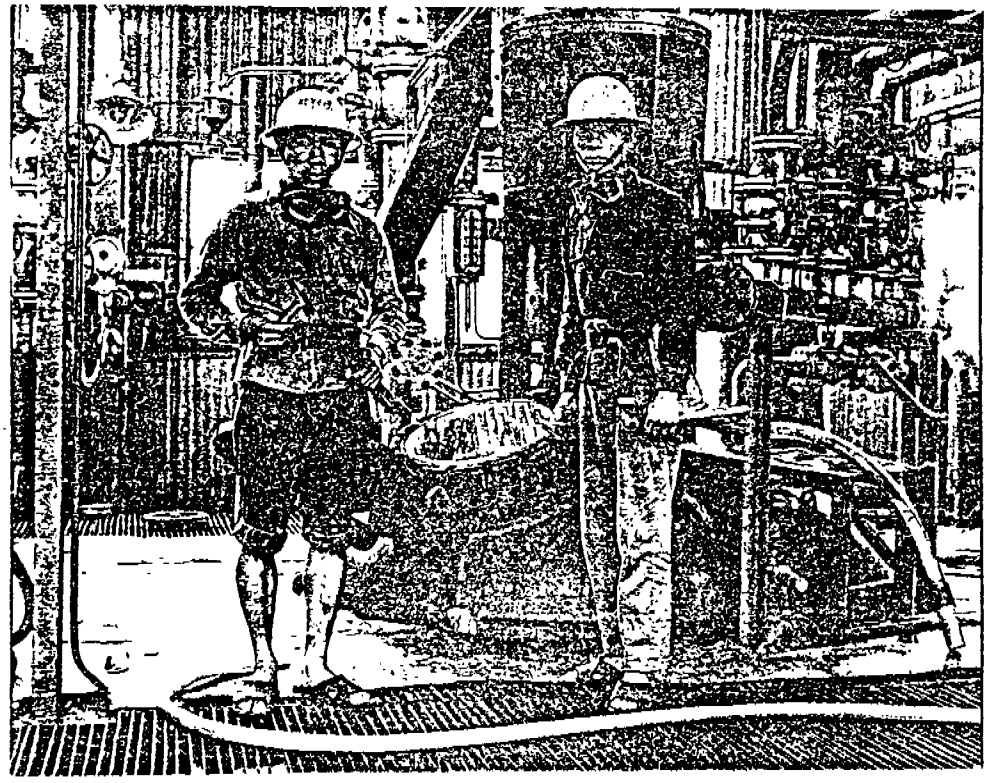


Figure 3 Polymerization Reactor Vessel Cleaners

on the third floor of the polymerization building could reach 10,000 ppm near a bleeding reactor. Therefore, it is not difficult to conceive that the old ACGIH (American Conference for Governmental Industrial Hygienist) recommended standard of 200 ppm for 8 hours, and 500 ppm for ceiling exposure, can be easily exceeded if workers spend an hour or two of their shift time working around the polymerization vessels.

To control vinyl chloride exposure due to reactor bleeding, it was suggested that a special lid for the reactor hatch opening be fabricated. The suggestion was adopted and a hatch opening lid was made a week later. This lid was made in stainless steel and lined with a ring of soft rubber on the bottom surface. The stainless steel metal and the rubber lining was to eliminate any chance of creating sparks when the lid was placed on the reactor hatch opening. Two short pieces of stainless steel pipe were welded on the lid, and another two pieces of PVC pipe were fitted to the stainless steel pipes to make soft, non-sparking seats for connecting the air and water hoses. Figures 4A and 4B show top and bottom views of the special hatch opening lid.

The operating procedure was that immediately after the reactor hatch cover was opened, this special lid was placed on top of the hatch opening. Quickly, air and water hoses were connected to the fittings on the lid. Large amounts of purging air was blown into the reactor and exhausted through a vent pipeline to the outdoors. Figure 5 shows the special lid seated on top of the hatch opening. Purging air was blown into the reactor through the larger (black) hose on the left, while water can be added to the reactor through the smaller (white) hose on the right. The vent pipeline was controlled by valves which are opened before opening the reactor hatch cover. For extra safety precaution, the reactor could be purged with nitrogen before air purging.

The adoption of this special hatch opening lid and the related changes in operating procedures eliminated almost the entire 30

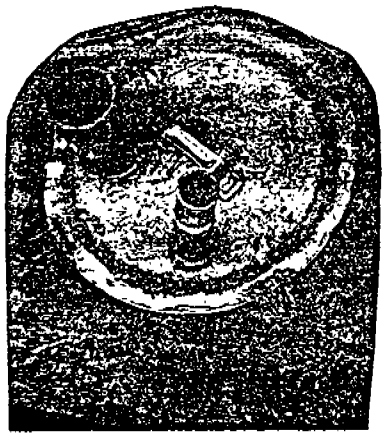


Figure 4A Top View of the Special Reactor Vessel Hatch Opening Lid

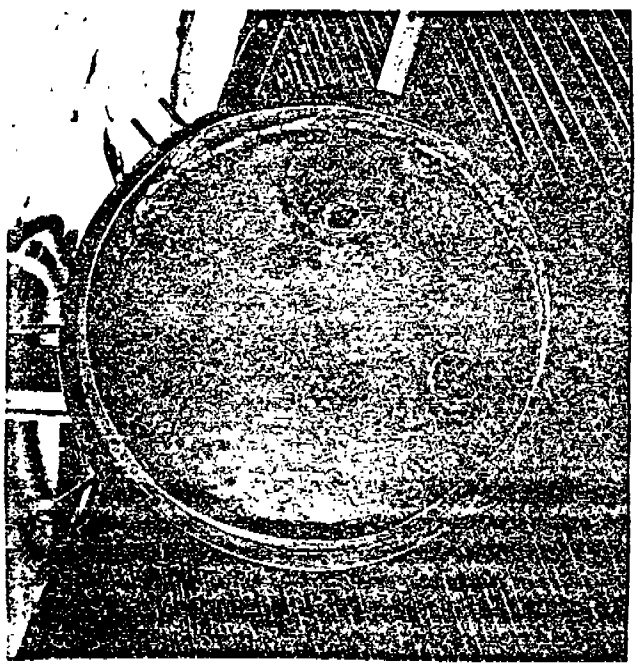


Figure 4B Bottom View of the Special Reactor Vessel Hatch Opening Lid

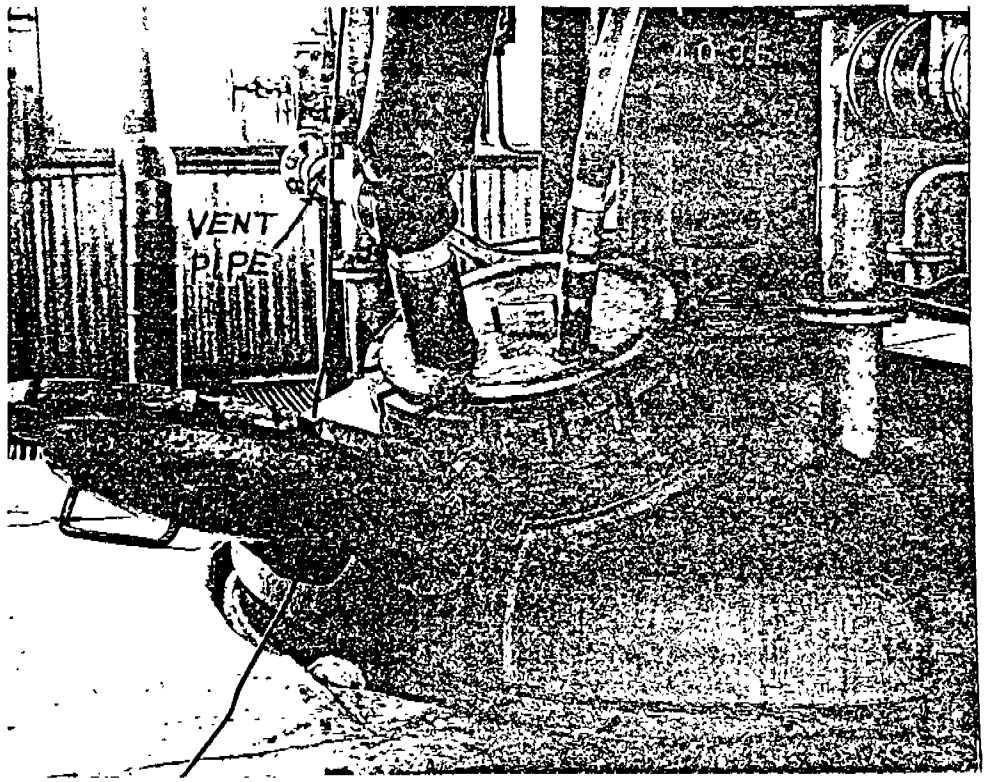


Figure 5 Air Purging of a Polymerization Reactor Vessel with the Special Lid Seated on Top of the Hatch Opening

minutes of the old reactor bleeding time. As a result, there was a drastic reduction of vinyl chloride concentration in the working area, and at no time would the VC concentration go as high as 1000 to 10,000 ppm near the reactor hatch opening.

However, this special hatch opening lid did not remain seated on the hatch opening throughout the reactor bleeding time. This lid has to be removed for about 2 minutes so that a worker can use high pressure water jet to wet and flush down the PVC scales formed on the upper portion of the reactor walls. During this 2 minute interval, the worker was exposed to approximately 500 ppm of vinyl chloride while he held the water hose to do the flushing. The idea of an automatic water jet flushing system was discussed with the plant management. If we cannot adopt some means of automatic water jet flushing technique to replace the manual flushing, then the alternative is to provide this worker with a full-face supplied air respirator during his two minute water flushing operation.

After adoption of this special lid, it is estimated that, even counting the two minutes of lid opening time for water flushing, the time-weighted average concentration of vinyl chloride on the third floor of the polymerization building has been reduced to less than 5 ppm. Considering that the unit workers spend half of their working time inside the enclosed control room, then their 8 hour time-weighted average VC exposure should be less than 2.5 ppm. For the reactor vessel cleaners, assuming full plant production and they spend four hours per shift inside the reactors, their time-weighted average VC exposure should be around 5 ppm.

The most recent United States Emergency Temporary Standard for exposure to vinyl chloride is 50 ppm both as ceiling concentration and as time-weighted average concentration. Judging from results of this survey, Toufen Main Plant should have no difficulty meeting the Emergency Standard as far as 50 ppm time-weighted average concentration is concerned. However, it may occasionally exceed

the 50 ppm ceiling value for short durations; for example, during the 2 minutes water flushing operation.

B. Hazards of Vinyl Chloride:

The hazards of vinyl chloride have been discussed in length during several management meetings both at China Gulf Plastic Corporation's headquarters in Taipei, and at the debriefing session with the Toufen Plant supervisory personnel. In essence, medical and epidemiological evidences have concluded that vinyl chloride is carcinogenic for humans. The cancer, angiosarcoma of the liver, associated with VC exposure is of a very rare type which, unfortunately, is progressive and invariably fatal. Vinyl chloride and/or polyvinyl chloride exposure has also been identified as being associated with occupational acroosteolysis, a progressive abnormality of the skin and bones that is seen most often in the hands and toes of the affected workers.

C. Recommendations:

1. Attached as Enclosure 1 is the U. S. National Institute for Occupational Safety and Health (NIOSH) Recommended Precautionary Monitoring and Control Procedures for Polymerization Processes Involving Vinyl Chloride. All parts concerning VC should be adopted, as written. All parts concerning PVC should also be given careful consideration.

2. Attached as Enclosure 2 is the U. S. Occupational Safety and Health Administration's (OSHA) Emergency Temporary Standard for Exposure to Vinyl Chloride. Until Permanent Standard for Vinyl Chloride Exposure is published by OSHA at a later date, rules and regulations as specified under this Temporary Standard should be observed.

3. Most recent research findings from animal experiments indicate that the 50 ppm level specified in the Temporary Standard may be

too lenient. The Permanent Standard may require industry to meet a much more stringent set of rules and regulations. Therefore, every endeavor is necessary to reduce workmen's vinyl chloride exposure through process modifications and engineering methods of control. For example, use of hydraulic reactor cleaning process (high pressure water-jet system) at B. F. Goodrich Company substantially reduced the number of entries into reactors for manual cleaning. The newly adopted reactor hatch opening lid could stand more improvement in the area of perfect seal and safety and fire prevention precautions.

4. All VC and PVC stacks and vents should be extended to higher elevations above the roof level to take advantage of the natural dispersion. This would reduce the ambient air concentrations in the vicinity of the emission sources.

5. A lot can be improved in the area of local exhaust and general dilution ventilation to reduce the VC concentrations in the Polymerization Plant. All windows of the Polymerization Building should remain open except during typhoons or storms.

IV. DUSTS OF LEAD, CADMIUM, AND BARIUM

A. Observations and Results of Measurements:

Only in a few applications can PVC be used without a number of additives which enable the PVC compound to be processed and converted into the finished products. These additives which include plasticizers, stabilizers, lubricants, fillers, pigments, etc., are called compounding ingredients. Because PVC resin is unstable at the elevated temperatures required to process PVC compounds, stabilizers are added to avoid the disintegration of PVC resin and to prevent discoloration. At Toufen Plant, the long-chain aliphatic acid salts of lead, cadmium, and barium are used as stabilizers. The annual consumption of stabilizers are 80.5 tons of lead stearates, 30.5 tons of cadmium stearate, and 39.5 tons of barium stearate. (1973 figures).

The compounding processes start in the Compounding Ingredients Mixing Room (配料室) which is located on the second floor of the Extrusion Plant. Accurate quantities of powders of lead, cadmium, and barium stearates are weighed according to recipe. The weighing was done under a canopy hood which exhausted to the outdoors. The average hood face velocity of this canopy hood was inadequate (only 60 feet per minute). To make things even worse, the hood face was at least 3 to 4 feet above the surface of dust generation. Therefore, the dust cloud generated during the weighing operation was outside the zone of influence of the canopy hood. It was observed that the fine dusts in suspension drifted away and dispersed, while the coarse particles settled on the floor and other surfaces.

After the compounding ingredients were measured, they were dumped into several mixers where they were thoroughly mixed together. Figure 6 shows one of the mixers in operation. The mixer operator was wearing a dust mask which should reduce dust inhalation hazard for him. The lids of the mixers remained open during the mixing process.

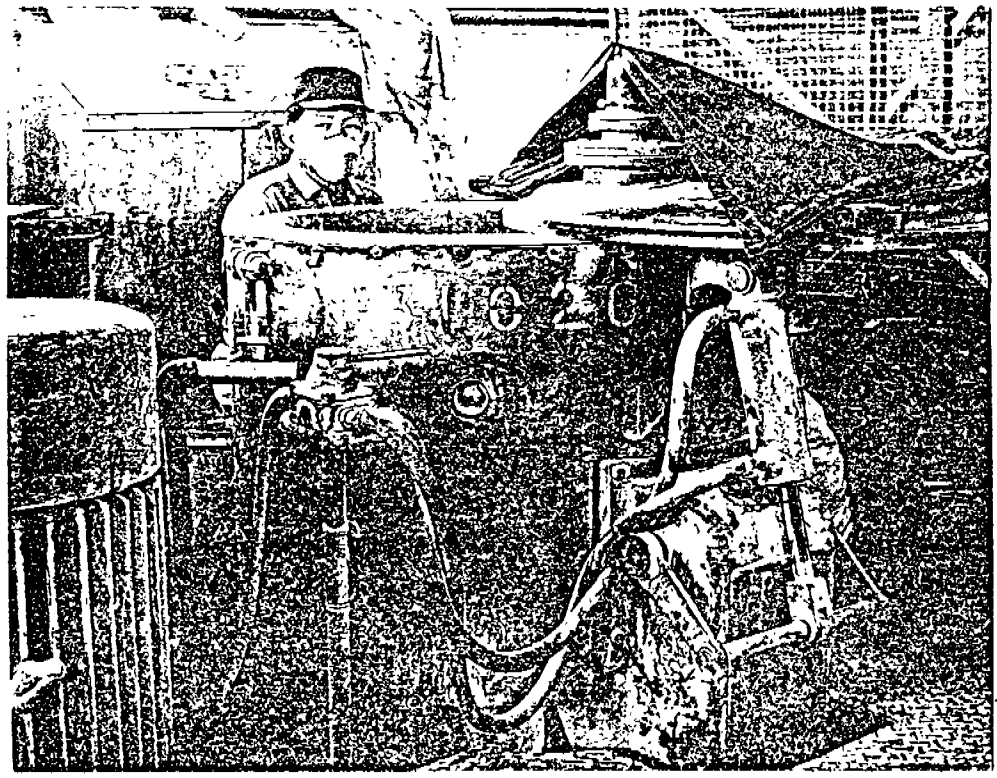


Figure 6 Compounding Ingredients Mixer

Although no dust clouds were observed above the mixers, it appeared that the real fine particles could still escape out of the mixer and float in the air. A few air samples were taken with MSA lead dust filter papers in the vicinity of the mixers. The lead dust concentration was measured to be around 0.05 to 0.1 mg/M^3. The current U. S. Standard for occupational exposure to lead compound is at 0.15 mg/M^3. Therefore, although the lead in air concentrations around the mixers were within the permissible level, still they were too close to the limit to be disregarded.

Next the mixed materials flowed in pipelines to a packaging station on the first floor of the Extrusion Plant. The materials dropped out from a filling spout which was controlled with a sliding gate. Bags and barrels were filled at the packaging station. Large clouds of dust were generated during the filling and packaging operation. At the packaging operator's breathing zone, the lead dust concentration was estimated to be around 2 mg/M^3 when measured with MSA lead filter paper. The packaging operator usually wore a dust mask when he was filling the bags and barrels. However, since this packaging station was not separated and confined, but right in the open area of the Extrusion Plant, any dust generated at this station would be dispersed and carried away by cross-drafts and air currents. Eventually, the toxic dusts would affect the many unprotected and unsuspecting workers elsewhere in the Extrusion Plant.

There was another work station on the first floor of the Extrusion Plant where compounding ingredients were mixed and transferred into barrels. Figure 7 shows the operation at this work station. An operator was using a pail to scoop up the mixed compounding ingredients from the storage bin and dump them into large barrels. A huge cloud of dust was observed around this work station. Again the operator was wearing a dust mask for his own protection, but the wind carried the dust to the nearby unprotected extrusion machine workers.

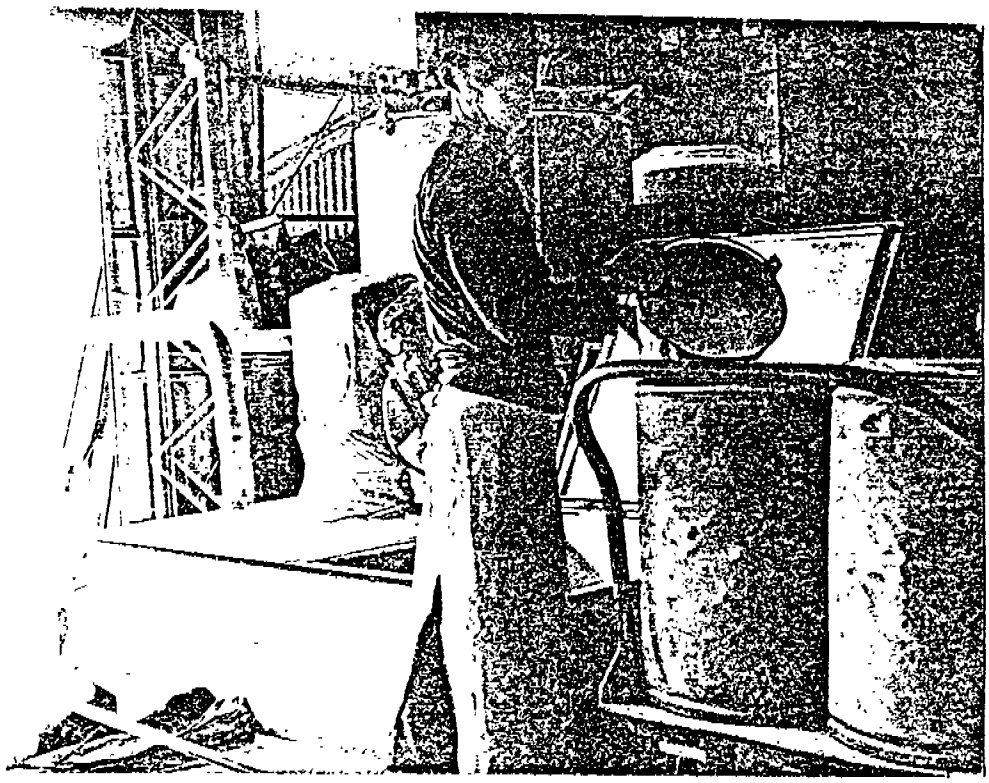


Figure 7 Manual Transfer of Powdery Compounding Ingredients at the Downstair Mixing Operation.

The personal dust exposures were evaluated by drawing a measurable amount of air through a pre-weighed, 37 millimeter Millipore filter mounted in an open-face filter holder. The holder was fastened to the worker's lapel and air drawn through the filter by means of a battery-powered personal sampler pump. The increase in filter weight was an indication of the breathing zone dust concentration. Table I summarizes results of the personal dust exposure study. Please note that the measurements were in terms of total dust concentrations. No doubt that at least 95% by weight of the dusts caught on the filters were PVC powders. But even if only one percent by weight of the dust collected were lead, cadmium, and/or barium dusts, the permissible occupational exposure limits for these compounds were exceeded in most samples. The permissible concentration for inert dusts (dusts that cause no adverse effects on lungs, and do not produce diseases, but only cause nuisance; e. g. calcium carbonate powders, cement dust, starch, etc.) is set at 10 mg/M^3. Therefore, even if all dust collected on the filter samples were inert dust, the threshold limit value (TLV) was still exceeded.

B. Hazards of Lead, Cadmium and Barium Dusts:

Lead poisoning has always been one of the most important occupational diseases, and industrial lead poisoning almost always results from inhalation of lead-containing dust or lead fumes. Early signs and symptoms of lead poisoning may include a fall-off in physical fitness, fatigue, headache, abdominal pain, constipation, decrease in appetite and stomach pain. The disease may progress to greater severity, manifesting itself in the gastro-intestinal tract and in the peripheral and central nervous system. The present TLV for lead dust is 0.15 mg/M^3.

The inhalation of dust of cadmium primarily affects the respiratory tract. Symptoms of mild acute cadmium poisoning include respiratory

Table I RESULTS OF DUST ANALYSIS CHINA GULF PLASTICS CORPORATION, TOUFEN MAIN PLANT
DUST SAMPLES COLLECTED ON FILTERS March 8, 1974

Employee Number	Job and Work Location	Field Sample No.	Sample Time	Personal Exposure of Dust Concentrations (mg/m^3)*
58127	Operator, 3102D	28E	1 Hr. 45 min.	11.58
56118	Operator, 3111EFGH	28F	1 Hr. 37 min.	24.11
55163	Operator, 3102C	28K	1 Hr. 44 min.	151.45
55161	Operator, 3115A	28L	1 Hr. 40 min.	6.09
58128	Operator, 3106	28Q	1 Hr. 40 min.	29.86
60125	Operator, 3102B	28R	1 Hr. 43 min.	31.72
62154	Barrel Filling	28X	1 Hr. 48 min.	83.03

* Most of these samples were overloaded, therefore, materials may have been lost from the filters before analysis.

tract irritation, sore and dry throat, chest pain and cough. Severe cases may involve bronchitis, pneumonitis, and pulmonary edema. Chronic intoxication manifesting itself in pulmonary emphysema, renal damage and proteinuria. The present U. S. Occupational Exposure Standard for cadmium dust is 0.2 $^{mg}/_{M^3}$.

The soluble barium compounds (barium stearate) are highly toxic. These compounds exert stimulant action on all forms of muscle, and may cause irregular contractions, coronary constrictor action in the heart. The U. S. occupational exposure standard for soluble barium compounds is 0.5 $^{mg}/_{M^3}$.

C. Recommendations:

Because lead, cadmium, and barium compounds are necessarily present and have to be processed in dry, powdery conditions, the elimination of hazardous exposure to these toxic dusts is primarily an engineering problem. Following are certain general principles of procedure, and specific suggestions related to conditions at Toufen Plant:

1. Hazardous dust generating processes should not be distributed throughout the plant. Preferably, they should be localized in a few specific areas where they can be subjected to concentrated procedures of control. For example, it may be possible to relocate the downstair mixing operation (shown in Figure 7) to the second floor Compound Ingredients Mixing Room. Or it may be possible to bring the downstair packaging station and the downstair mixing operation together for unified treatment.

2. Dusts of lead, cadmium and barium must be prevented from entering the air of an occupied workroom where workers are unprotected against dust inhalation. This is achieved by conducting the dusty operations in conditions of isolation, enclosure, and exhaust ventilation. For example, should the downstair packaging station and the downstair mixing operation remain where they are, then it is necessary that both operations be isolated from the rest of the

Extrusion Plant by installing walls and ceiling around them. We shall have, in effect, two small rooms within the large plant area. The two small rooms shall be constantly under negative air pressure by installing adequate and proper type of exhaust ventilation.

3. Efficient exhaust draught should be provided at the point of material transfer such as chutes and filling spouts. Figure 8 shows an example of an overhead exhaust hood which can be fitted to the gravity flow filling spout at the downstair packaging station to control the dusty operation. For the type of barrels used at Toufen Plant, a hood exhaust capacity of 300 cfm (cubic feet per minute) is sufficient, and the minimum duct velocity should be 3500 fpm (feet per minimum) to prevent dust deposition and settling.

4. For the manual transfer of powder from the storage bin to barrel by scoop or shovel, the arrangement of a slotted hood as shown in Figure 9 is suggested.

5. The lid of the compounding ingredients mixer should be closed during the mixing stage to reduce unnecessary escape of fine dusts into the working area. If it is important for the mixer operator to watch the mixer inside during mixing, then a transparent, plastic lid should be used. The slotted hood as shown in Figure 9 can also be adopted for the mixers during charging powder to the mixer.

6. The canopy hood for the compounding ingredients weighing operation was too small in exhaust capacity and located too high for efficient dust control. If the same hood is to be used for the operation, then the exhaust fan should be replaced by a larger centrifugal fan that is capable of delivering approximately 3000 cfm at roughly 1.5 inches (of water) fan static pressure. This would increase the hood face velocity to about 300 feet per minute, a minimum requirement for the control of toxic dusts. However, merely increasing the hood exhaust capacity will not produce an efficient exhaust draught. The most important thing to do is to lower

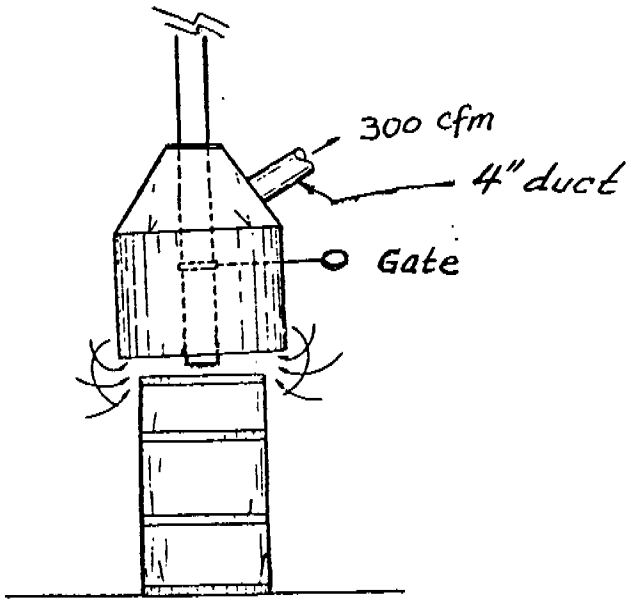


Figure 8 Dust Control by Hood around Filling Spout

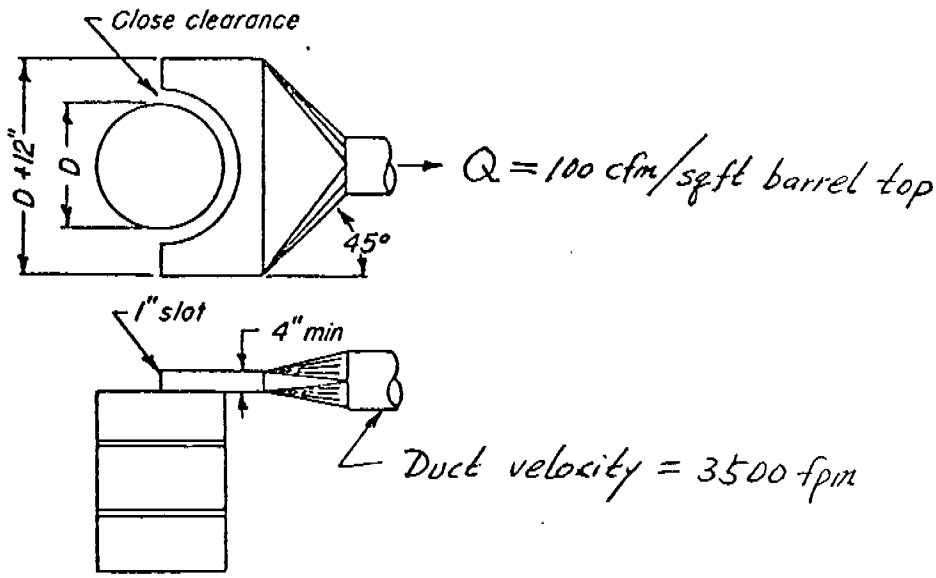


Figure 9 Slotted Hood for Manual Loading of Powders

the hood closer to the zone of dust generation. For the control of toxic dust, the capture velocity (sometimes called control velocity) at the point of dust generation should be at least 75 fpm. Therefore, for face velocity at 300 fpm, the hood shall be lowered to within 18 inches from the actual source of dust generation to obtain the required 75 fpm capture velocity. It is not necessary to physically drop the hood down to the 18 inches above the zone of dust generation. Instead, we can hang long strips of heavyweight flexible PVC leather on the existing hood. This would have the same effect of lowering the hood face down without causing inconvenience in the weighing operation. Figure 10 shows a rough sketch of this hood, with hanging strips of PVC drapery. However, it is important that the operator can work efficiently with his head outside the hood so that he will not breathe excessive dust.

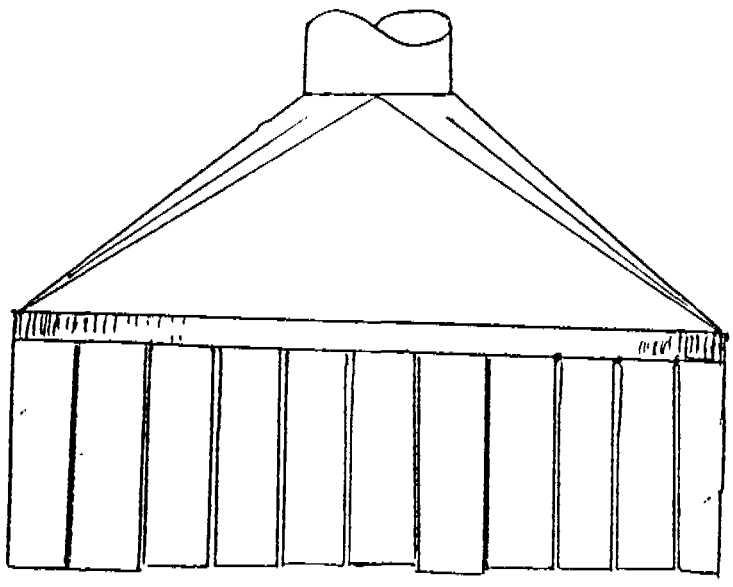


Figure 10
Canopy Hood with Hanging Strips of PVC Drapery

7. A far better hood arrangement would be to replace the existing canopy hood with a side-draft hood or a floor level laboratory hood. Figure 11 illustrates the difference between an overhead canopy hood and a side-draft hood. The side-draft hood can remove the dust before it enters the breathing zone of the worker. Figure 12 shows the sketch of a recommended exhaust hood which can be used for replacing the existing canopy hood.

8. It is important to exercise great care to prevent the reintroduction of exhausted, contaminated air back into the workrooms or other occupied area. The exhaust stack shall be extended well above the roof level to avoid wash-down of the exhausted air by local wind turbulence (suggest minimum stack height to be 15 feet above the tallest adjacent building). The desirability of collecting exhausted dust so as not to contribute to air pollution in the neighborhood should be considered, especially if required by Taiwan's air pollution control regulations.

9. The workers who are exposed to toxic dusts should wear protective respirators which should be washed or renewed at least once a week. It should be emphasized that the selection, maintenance, replacement, as well as all decisions as to when and how the respirators are to be used, must be set up under the control of trained and responsible personnel.

10. Adequate sanitary facilities should be provided. Workers should be encouraged and educated to wash before eating. Certain groups of workmen who are subject to gross contamination should change clothing completely when going to work, and take a shower and change at the end of the day's work. For this group, double lockers for the two sets of clothing are needed. Workers must not eat in the dust contaminated workrooms.

11. Work areas associated with lead, cadmium and barium processes should be kept free of dust deposits by either wet cleaning or by vacuum cleaners.

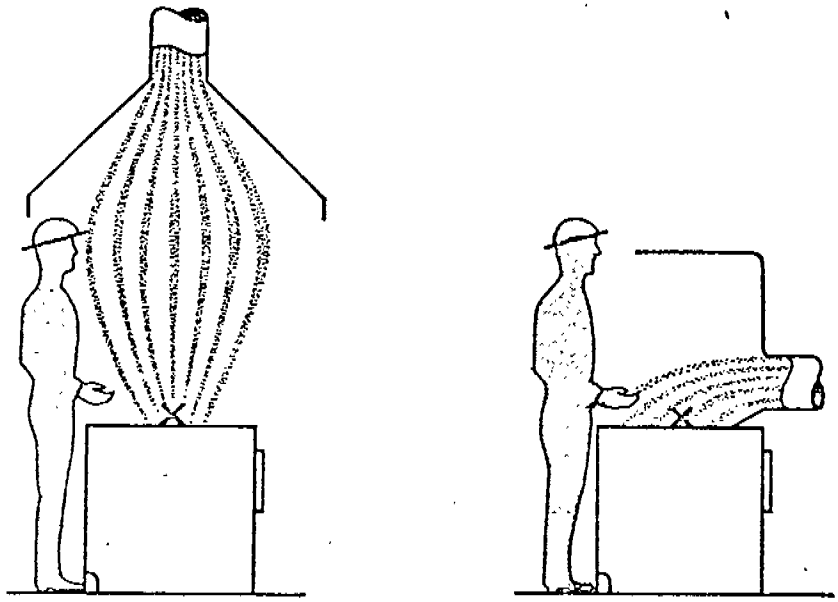


Figure 11 A correct exhaust ventilation device should remove the dust before it enters the breathing zone of the worker.

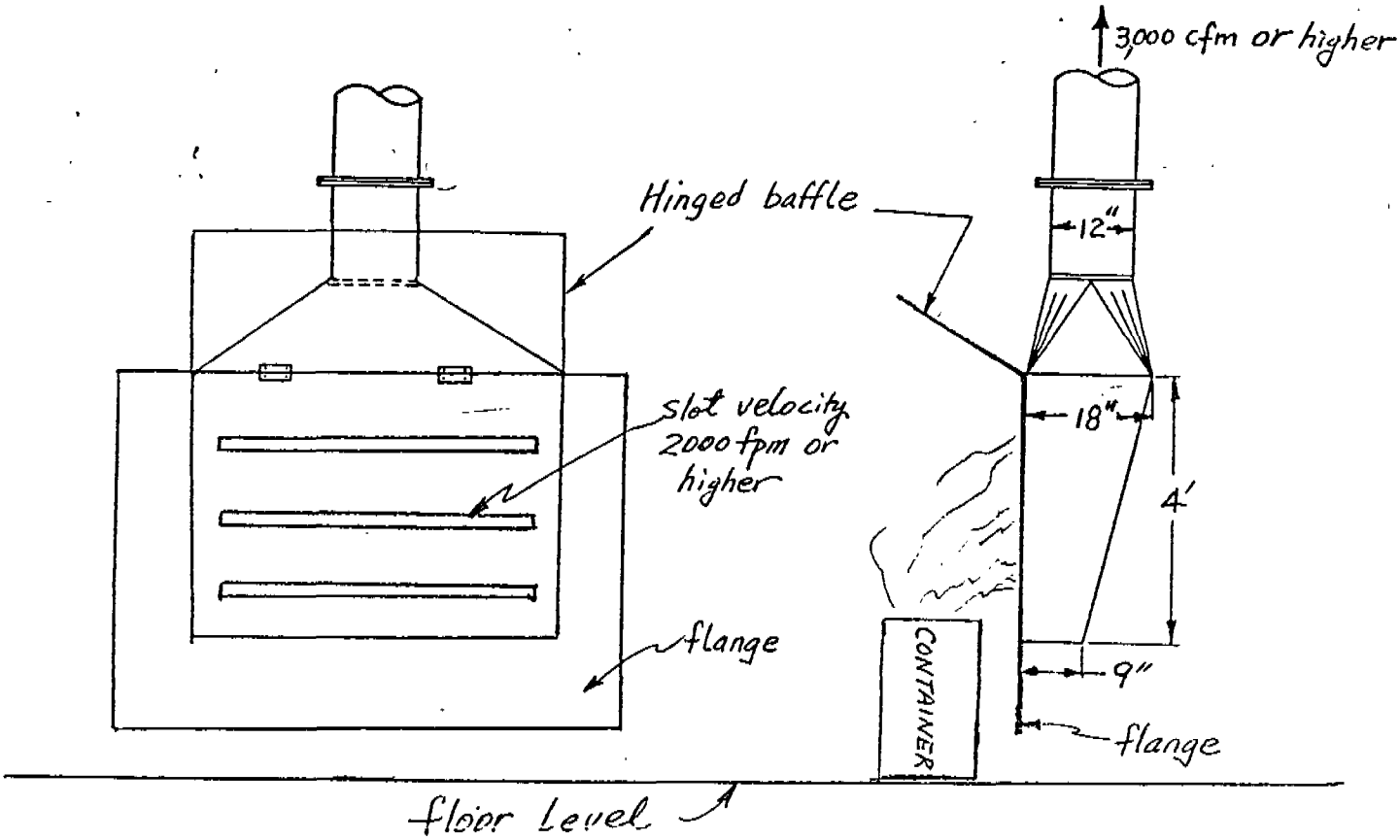


Figure 12 Suggested Side-Draft Hood for Control of Lead, Cadmium & Barium Dusts.

V. INDUSTRIAL SOLVENTS

A. Observations and Results of Measurements:

Industrial solvents are used at Toufen Main Plant for a variety of purposes. Different forms of surface coatings are made possible by solvents, such as printing inks, color paints, and spreading preparations for PVC films and fabrics. Solvents are also used at Catalyst Plant and at R & D Pilot Plant as reagents or to promote a desired chemical reaction. Table II lists the major types of solvents used, their applications, and the annual rates of consumption for the year 1973.

Due to work order shortage, the Flexible Products Fabrication Plant (軟質工廠) was operated at less than half capacity during March, 1974. In fact, the whole plant was shut down for about a week, and many processing machines were either idle or under maintenance and repair during the whole period of this industrial hygiene survey. Nevertheless, based on the limited sampling results obtained, it can only be concluded that very serious solvent exposure hazards existed at the Flexible Products Fabrication Plant.

MEK, toluene, MIBK, and cyclohexanone were used at a surface treating machine and two printers at the PVC Leather Unit. Around the Two-Color Printer (3233A), the total solvent vapor concentrations, as measured with Century Organic Vapor Analyzer, varied between 400 and 800 ppm. At the time of this measurement, only a single color was applied with this Two-Color Printer. The machine operator remarked that solvent vapors were much worse when two colors were printed. Around the Single-Color Printer (3233B), total solvent vapor concentration ranged from 200 to 500 ppm. The worst condition was recorded at the Surface Treating Machine where total solvent vapor concentration went as high as 1,000 ppm; and toluene alone, as measured with MSA toluene detector tubes, was around 200 ppm.

None of the above machines was ventilated with local exhaust hood, and the general ventilation condition inside this building was grossly

TABLE II SOLVENT CONSUMPTION IN 1973

Solvent	Consumption (Tons/year)	Application
Methyl ethyl ketone (MEK)	166	Printing, Surface treating and Coating machine
Toluene	163	Printing, Surface treating and Coating machine
Cyclohexanone	7	Surface treating machine
Butyl acetate	49	R & D Dept. polymerization pilot plant
Ethyl acetate	5.3	R & D Dept. polymerization pilot plant
Methyl isobutyl ketone (MIBK)	7.8	Printing machine & polymerization catalyst plant
Trichloroethylene	3.9	Polymerization catalyst plant, co-polymer
Methanol	84	VCM purifying plant
Dimethylformamide (DMF)		Will be used in the new-built polyurethane plant
Tetrahydrofuran (THF)		Will be used in the new-built polyurethane plant

insufficient for diluting solvent vapors to permissible levels at workers' breathing zone. Each machine was attended by four workers per shift. The workers usually stayed very close to the machine and therefore received full dosage of solvent vapors without much relief or resting time during their eight hour shift. The above mentioned vapor concentrations, as commented by one worker, were nice and comfortable compared to situations during last summer when the weather was hot and humid and the plant was in full operation.

Figure 13 and 14 shows the two huge printers inside the Printing Shop (印花工場): a Four-Color Printer (3224A) by the outside wall, and a Six-Color Printer (3224B) by the inside wall neighboring the Laminating Shop (貼合工場). Concentrations of solvent vapors ranged from 100 to 1,500 ppm at various locations under and around the Four-Color Printer. The Six-Color Printer was not running at the time, and vapor concentrations under and around this machine were around 100 ppm. Neither of these printers was ventilated.

Very little solvents were actually consumed inside the Laminating Shop. However, because the Laminating Shop was connected to the Printing Shop by two open doorways, the Printing Shop solvent vapors entered the Laminating Shop through these two doorways, affecting workers in this otherwise relatively clean shop. Figure 15 shows a view of the Laminating Shop during lunch time. Three workmen were eating lunch beside Laminating Machine 3226A.

The situation at the Printing Shop Office was not much better. Although this office was fully enclosed with door and windows. The total solvent vapor concentration as measured on March 7, 1974 at 3:50 p.m. was 100 ppm.

The polymerization pilot plant in the R & D Department was not in operation during the time of this survey. Therefore, conditions of solvent usage at that location were not determined. Operations involving trichloroethylene at Catalyst Plant were also not observed. However, I was informed that trichloroethylene was used only in closed system and should not create inhalation hazards.

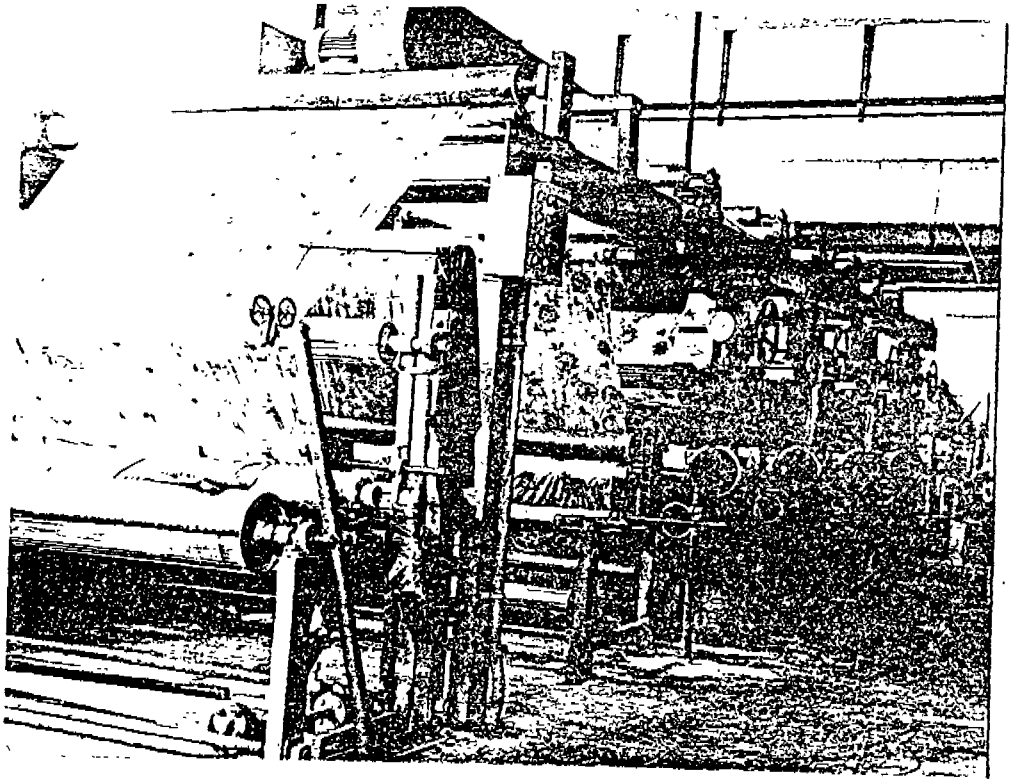


Figure 13

Four-Color Printer (3224A)

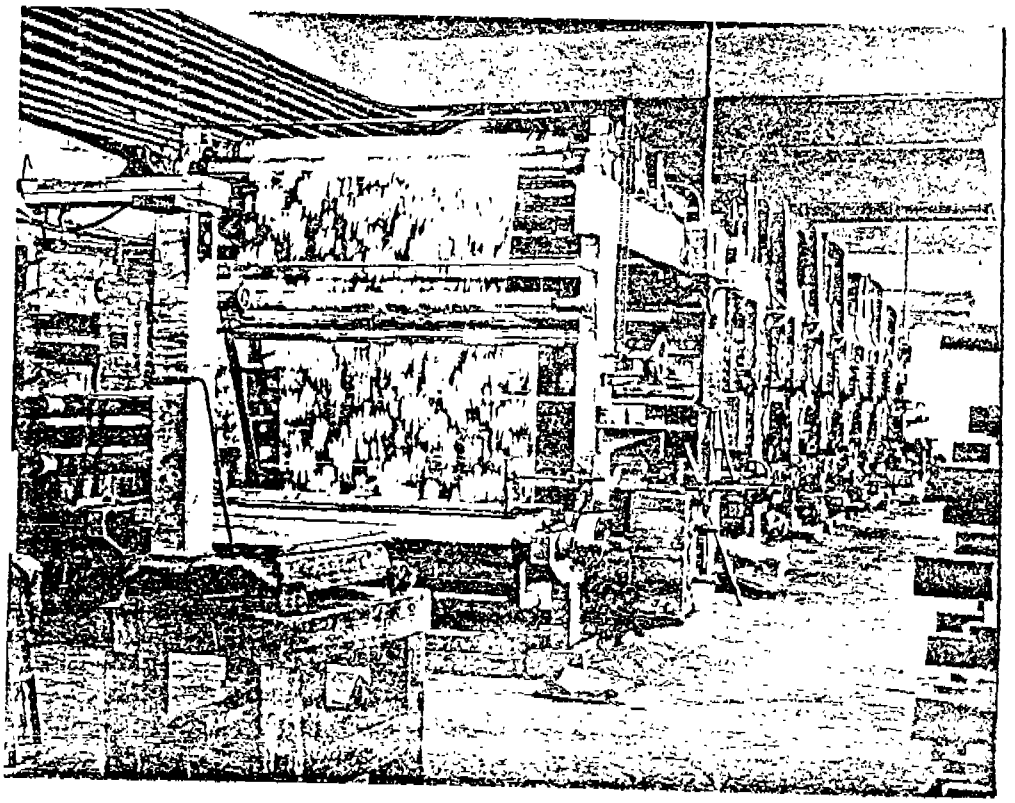


Figure 14

Six-Color Printer (3224B)

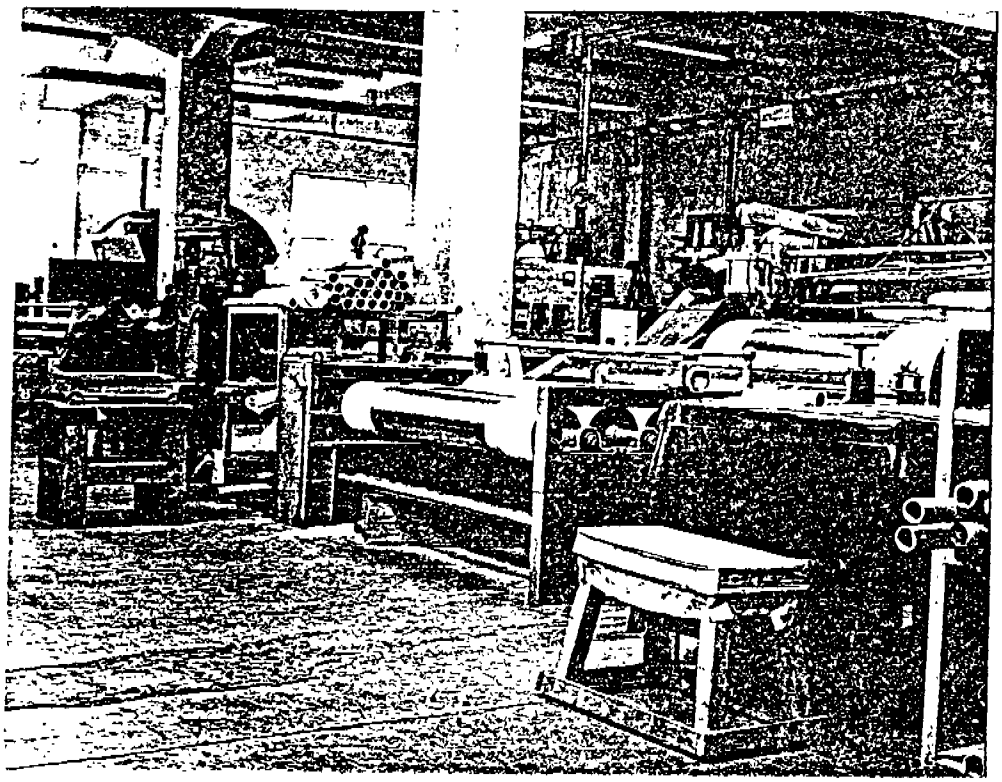


Figure 15

Laminating Shop

B. Solvent Hazards:

For the various operations at Toufen Main Plant which involve the use of industrial solvents, the worker may come in bodily contact with the liquid solvents or inhale the solvent vapors. When vapors are inhaled, they pass rapidly into the general circulation and are distributed to the heart and the central nervous system. The property of causing narcosis is common to most industrial solvents. In addition, many solvents have irritating effects on eyes, nose, and throat. Certain solvents have toxic properties which, though being slower in onset and usually insidious, may cause irreversible damage to liver, kidney, or other important organs of the body.

While inhalation of vapor is the major hazard of solvents, contact of the liquid with the skin is also hazardous because it may result in dermatitis. The skin becomes cracked, chapped, and vulnerable to other harmful irritants and sensitizers.

To give guidance concerning the extent to which the atmospheric contamination should be controlled in the working environment, figures indicating the maximum permissible concentrations for the many industrial solvents have been published. The maximum permissible concentrations are sometimes referred to as threshold limit values (TLV). Table III lists the solvents used at Toufen Main Plant, their major toxic effects, and their maximum permissible concentrations for occupational exposure of 8 hours per day, five days per week.

When two or more types of solvents are present, their combined effect, rather than that of the individual solvents, should be given primary consideration. In the absence of information to the contrary, the effects of the different solvents should be considered as additive. For example, workers are allowed to be exposed to 100 ppm of Toluene or 200 ppm of MEK per an 8 hour working day. However, if both 100 ppm of toluene and 200 ppm of MEK are present in the environment, then the duration of exposure should be limited to 4 hours per day. In general, if the sum of the following fractions $\frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots \frac{Cn}{Tn}$ exceeds 1.0, then the

TABLE III TOXICITY OF INDUSTRIAL SOLVENTS USED AT TOUFEN PLANT

Solvent	Primary Toxic Effects	Maximum Allowable Concentration TLV
Methyl ethyl ketone (MEK)	Eye, nose and throat irritation at 100 ppm, headache, nausea and vomiting reported at 500 ppm.	200 ppm
Toluene	Headache, nausea, dizziness, impairment of coordination at less than 200 ppm. Might cause liver damage. Also, eye, nose, skin irritation.	100 ppm (average) 200 ppm (ceiling)
Cyclohexanone	Throat irritation at 50 ppm. Caused liver & kidney damage in experimental animals at 190 ppm.	50 ppm
Butyl acetate	Throat irritation at 200 ppm. Narcotic effects at high concentrations.	150 ppm
Ethyl acetate	Mild eye, nose, and throat irritation at 400 ppm.	400 ppm
Methyl isobutyl ketone (MIBK)	Eye, nose, and throat irritation; headache and nausea reported at 100 ppm. Narcotic in high concentrations.	100 ppm
Trichloroethylene	Chronic exposure causes liver damage. Narcotic effects at 50 ppm. Acute narcotic effect causes death from respiratory failure if exposure is severe and prolonged.	100 ppm
Methanol	Avoid ingestion. Damage on optic nerve. Headache and blurred vision are frequent system of mild intoxication.	200 ppm
Dimethylformamide	Causes gastric irritation, nausea and headache. Liver and kidney damage reported.	10 ppm
Tetrahydrofuran	Irritating to eyes and mucous membranes. Narcotic in high concentrations. Causes liver and kidney damage in animals.	200 ppm

threshold limit of the mixture should be considered as being exceeded. C_1, C_2 ··· indicates the observed atmospheric concentrations of individual compounds, and T_1, T_2 ··· the corresponding threshold limit values.

Ordinarily, the possible hazards related to solvent usage in the Toufen Plant can be due to chronic exposure, i. e., repeated exposure for long periods of time to concentrations above the maximum permissible levels but below the concentrations which cause severe illness or intolerable discomfort. However, because of accidental spillage, carelessness or ignorance, the amount of vapor in the atmosphere may be extremely high and far above the maximum allowable concentration. Such an acute exposure may cause unconsciousness or even death if the individual is not promptly removed to an uncontaminated atmosphere and given proper medical attention.

Unless otherwise indicated, threshold limit values (TLV) are for industrial exposures of 8 hours per day, 5 days per week. However, the normal work schedule at China Gulf Plastics Company is 8 hours per day, 6 days per week. This increase in work time could result in over-exposure if the environmental concentrations of the air contaminants were not reduced accordingly. For example, the normal TLV for toluene is 100 ppm; but for 6 days per week work schedule, the permissible environmental level of toluene should be reduced to approximately 83 ppm.

C. Recommendations:

1. To prevent the exposure of workers to harmful concentrations of solvent vapor. The most effective measure is by means of ventilation, usually local exhaust. In local exhaust ventilation, the air-borne solvent vapors are removed or captured from the environment at or as close as possible to the source. Local exhaust ventilation should be installed on each and every one of the printers and surface treating machines. However, due to the huge physical dimensions of these machines, and the necessity for employees to work under, around, and sometimes even above the machines, the selection and design of efficient and economic local exhaust systems can be time-consuming and requires professional expertise.

2. Printers 3233A, 3233B and the nearby Surface Treating Machine may be controlled with overhead canopy hoods. The lower the canopy and the more completely the equipment is enclosed, the better is the control of vapors. Very large canopy hoods cannot be served effectively by a single suction pipe. There is a strong tendency for the flow to concentrate over the area nearest the pipe mouth to the detriment of more distant areas. Therefore, for the above mentioned large size printers and surface treating machine, the hood should be broken down into a plurality of smaller hoods, each with its own suction pipe. Another method of achieving even air distribution is by incorporating a slotted suction duct in the neck of the hood as shown in Figure 16 below. The cross section of this slotted exhaust duct should be as great as possible, approaching that of a plenium chamber, in order to promote uniform slot velocity from end to end.

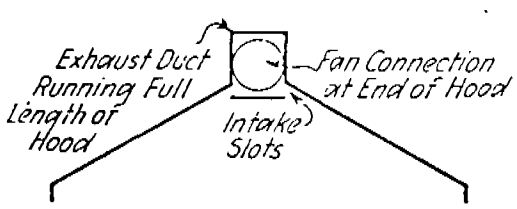


Figure 16

3. For the Four-Color Printer (3224A) which is located very close to the Printing Shop outside wall, a series of propeller type wall fans mounted on the outside wall should make it possible to exhaust the solvent vapors to the outdoors before they can accumulate to hazardous concentrations in the workman's breathing zone. Figure 17 shows 3224A is exhausted by seven wall fans, each approximately 18" in wheel diameter, powered by a 1/4 horsepower direct drive totally enclosed motor. Choose a low fan speed (around 1200 rpm) to obtain longer service life. The exhaust capacity for each fan should be about 2000 cfm at approximately 1/4" fan static pressure. This 1/4" SP is for the movable louver installed on the outdoor side of the fan. The louvers may be required for the typhoon season or during the time when the fans are not in service.

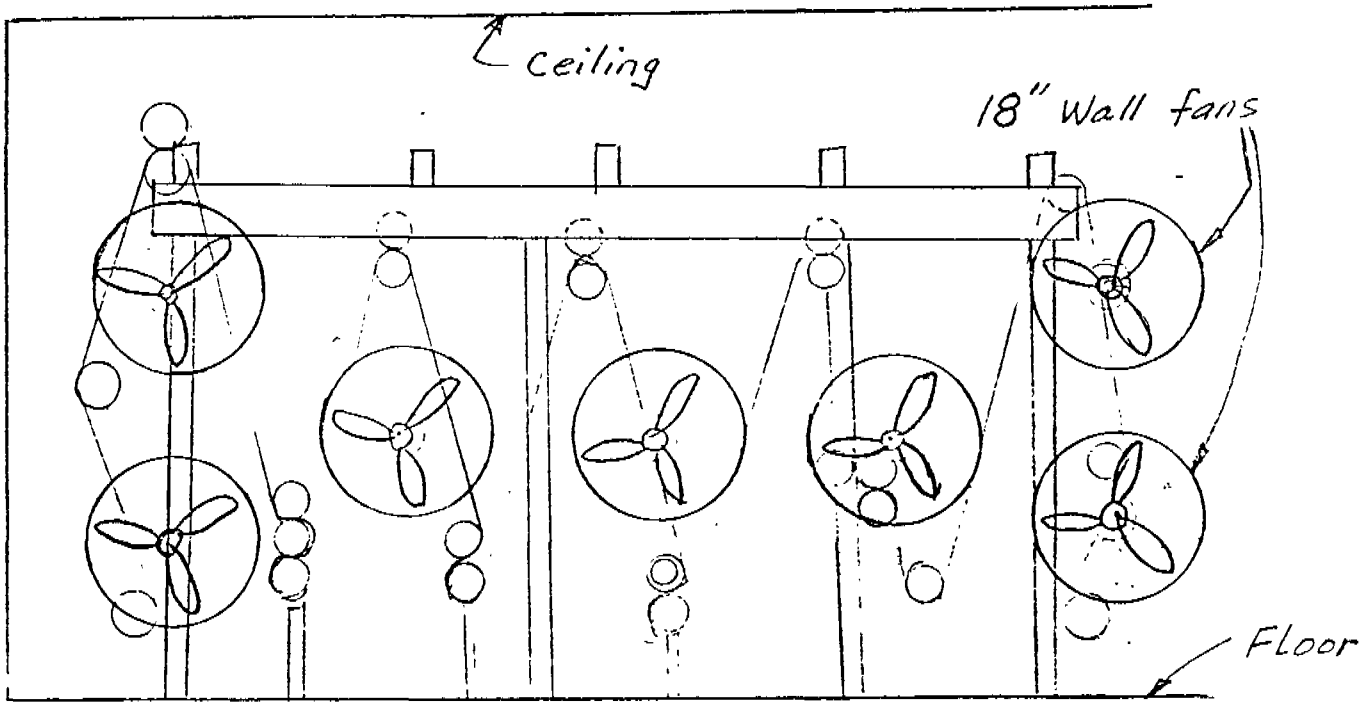


Figure 17

Suggested Ventilation for Four-Color Printer (3224A)

4. For the huge six-color printer (3224B) which is located close to the inside wall, there is very little headroom available for overhead suspended hoods. As suggested by Mr. Wilbur Shyeh, General Factory Manager, we may be able to utilize the two or three foot gap between the printer and the wall for instalation of a side-draft local exhaust system. For such a long machine we may even have to use two separate local exhaust systems each servicing half the length of the machine. Large plenum and slotted air intakes are necessary in order to achieve uniform air distribution. Again, it would take a good deal of engineering experience and detailed calculations to design an efficient and economic system for this machine.

5. If we cannot prevent air movement from one workshop to another by segregating air intakes and confinement, then it is important to design the general dilution ventilation system in such a way that the air movement is from cleaner workplaces to dirtier workplaces. For example, large quantities of Printing Shop air exhausted directly to the outdoors would create a general air movement from the much cleaner Laminating Shop to the more contaminated Printing Shop.

6. Engineering controls for solvent vapor should be used wherever feasible to maintain solvent vapor concentrations below the prescribed limits. Appropriate respirators should be provided and used for the nonroutine operations and during the period when installation of ventilation system is pending. Gauze type dust masks are totally ineffective in solvent vapor control. Gas masks and chemical cartridge respirators for organic solvents should be provided. Please refer to the attached Industrial Hygiene Standard No.23 for selection of appropriate respirators.

7. Administrative controls in the form of job rotation can also be used to limit each worker's exposure within the permissible limit. However, please bear in mind that workers at Toufen Plant routinely work six days a week (sometimes even seven days a week). Therefore, the permissible exposure level should be reduced accordingly.

8. General housekeeping should be strengehtned in the Printing Shop and around machines where solvents are used. Emphasis shall be placed upon cleanup of spills. Such items as rags, mops, clothing shall be inside closed containers. Lids should be used to completely cover the solvent tanks and containers when they are not in use.

9. For those employees whose work requires continued exposure to liquid solvents, they should be provided with impervious clothing, gloves, or coverings to protect the potentially exposed area of the body. Solvent-wetted clothing, unless impervious, shall be removed promptly.

10. Glasses, preferably shatter-resistant and with side shields, should be worn when there is a danger of liquid solvents splashing into the eye.

11. Avoid unnecessary skin contact with solvents. Solvents should never be used to clean hands, as this will defat the skin and leave it open to other injurious agents with resultant irritation and dermatitis. Wear gloves or use protective creams where skin contact is unavoidable. Report any irritation of the skin, and other symptoms, to the plant physician for immediate treatment. Prompt care will avoid delayed and more serious consequences.

12. Drench-type showers, eye-wash fountains, and cleansing facilities should be installed and maintained to provide prompt, immediate access by the workers. Consumption of food and beverages in the work area should be prohibited.

13. Fire and explosion hazards of industrial solvents are well known. These hazards may be increased under improper conditions of storage, by heat treatment, or by chemical reaction with other chemicals. Smoking materials, including personal matches and lighters should be prohibited in all areas where solvents are used. Appropriate extinguishants should be readily available for solvent fires. Maintain only the necessary amount of solvents at workplace. Larger amounts

should be stored in a stockroom. Storage area should be well-ventilated. No doubt most of these safety and fire-prevention related suggestions have already been adopted by the Plant management.

VI. MERCURY

A. Observations and Results of Measurements:

Toufen Main Plant has a Chlor-Alkali Unit where chlorine is manufactured by the electrolysis of brine. Sodium hydroxide and hydrogen are simultaneously produced as by-products. Figure 18 shows the general layout of the mercury cells inside the Brine Electrolysis Building. On the lower portion of the photo is the new expansion section showing foundations for the future mercury cells.

In the mercury cell working on brine, the cathod consists of continuously circulating mercury and the anode of graphite. When the salt in solution is decomposed, the chlorine is liberated as gas. The sodium ion accepting an electron and forming a sodium metal ion, which dissolves in the mercury to form amalgam. The sodium amalgam is then transferred by tilting the cell to the denuding chamber containing water, where the sodium metal reacts to form hydrogen gas and a solution of caustic. Figure 19 and 20 shows the longitudinal views of a mercury cell from the brine inlet end (head box) and from the amalgam decomposer end (end box), respectively.

Working area atmospheric concentrations of mercury vapor at the Brine Electrolysis Building were measured with a J-W Mercury Vapor Detector (Model MV-2, Sensitive Ranges: 0-0.2 and 0-1.0 mg/M^3 of mercury). Along the side aisle near the head boxes of mercury cells, mercury concentration varied between 0.03 to 0.05 mg/M^3. At the center aisle near the end boxes of the mercury cells, mercury concentration varied between 0.2 to 0.5 mg/M^3, with average concentration estimated at 0.25 mg/M^3. The high capacity wall fans were turned on, and about half of the windows in the Electrolysis Building were open. It is conceivable that, if the wall fans were off and windows were closed, the working area mercury vapor concentrations could accumulate to much higher levels. In the United States, the Threshold Limit Value (TLV) for 8 hours per day, 40 hours per week occupational mercury exposure standard is 0.05 mg/M^3.

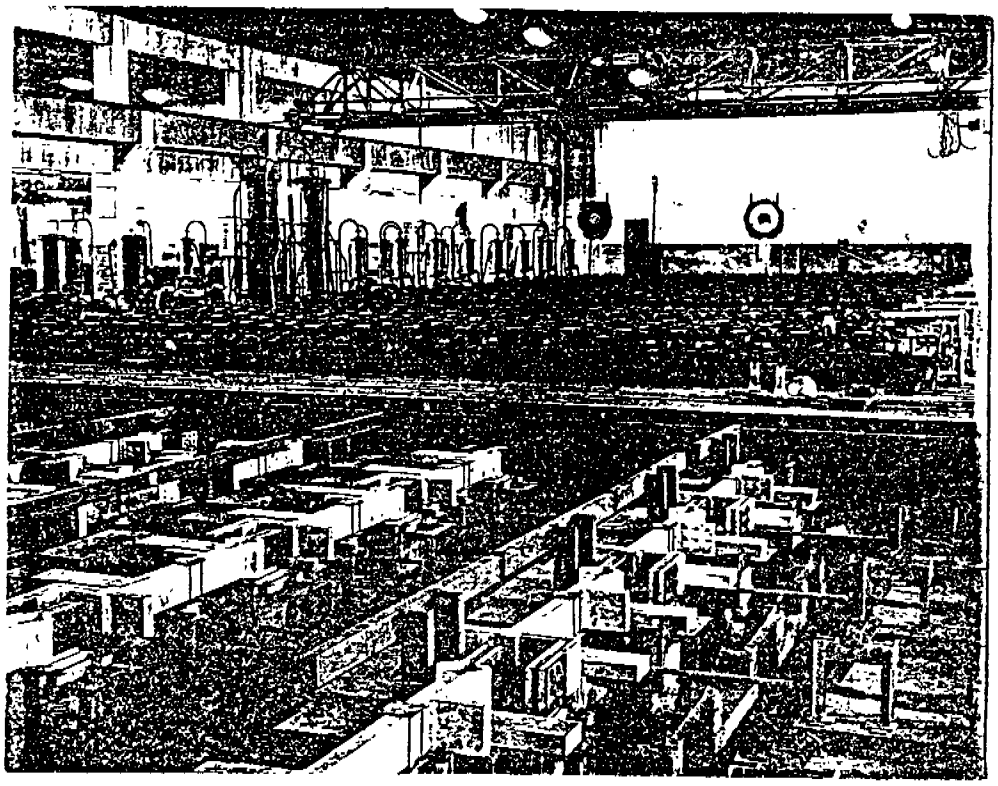


Figure 18 Mercury Cells Inside Brine Electrolysis Building

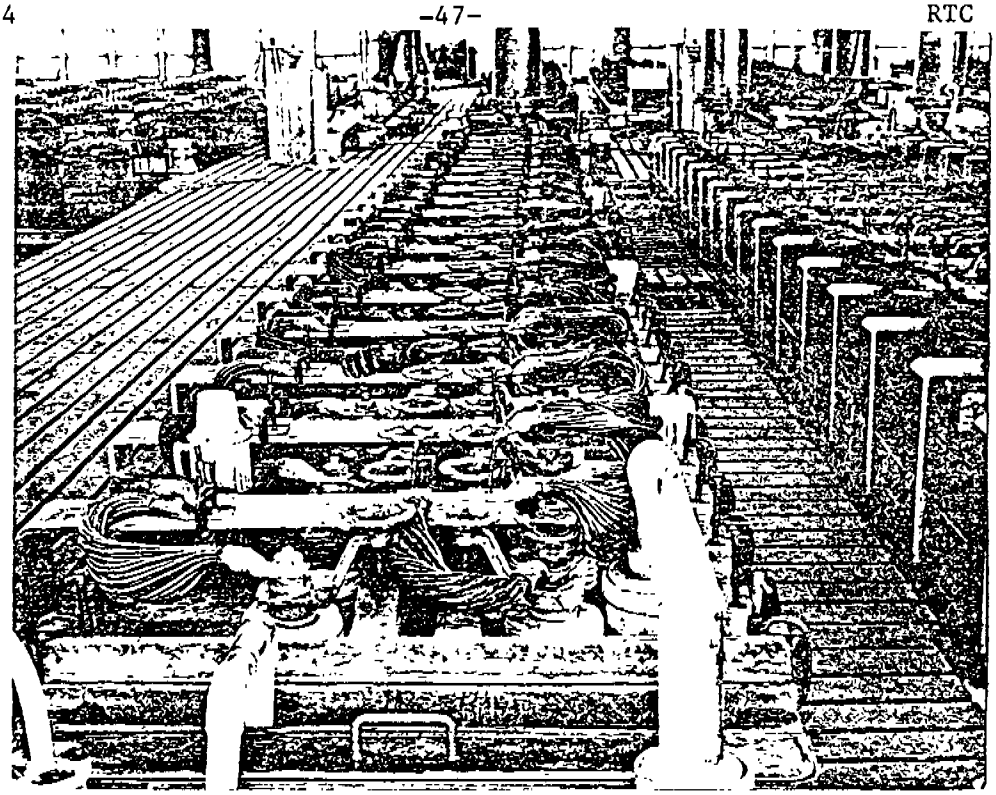


Figure 19

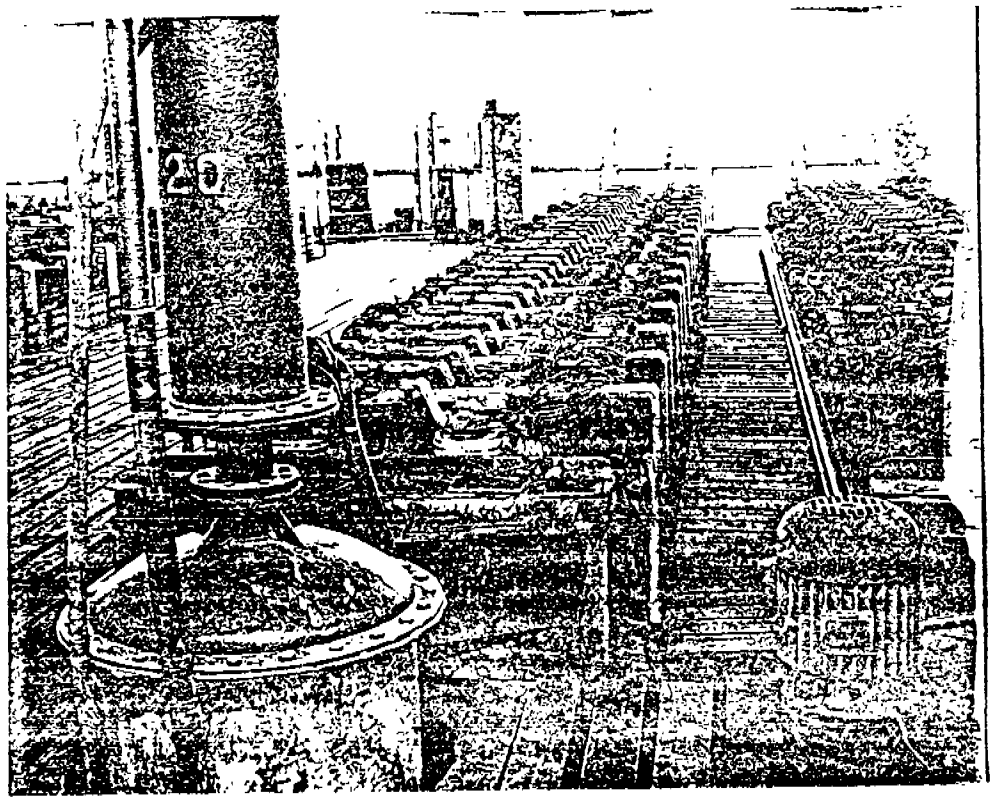


Figure 20

Longitudinal Views of Mercury Cells

Located in the basement of the Brine Electrolysis Building is the flake soda production and packaging facility. Due to leaks and spills of the mercury cell above, drops of mercury metal were observed to scatter everywhere on the basement floor and in the drainage ditches. Concentrations of mercury vapor ranged from 0.12 to 0.15 $^{mg}/_{M^3}$ at the work station near the flake soda machine where three employees worked to attend the machines and to bag the flake soda. Above the waste water drainage ditch inside the basement, the mercury concentration was measured at 0.2 $^{mg}/_{M^3}$. Figure 21 shows a worker squatting inside a shallow concrete pit to pack flake soda into bags. Although the outdoor air was rather cool, the air in the basement was warm, humid and stuffy. This was due to poor air circulation, water dripping from cell room above, wet floors, and steam and heat generation from the flake soda machines.

B. Mercury Hazards:

Mercury is readily volatilized in air at normal temperatures. The primary route of entry is by inhalation, although percutaneous absorption of metal and ingestion of soluble mercury salts are also possible, considering that some workers were observed to wear no shoes, and that food and beverages were consumed at the workplace.

Occupational poisoning due to mercury or its inorganic compounds is usually chronic in form. Chronic excessive exposure to mercury compounds may result in one or more of the three classical signs of gingivitis, tremor and emotional instability. Headaches, insomnia, digestive disturbances, renal damage, hearing impairment, restriction of visual fields have also been described in the medical literature.

C. Recommendations:

1. In view of the fact that mercury vaporizes at normal temperatures, the mercury cells should be routinely examined for leaks and gaps. Try to reduce the time of exposing the mercury bed during mercury cell maintenance.

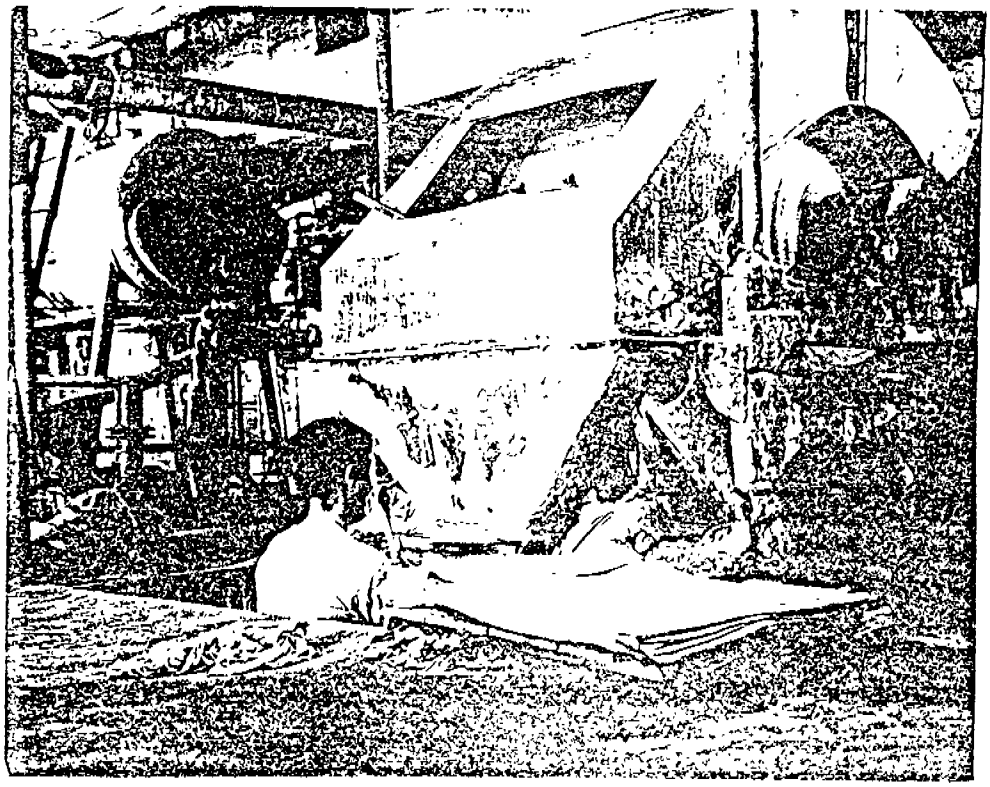


Figure 21 Flake Soda Operation

2. Ventilation is the prime control measure to reduce the work area mercury vapor concentration. The existing four wall fans should be kept on, blowing fresh air into the building continuously. All windows should be open to promote air circulation. Additional wall fans should be installed on both sides of the new expansion section of the mercury cell room, preferably blowing in from one side and exhausting out through the other.

3. Because mercury concentrations were the highest along the center aisle, a local exhaust system in the form of a down-draft, metal grilled hood along the length of the center aisle can also be considered as an alternate form to provide the high standard of ventilation. An additional advantage of this local exhaust system is that, if properly designed and balanced, the same system can serve to exhaust the mercury cell room above and the basement down below where the flake soda production station is located.

4. The basement of the Brine Electrolysis Building should have more air circulation and/or exhaust ventilation. This can be achieved by removing a large portion of the basement walls on all sides. Additional alleviation of mercury exposure can be provided by installing forced ventilation system at the work station.

5. Scrupulous cleanliness and personal hygiene are of the essence wherever there is contact with mercury. Work areas should be regularly cleaned to remove mercury deposits that might vaporize and contaminate the air. Workers should wash thoroughly or, preferably, shower at the end of each work shift. Adequate washing facilities should be provided and the importance of good dental hygiene should be stressed.

6. In view of the importance of the skin as a route of absorption for all mercury compounds, workers must wear shoes in the basement of the Brine Electrolysis Building. It also makes good sense to have separate lockers for street and work clothes to prevent contamination of the former and also to prevent the introduction of the mercury compound into the worker's residence.

7. Food and beverages should be consumed only in an area away from mercury contamination. Workers should be educated to thoroughly wash their hands before eating.

8. Where attempts to reduce atmospheric concentrations of mercury to less dangerous levels have not been successful, workers' total exposure can be reduced by limiting working hours in dangerous areas through administrative methods such as job rotation.

VII. PLATING ROOM

Metal cleaning and plating processes are conducted in open-surface tanks, some of these involve heat and gassing of the liquid. Gassing may cause formation in the air over the tank of a mist of the liquid in the tank. Rate of gassing depends on rate of chemical or electrochemical action and therefore depends on the material treated and the solution used in the tank.

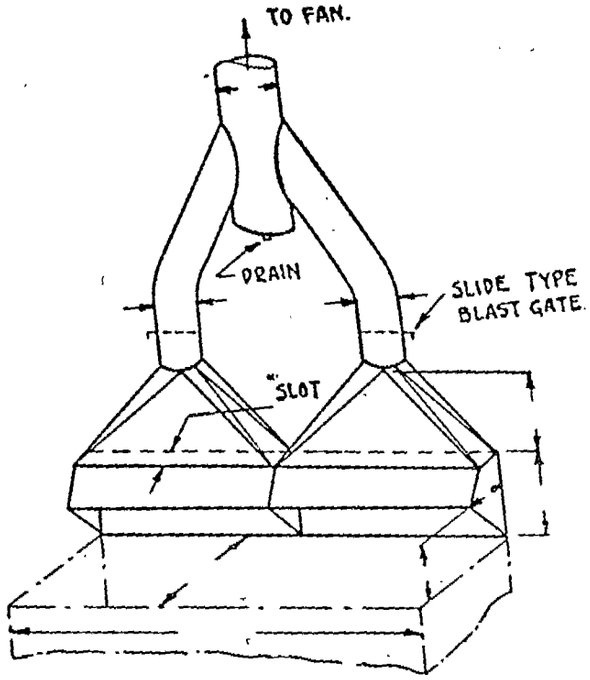
The chrome plating tank containing chromic-sulfuric acids required good tank-ventilation control. One of the side slots on the existing downward lateral exhaust slots on this tank was removed. This slot should be replaced because the tank is too wide for a single slot on one side of the tank to control gassing from the opposite side of the tank.

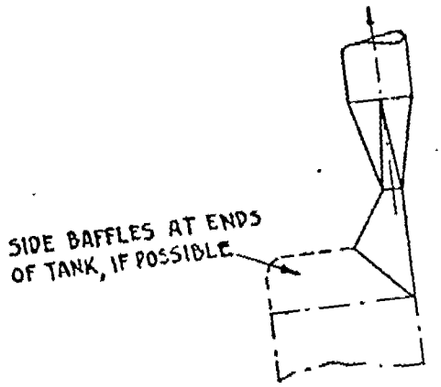
Suggested minimum exhaust requirements for the chrome plating tank should be based on 150 cubic feet of air per minute per square feet of open tank surface. Slot velocity should be maintained at approximately 2000 ft per minute. Slot width should not be less than 1" to offset reduced slot area which normally results from the deposited salts in the slot opening.

Phosphoric acid solution is used to remove light rust on steel in a dipping tank. Usually the operation does not produce harmful gases, vapors, or mists that require control measures other than protection from splashing and contact with the acid. If mists, fogs, or elevated temperatures are involved, ventilation control is necessary.

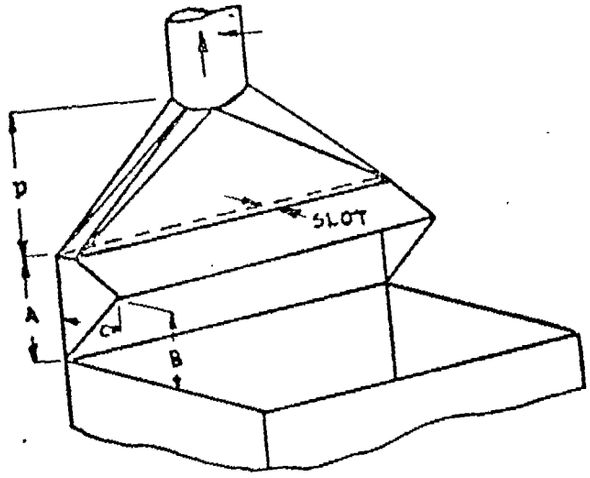
It is good practice to vent the cyanide bath which contains sodium and copper cyanide. It is of the greatest importance that they be maintained well on the alkaline side and protected from accidental addition or accumulation of acid, which might release potentially fatal concentrations of hydrogen cyanide. Overflow or drippings from the cyanide bath should not be permitted to mix with acid overflow and drippings from the adjoining acid tanks.

Figure 22 shows the recommended ventilation for cyanide bath and acid dip





SIDE VIEW OF TANK AND HOOD



HOOD DIMENSIONS, INCHES.

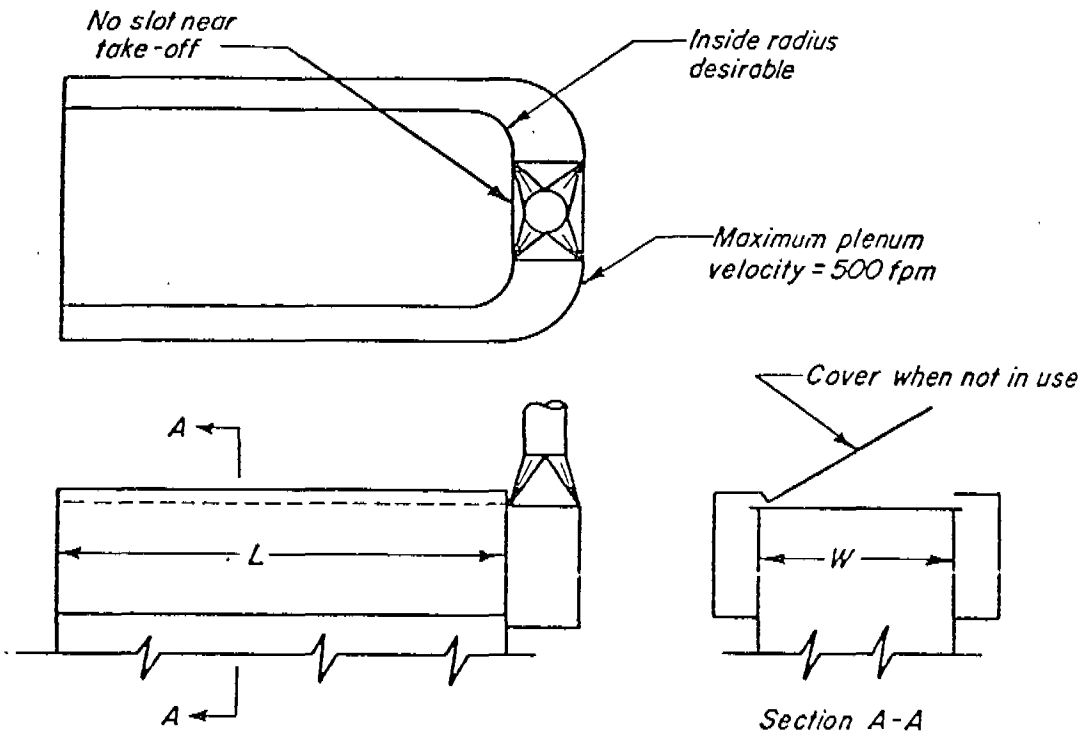
TANK WIDTH	A	B	C	D
24	12	8	9	19
30	16	12	9	19
36	20	12	9	19

Figure 22 Recommended Ventilation for Cyanide Bath and Acid Dip Tank

tanks. However, effective exhaust for these types of operations can also be provided by lateral tank exhaust. Figures 23 and 24 illustrate several approaches in designing the lateral tank exhaust. It is desirable to have the hoods, ducting and exhaust fans made of plastic or other corrosion-resistant material. The existing small wall fan in the plating room should remain continuously in operation even when there is no plating or metal cleaning activities inside the plating room.

Eye goggles should be provided and be required to be worn when working inside the plating room. Good head and face protection from splashes of corrosive chemicals can be provided by the combination of safety hard hats and a plastic face shield. The wearing of acid-proof elbow-length gloves, apron, boots should also be strictly enforced. Wet, slippery floors and the lifting of heavy objects present daily risks to the worker. An effective accident control program should be carried out by supervisory personnel and workers.

Emergency flood shower and eyewash fountains are absolutely required in the plating room. These shall be routinely tested for proper functioning after installation.



$Q = 50LW$

Slot velocity = 1000 fpm maximum

Entry loss = 1.78 slot VP + 0.25 duct VP

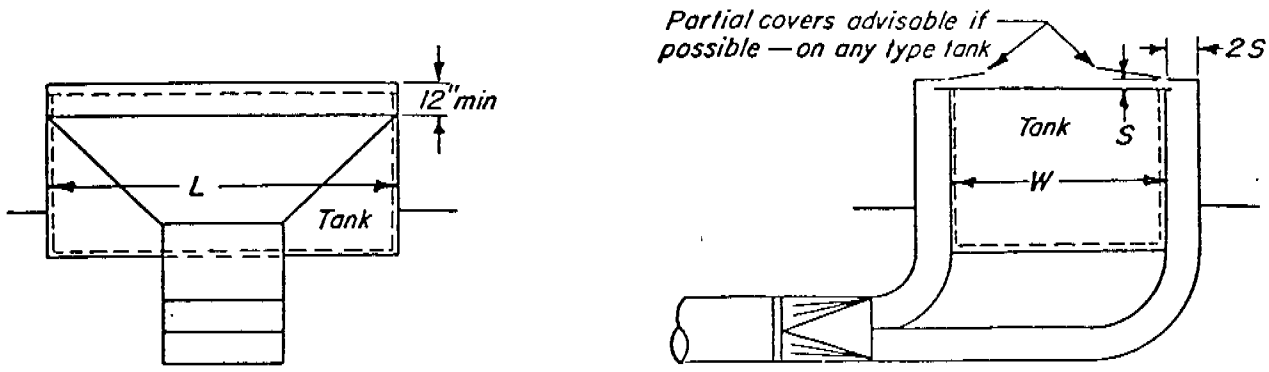
Also provide:

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.

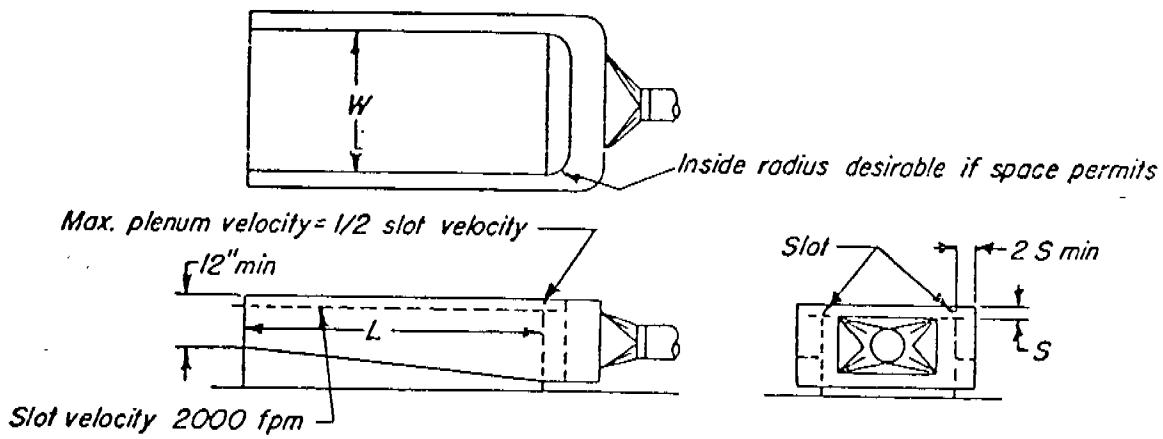
NOTE: Provide downdraft grille for parts that cannot be removed dry; Q = 50 cfm/sq ft grille area.

Figure 23

Lateral Tank Exhaust



DOWNWARD PLENUM



END TAKE-OFF

Figure 24 Other Approaches in Designing the Lateral Tank Exhaust

VIII. DOP FUMES

Large amounts of dioctyl phthalate (DOP) are used as plasticizer at both Toufen Main Plant and Taoyuan Plant. Apart from the resin, the plasticizer is the most important ingredient in a flexible vinyl compound. It determines the flexibility and influences the other properties such as tensile strength, modulus, hardness, and elongation at break. DOP is a light colored, oily liquid and has a mild oily odor. Its toxicity has been widely investigated, and it seems clear that there is no reason for predicting that the use of this material in industry would be associated with health hazards.

Unfortunately, DOP has a tendency to fume under heat treatment. High concentrations of DOP fumes, although low in toxicity, can be obnoxious and sometimes even nauseating. Figure 25 shows heavy DOP fumes generated from one of the calendering machines at Toufen Plant. The machine was vented with an overhead canopy hood. However, because of inadequate exhaust capacity, and because the hood was located too high above the machine, visable fumes could be seen curling outward under the rim of the hood to escape into the general room air.

Canopy hoods are the correct choice of hood type for the control of DOP fumes because the fumes are generated from heat processes, and they will rise due to elevated temperature. However, the canopy hood should be lowered as close to the source of fume generation as possible. Hanging strips of PVC leather around the hood edges, as shown in Figure 10 on Page 28 , would achieve the effects of lowing the hood down without interfering with machine accessibility.

The recommended face velocities through canopy hoods for hot processes depends on distance of the vertical rise of the fume and the temperature difference between the hot surface temperature of the machine and the ambient air temperature. For less than 200° F difference in temperature, and for canopy hood mounted not more than three feet above the surface of fume generation, a hood face velocity of 150 feet per minute should be

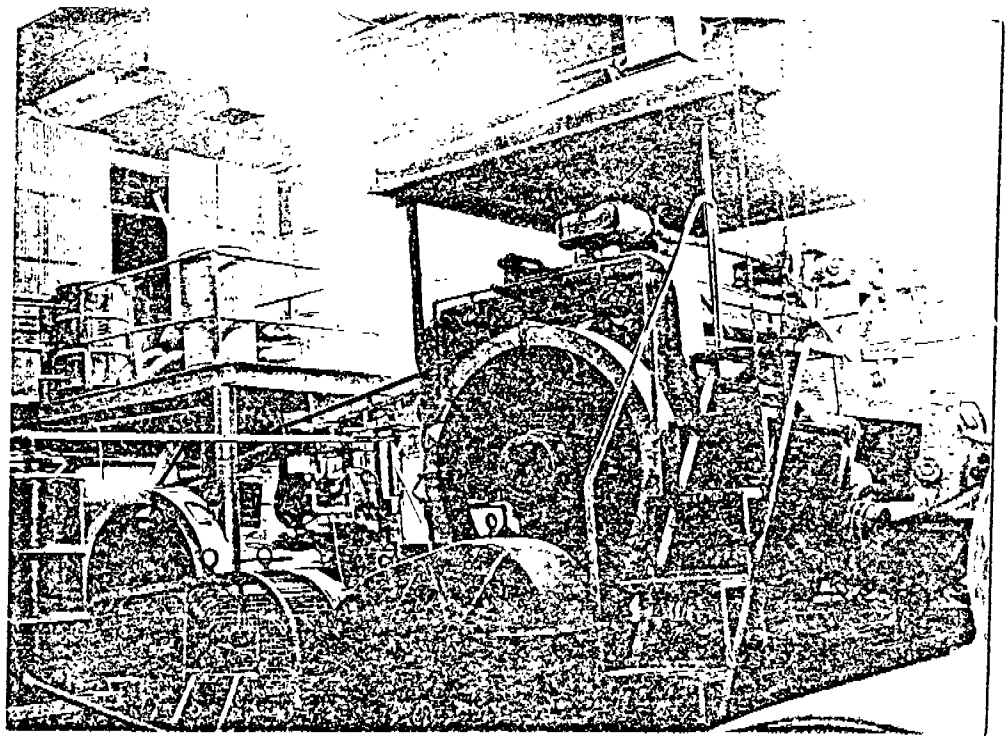


Figure 25 DOP Fumes Generating from one of the Calendering Machines

sufficient. Most of the canopy hoods for calenders at Toufen Plant have face velocities less than 100 fpm. Some of them were measured at less than 50 fpm. For example, Machine #3234A, 3234B, 3214C, and #4 calender were all under 50 fpm, and No. 6 calender was operated with only gravity flow ventilation.

Some of the hoods for DOP fume control at Taoyuan and Toufen Plants are double canopy hoods. A double hood consists of a canopy slot around the rim and a central opening under the suction pipe. The high velocity through the slot forms a shallow air curtain at the rim which prevents vapors from curling outward around the hood skirt. Double hoods permit the use of slightly lower exhaust capacity for the same degree of effectiveness. The chief objection to double hoods are the increased construction cost and the tendency for the inner chamber to act as a trap for condensible vapors and fumes.

It should be clear that a canopy receiving hood can function properly only when the buoyant flow of hot, contaminated air at hood level is matched by an exhaust capacity at least as great in magnitude. Therefore, if spillage occurs at the rim of a plain hood due to under exhaust, this will not be cured by inserting an inner piece to form a double hood. Since frugality in exhaust capacity is not of great importance when heated make-up air is not required in Taiwan in the winter time, it would be advantageous to use just plain canopy hoods at slightly higher exhaust capacity rather than spend more money on the costs and maintenance of double canopy hoods.

IX. MISCELLANEOUS AIR CONTAMINANTS

Specific air contaminents at various locations in Toufen Main Plant were measured with MSA chemical detector tubes on March 11, 1974. Following are the sampling results, none of the air contaminents measured showed detectable concentrations.

Location	Air Contaminant	Concentration
Boiler House	Carbon Monoxide	below detectable level (<10 ppm)
Chlorine Plant	Hydrogen Chloride	" (<2 ppm)
Catalyst Plant	Hyrdogen Cyanide	" (<1 ppm)
"	Carbon Monoxide	" (<10 ppm)
"	Trichloroethylene	" (<25 ppm)

X. NOISE

A plant noise survey was conducted using a calibrated sound level meter (General Radio type 1565-A). The current United States occupational noise exposure standard allows workers to be exposed to 90 dBA noise level for 8 hours a day, 40 hours a week. There were a few locations at Toufen Main Plant where noise levels in excess of 90 dBA were recorded. These include the Boiler House (94 dBA), the Refrigeration Unit (91 dBA), and the PVC Drying and Packing Operations (90 to 97 dBA). However, in terms of the duration of exposure, the Boiler House was seldom occupied and the Refrigeration Unit workers usually stayed in an enclosed control room where noise level was measured at 74 dBA. Therefore, these two locations did not present noise problems.

Because noise-induced hearing damage should be evaluated in terms of sound level and duration of exposure, a noise dosimeter study is a convenient method of integrating an employee's exposure to noise throughout his entire work shift. A noise dosimeter is an instrument that takes into consideration both noise intensity and duration of noise exposure. It gives measurements in terms of percentages of permissible exposure. Therefore, if the permissible noise exposure of 90 dBA for 8 hours is assigned a value of 100%, a 50% reading recorded by the noise dosimeter means the worker has been subjected to half the allowable amount of noise exposure, and a 101% reading would mean that the worker has been over-exposed to noise.

A noise dosimeter survey was conducted at the PVC Drying and Packing Operation. Calibrated duPont noise dosimeters were worn by workers during their work shift. Table IV summarizes the results of this dosimetry survey. None of the six workers surveyed showed excessive noise exposure when compared with the current United States Occupational Noise Standard. This was because on the day this survey was conducted, workers only spent about 80 minutes at high noise areas packaging PVC powders. I was informed that workers usually spend less than three hours per day packaging PVC powder. Therefore, based on results of this dosimetry survey, employees' noise exposure should usually fall within the permissible level at the Drying and Packing Operations.

TABLE IV

SUMMARY OF NOISE DOSIMETRY SURVEY

DRYING PLANT - March 8, 1974

Name & Employee Number		Job	8 Hour Equivalent Noise Exposure (%)
Chiang	55140	Panel Operator	18
Wu	61444	Packing Operator	36
Lin	56101	Bag Mover	40
	62110	Packing Operator	13
	62187	Packing Operator	13
	55127	Foreman	0

Should the plant in the future increase PVC production significantly above the present level so that workers will spend more than three hours per day packaging PVC powder in the Drying Plant, then it will be necessary to reduce the plant noise level by engineering control methods. However, presently it is recommended that hearing protective devices (ear plugs and ear muffs) be made available to the Drying Plant workers and they should be educated and encouraged to use these devices voluntarily for protection from noise. Please consult the attached Industrial Hygiene Standard No. 2A for guidelines on ear plugs and muffs.

XI. LIGHTING

A. Observations and Results of Measurement:

At Toufen Main Plant, the general space illumination and on-task lighting intensity were measured with a Gossen Tri-Lux Footcandle Meter, a photo-electric photometer that eliminates personal visual judgment to give unbiased, accurate assessment of lighting adequacy. In general, the lighting levels at all units visited during the night shift were inadequate. Especially poor illumination existed at Polymerization Building (3 foot-candles), Electrolysis Building (4 footcandles), Monomer Control Room (5 footcandles), Refrigeration Plant (1 footcandle), and the pipe end enlargement unit neighboring the Extrusion Plant (1 footcandle).

B. Recommendations:

The quantity of illumination should be tailored to the seeing tasks involved in the work. Table V below shows the minimum recommended lighting levels for various seeing tasks as recommended by the Illuminating Engineering Society of the United States.

TABLE V Minimum Recommended Lighting Levels

Seeing Task	Footcandles on the Task
Casual	30
Rough	50
Medium	100
Fine Machine Work	200

Most of the tasks at various units at Toufen Main Plant belong to casual or rough seeing task catagories. In view of the trend of energy conservation, I would like to suggest that we try to achieve at least one-third, and preferably one-half of the on-task footcandle levels as recommended in Table V . Therefore, let us try to increase the lighting levels to at least 10 footcandles for those places where work is to be performed during the night shift.

In many situations the desired lighting levels can be supplied with additional light fixtures hanging from the ceiling. However, it is sometimes more economical to provide the on-task illumination requirement by installing supplemental lighting in the form of adjustable lamps or table lamps which shine directly on the job to be performed. It gives better contrast to have the task brighter than the immediate surroundings. A good rule of thumb is that the general overhead lighting should supply at least one-third of the light required on the task.

An industrial worker's visual environment has a dramatic influence on his health and productivity. Adequate, well balanced levels of illumination are essential in establishing safe working conditions. Direct glare, dark shadows, and excessive visual fatigue are factors associated with accidents. Many accidents which have usually attributed to an individual's carelessness may, in fact, be traced to difficulty in seeing. Proper lighting will induce greater accuracy and alertness by reducing eye strain and postponing fatigue. Furthermore, good lighting is essential to a efficient, pleasant workplace. Surrounded by pleasantness, a worker is more content; stimulated by it, he is more productive.

XII. PERSONAL PROTECTIVE EQUIPMENT

A. Personal protective equipment for eyes, face, head, extremities, protective clothing, respirative devices, and protective shields and barriers shall be provided, used, and maintained in a sanitary and reliable condition. Employees shall be given instruction on the use of respirators assigned to them, cleaning of the respirators, and how to test for leakage. Employees experiencing breathing difficulty while wearing respirators shall be medically examined to determine their ability to wear the respirator.

B. A review of the respiratory protective equipment program indicates that there is a need to authorize one single department responsible for the proper selection of respirators for the protection required. A centralized inspection and maintenance station is advisable to assure control of the use, cleanliness, repair, and inventory of respirators and accessory parts. All respiratory protective equipment should be inspected at least once a month.

C. The selection of respiratory protective equipment must be based on a thorough evaluation of the hazards involved. Figure 26 shows the type of equipment suitable for specific classes of hazards. Only self-contained breathing apparatus and airline supplied compressed air respirators shall be used in atmospheres which pose an immediate threat to life or extreme hazard to health. For emergency use the self-contained breathing apparatus shall be placed in strategic locations as required and identified. They shall be checked on a routine basis. Compressed air for breathing purposes shall be routinely monitored for carbon monoxide and oil mists contaminations.

D. A formal confined space entry permit system should be used in the plant. Written authorization for entry can be issued only after the supervisor in charge and the Safety Department are satisfied with vessel preparation, air quality, precautions to be taken, personal protective equipment to be used, and rescue procedures to be followed. Industrial Hygiene Standard No. 6 on Confined Space Entry is attached for reference.

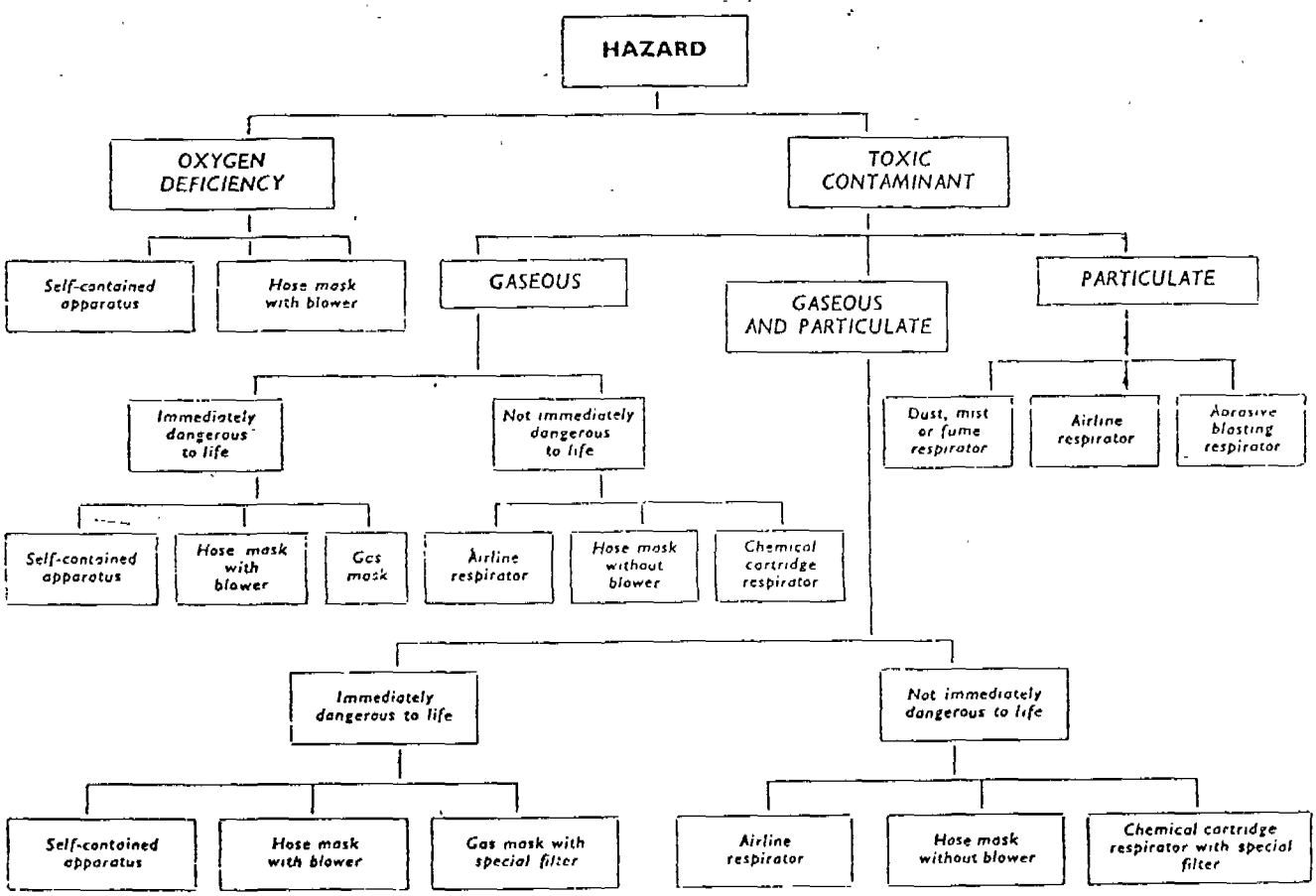


Figure 26 The Main Classes and Degrees of Respiratory Hazards, Together with Indications for the Selection of a Suitable Respirator.

E. Suitable eye protectors shall be provided and be worn where machines or operations present the hazard of flying objects, glare, injurious radiation, corrosive splashes, or a combination of these hazards.

F. For employees who work in especially hazardous environment, for example, the flake soda workers down in the basement of the mercury cell room, the polymerization reactor vessel cleaners, the compounding ingredients mixing room workers, and workers who transfer powders containing lead, cadmium, and barium, should put on a clean uniform at the start of each workday, take a shower at the termination of an eight hour shift, change into another set of clothing, and send the dirty clothing to the plant-sponsored laundry service for cleaning.

XIII. HOUSEKEEPING AND SANITATION

A. Good housekeeping promotes safety, economy and efficiency. Housekeeping practice throughout the factory and especially at the Fabrication Plants could be improved. All work areas, shops, storage, and operations offices should maintain a regular schedule for housekeeping. Chemical, solvents and oil spills should be cleaned immediately after each occurence. Oil and solvent soaked rags were piled on the floor which could cause spontaneous fire.

B. Chemical and material storage and labeling practices should be reviewed and strengthened. The Plant should have an inventory of all chemicals (except reagent chemicals) produced or purchased, and have material safety and toxicity information readily available on them. The attached Industrial Hygiene Standard No. 29 describes Gulf Industrial Hygiene Department's Product Health and Safety Data Cards service. Requests for data cards on products used or processed in any Gulf facility should include: (a) Product name or number, (b) manufacturer (not supplier) name and address.

C. At Toufen Main Plant, the city water supply was frequently under insufficient pressure. Many times I discovered that there was no running water from the faucets in the second floor restroom of the Administrative Building. A few times the faucets were apparently under negative pressure judging from the air-sucking noise they made when they were turned on. This situation can be dangerous because contaminated water may find its way into the water distribution system due to back siphonage. Therefore, I advise that the water distribution system should undergo a thorough check for back siphonage. Vacuum breakers and/or air gap separation techniques should be installed and used at every point where back siphonage is a potential problem.

D. Most Chinese would not drink tap water unless it has been boiled before. For drinking water supply, the Plant provides boiled water in large containers at various locations. This is a good custom considering that the tap water at Toufen Plant may not be all safe and wholesome.

However, I wish the following three suggestions concerning drinking water be adopted:

1. All drinking water stations should be located in clean areas such as office rooms and rest areas. They definitely should not be located at places where dust (lead, cadmium, barium, PVC dust, etc.), gases (vinyl chloride monomer), vapors (toluene, MEK, etc.) or other types of air contaminants are present.

2. For hygienic reasons, containers such as barrels or tanks from which the water must be dipped should not be used. The preferred containers are those capable of being tightly closed and equipped with a tap.

3. A common drinking cup and other common utensils should be prohibited.

E. To prevent cross-contamination, the plant water distribution systems should also undergo a thorough check for possible cross-connections between process water and potable water. Install check valve and backflow preventers at all points of cross-connection. All potable and non-potable water outlets should be clearly identified so that there will be no confusion as to which water is drinkable.

F. Adequate facilities for maintaining personal cleanliness shall be provided at convenient places. Installing more lavatories and washing facilities can promote worker's personal hygiene. Hand soap or similar cleansing agents should be provided at each washing facility. Sanitize all toilets, showers, lavatories, urinals on a daily basis.

G. Consumption of food and beverages should be prohibited in any area exposed to toxic materials or substances that may be injurious to health. For shift workers, either they be provided with a certain common eating time, or they be able to eat in turns away from work. Eating on the job should be discouraged.

XIV. INSTRUMENT ACQUISITION

China Gulf Plastics Company would benefit from acquiring the following instruments:

A. For monitoring of vinyl chloride monomer, solvent vapors, and many other types of organic compounds, the following two instruments are recommended. Century Analyzer is more sensitive and has less base-line drift than J-W Indicator; however, they are both excellent for leak detection.

1. Century Organic Vapor Analyzer, Model OVA-98-A

   Century Systems Corporation
   P. O. Box 133
   Arkansas City, Kansas 67005
   Phone (316) 442-4500

   Approximate Price: $3,000.00

2. J-W Super-Sensitive Indicator, Model SS-P

   Johnson-Williams Products
   Bacharach Instrument Company
   2300 Leghorn Street
   Mountain View, California 94040
   Phone (415) 967-7221

   Approximate Price: $1,000.00

Recently, there have been quite a few instruments developed which are specific to vinyl chloride. However, these instruments have not been field tested. More information on these instruments will be sent when more data on them becomes available.

B. For monitoring environmental mercury vapor concentrations.*

1. J-W Gas Analyzer, Mercury Vapor Detector, Model MV-2

   Johnson-Williams Products
   Bacharach Instrument Company
   2300 Leghorn Street
   Mountain View, California 94040
   Phone (415) 967-7221

   Approximate Price: $800.00

* Detections of mercury vapors by chemical detector tubes (both MSA brand from U. S. A. and Kitagawa brand from Japan) failed because the tubes did not have the required sensitivity for low concentrations of mercury.

C. Lighting Measurement:

1. General Electric Type 213 Light Meter.

2. Gossen Tri-Lux Footcandle Meter.

3. Or select any other type of Footcandle Meter.

D. Ventilation Measurement:

1. Alnor Series 6000 Velometer

Alnor Instrument Company
420 N. La Salle Street
Chicago, Illinois 60610
Phone (312) 467-1331

Approximate Price: $400.00

E. Dust Measurement:

1. Portable Personal Sampling Pumps:

a. Micronair Personal Air Sampler

National Environmental Instruments, Inc.
P. O. Box 590
Fall River, Massachusetts 02722

b. Monitaire Sampler

Mine Safety Appliance Company (MSA)
201 North Braddock Avenue
Pittsburgh, PA 15208

2. Filters and Holders:

   a. Millipore Filter Corporations
      Ashby Road
      Bedford, Massachusetts 01730

   b. Gelman Instrument Company
      600 South Wagner Road
      Ann Arbor, Michigan 48108

Enclosure 1

NIOSH Recommended Precautionary Monitoring and Control Procedures for Polymerization Processes Involving Vinyl Chloride

I. General Housekeeping Procedures

A. The spillage of Vinyl Chloride and Polyvinyl Chloride in and around the production facilities should be controlled as follows:

1. Housekeeping procedures should be implemented to assure immediate removal of VC and PVC material around polymerization operations including drying, packaging and loading operations.

2. Recovered PVC material which is to be packaged should be stored in closed containers.

3. Waste PVC material should be stored in closed containers and consideration should be given to the adequacy of its disposal and/or destruction. Care should be taken in the storage of closed containers to insure that unsafe conditions do not result from an internal build-up of pressure in the container.

B. Inventories of beginning and recovered quantities of VC and quantities of PVC produced, packaged and recovered should be made to determine losses and probable areas affected.

C. PVC material should be removed from overhead structures and conduits where it tends to collect.

D. Consumption of food should be permitted only in separate facilities provided for this purpose, and no food products should be permitted elsewhere in the polymerization facility.

II. Protective Clothing

A. A daily change of protective clothing including full coveralls, or the equilvalent, should be provided each employee in areas where possible exposure to VC PVC could occur. Clothing contaminated by accidental spills should be changed as soon as feasible.

B. Protective gloves and footwear, or footcovers, should be worn as appropriate in those PVC operations where exposure to PVC material is possible.

C. Protective head covers should be worn during PVC operations as appropriate (e.g. hard hats in those areas where physical protection of the head is necessary and hair coverings, or the equilvalent, in

operations such as cleaning of polymerization reactor tanks and packaging operations).

D. Where employees are engaged in maintenance or cleaning operations of polymerization reactors tanks they should wear full impervious suits to guard against skin contact of PVC material and VC vapors. Procedures for safe entry to confined spaces should be observed.

III. Showers

Showers at the termination of an eight-hour work shift should be mandatory for all workers with possible contact with VC-PVC.

IV. Monitoring

A. Environmental Monitoring

1. In-plant environmental monitoring programs should be implemented; and where workers are required to enter polymerization tanks, a survey of the VC concentrations should be made in the reactors immediately after opening, immediately prior to entry of maintenance personnel and during the tank cleaning operation.

2. Data obtained from the environmental monitoring program should be used to indicate those areas where efforts should be directed to reduce airborne levels of VC.

3. Positive programs to initially control VC levels well below the present Federal Standard of 500 ppm should be developed (some companies are targeting at 50 ppm) and efforts to further reduce levels should be given consideration concomitantly with the necessary modifications in engineering and design controls.

4. The concentration of VC in exhaust ventilation should be determined to estimate the amount of VC lost during operations and the possible exposure of personnel immediately outside the facility.

5. Monitoring for PVC particulate material should be accomplished to estimate the degree of exposure to this substance throughout the facility.

B. Personal Monitoring

1. Integrated, eight-hour personal monitoring samples should be obtained from those employees considered to receive the greatest exposure to VC or PVC.

2. Breathing zone samples should be obtained to complement environmental monitoring program for VC, and similar samples should be obtained for PVC.

V. Respiratory Protection

Because VC is a gas under ambient conditions and PVC is a solid under these conditions, it is recommended that respiratory protection for employees take these circumstances into consideration.

A. Where employees are engaged in cleaning and maintenance operations inside polymerization reactors they should be equipped with an atmosphere-supplied respirator in order to protect against both VC vapor and PVC particulates.

B. During housekeeping procedures and packaging operations where the possibility of PVC dust inhalation is a factor, it is recommended that an air-purifying respirator equipped with a mechanical filter designed to remove particulate material be worn. Respiratory protective devices which meet this requirement, as well as protect against VC vapors in concentrations less than 0.1% have been approved by the NIOSH Testing and Certification Laboratory and bear the numbers: TC-23C-40, TC-23C-47, TC-23C-48.

C. Where employees are engaged in transfer operations of VC from railway tankcars to storage facilities or at any similar transfer point which requires manual operations, they should wear a self-contained breathing apparatus (SCBA) during such operations to guard against unexpected release of VC during such operations.

D. Other operations involving possible exposure to VC or PVC should be evaluated as the individual situation exists and respiratory protection provided as appropriate.

Enclosure 2

CHAPTER XVII—OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION, DEPARTMENT OF LABOR

PART 1910—OCCUPATIONAL SAFETY AND HEALTH STANDARDS

Emergency Temporary Standard for Exposure to Vinyl Chloride

1. *Background.* Vinyl chloride (chloroethene), Chemical Abstracts Service Registry No. 75015, is a synthetic chemical made by oxychlorination of ethylene or by hydrochlorination of acetylene. It is the parent compound of a series of thermoplastic resin polymers and copolymers which are widely used for containers, wrapping tissues, electrical insulation, pipe, conduit and a variety of other products. Vinyl chloride has been made commercially in this country since 1939 and present production is in excess of seven billion pounds per year.

Vinyl chloride (VC) is a gas at ambient temperature and pressure and is a chlorinated hydrocarbon which has moderate liver toxicity. The present standard sets a ceiling value of 500 parts per million (ppm) (29 CFR 1910.93).

On January 22, 1974, the Occupational Safety and Health Administration was informed by the National Institute for Occupational Safety and Health (NIOSH) that the B. F. Goodrich Chemical Company reported that deaths of several of its employees from a rare form of liver cancer may have been occupationally related. As a result of this notification, and after consultation with NIOSH and a joint inspection of the plant by OSHA, NIOSH, and the Kentucky Department of Labor, a fact-finding hearing on possible hazards involved with the manufacture and use of both VC and polyvinyl chloride was announced on January 30, 1974 (39 FR 3874), and held on February 15, 1974.

2. *Carcinogenicity of VC.* Information produced at the hearing demonstrated that exposure of laboratory animals (mostly Sprague-Dawley rats) to VC by inhalation at and below the current OSHA standard of 500 ppm induced tumors, including angiosarcomas of the liver. Professor Cesare Maltoni, of the Instituto di Oncologia, Bologna, Italy, reported on a series of experiments on the effect of exposure of rats, mice, and hamsters to VC at concentrations of 10,000; 6,000; 2,500; 500; 250; and 50 ppm for varying periods of time (TR 43–63). Some of the experiments have been concluded, and others are still ongoing. The experimental results so far reported are that tumors have been observed in groups of animals exposed to VC at concentrations as low as 250 ppm. No tumors have been observed in the group of animals exposed to VC at a concentration of 50 ppm. It also appears so far that the total number of tumors, as well as the numbers of angiosarcomas of the liver, decrease as the concentrations of VC are reduced to 250 ppm. Finally, another experiment by Professor Maltoni is underway involving the exposure of 300 animals to VC at concentrations of 50 ppm, in order to assess in a more definitive way whether that level of exposure produces tumors in animals. Data reported by Torkelson, Oyen and Rowe (American Industrial Hygiene Association J 22:354–361 (1961)) indicate that exposure to VC at concentrations of 50 ppm failed to induce tumors in rats, hamsters, rabbits, and dogs.

The employees of the B. F. Goodrich Chemical Company who died from angiosarcoma of the liver had an average exposure of approximately 19 years to vinyl chloride, at unknown concentrations, and variable exposures to other volatile chemicals. (TR 93). Some employees of Union Carbide Company and Goodyear Company are also reported in a post-hearing comment from NIOSH dated March 11, 1974, to have had exposure to vinyl chloride and to have died from angiosarcoma of the liver. Finally, autopsies of four deceased employees revealed that liver angiosarcoma tumors were histologically indistinguishable from the angiosarcoma tumors observed in Professor Maltoni's experimental animals. It is concluded therefore, that vinyl chloride is carcinogenic for humans.

We therefore conclude that the present standard for VC should be lowered from a ceiling of 500 ppm to a ceiling of 50 ppm for the following reasons:

(a) In light of the evidence referred to above including the Maltoni experiments demonstrating that VC is carcinogenic in animals at 250 ppm, we conclude that VC must be considered carcinogenic in man at the same level;

(b) Although Professor Maltoni did not induce tumors in his experimental animals at an exposure concentration of 50 ppm, these data do not support the concept that occupational exposure of employees to concentrations of 50 ppm throughout their working lifetime would be without detrimental health effects;

(c) The question whether safe levels of exposure to carcinogens exist for humans and, if so, what such levels would be, is the subject of continuing scientific deliberation. In the case of VC, Professor Maltoni did not observe tumors in his animals at exposure concentrations of 50 ppm. In addition, Torkelson, Oyen, and Rowe found that exposure to concentrations of 50 ppm of VC failed to induce tumors in rats, hamsters, rabbits, and dogs. Accordingly, there is insufficient evidence at this time to conclude that VC at concentrations of 50 ppm or below poses a grave danger to humans.

(d) The emergency temporary standard adopted represents a substantial reduction in the permissible level of exposure and, in our practical judgment, is the lowest level that can be complied with immediately; and

(e) This standard will be in effect for a period of no longer than six months, during which time the whole question of possible safe exposure of humans to VC will be reconsidered more fully and in the light of more information, including experiments which are under way at this time (TR 47, 49, 71–74).

3. *Petitions for an emergency temporary standard.* In a telegram to the Assistant Secretary of Labor, received on or about March 14, 1974, the President of the United Rubber Workers International Union urged the establishment of an emergency temporary standard for VC. During the hearing of February 15, 1974, the Industrial Union Department, AFL–CIO, and the United Rubber Workers International Union made a joint petition for an emergency temporary standard for VC (TR 141–148), which was also joined by the Oil, Chemical and Atomic Workers International Union (TR 37). At the same hearing, several participants urged, on the other hand, a regular rulemaking proceeding as the most suitable for the orderly development of relevant information (TR 112, 180).

The petitions for an emergency temporary standard specified in detail the contents of the standard requested. In substance, the request is to issue a comprehensive fully-developed standard based on the recommendations of the Standards Advisory Committee on Carcinogens submitted to the Assistant Secretary of Labor on or about August 27, 1973. The recommendations are far-ranging, and cover special categories of operations, signs and labels, medical surveillance, reporting, etc., including a permit system for the use of a carcinogen.

We agree that an emergency temporary standard is necessary; we cannot say on the basis of the information developed so far that a comprehensive standard, such as the one requested, is either necessary or even desirable. It has been decided to promulgate a standard containing only those essential provisions which are deemed necessary to provide protection to employees from grave danger until a regular rulemaking proceeding in accordance with sections 6 (b) and (c) of the Act can be concluded. The reasons for a decision to establish a ceiling value of 50 ppm have already been stated. A decision on other possible, appropriate provisions is best made after consideration of all relevant data and views that interested persons may submit during the proceeding soon to be initiated.

With respect to arguments in opposition to issuance of an emergency temporary standard, the concern and efforts of several companies participating at the hearing for the protection of their employees are recognized. It may also be that some employers in some plants have fully complied with the interim controls recommended by NIOSH on January 30, 1974. There is, however, reason to believe that employees are currently being exposed to VC at concentrations well above 50 ppm. This was asserted several times at the hearing, and not seriously questioned. Moreover, a report, dated March 1974, of a survey by the staff of the Office of Standards Development, OSHA, of several facilities manufacturing VC and polyvinyl chloride revealed concentrations for some job classifications as high as 229 ppm. Therefore, a regulation is considered necessary to provide, immediately, adequate protection to workers ex-

posed to VC. Also, the eight-hour, time-weighted average standard suggested by several participants at the hearing (see, for instance, TR 178), has been rejected. The March 1974 report of the survey revealed that several kinds of work or operations are of short duration. Loading or unloading of a tank car may require approximately 15 minutes. The cleaning of a reactor may require approximately half an hour. An eight-hour, time-weighted average standard would permit exposure to VC at concentrations of 400 ppm for one hour. Such upward excursions, several times the 50 ppm level, cannot be permitted to occur.

4. *The standard.* The standard set out below contains only the requirements deemed necessary to provide protection before the conclusion of the rulemaking proceeding to be commenced shortly.

Because exposure to VC is hazardous, and because such exposure can occur in the processes of synthesizing or polymerizing of VC or in the handling of VC polymers or copolymers which contain absorbed VC, this standard applies to all such processes and to the handling, reacting, manufacturing, processing, releasing, repackaging, or storage of any of these materials. The monitoring requirements serve two purposes, to trigger into operation a compliance program and to check the effectiveness of the program. Also, engineering controls are favored for compliance, and respirators are intended to provide protection until such controls can be installed or in cases where such controls are not feasible.

Accordingly, by reason of the foregoing and on the basis of the record of the hearing of February 15, 1974, with exhibits, the written submissions received before the hearing pursuant to the notice of the hearing, the post-hearing written submissions by the participants at the hearing, the March 1974 report of a fact-finding survey recommendations received from NIOSH, and the other data referred to herein, it is found (1) that VC at concentrations in excess of 50 ppm is physically harmful and carcinogenic; (2) that exposure to VC at concentrations in excess of a concentration of 50 ppm poses a grave danger to employees; (3) that employees are presently exposed to VC at concentrations in excess of 50 ppm; and (4) that the emergency temporary standard set out below is necessary to provide immediate protection to employees from such danger.

Pursuant to section 6(c) of the Occupational Safety and Health Act of 1970, a proceeding will commence shortly in accordance with section 6(b) of the Act, in which the emergency temporary standard will serve as a proposed rule, together with other subsidiary rules. As soon as possible a draft environmental impact statement will be filed with the President's Council on Environmental Quality, and copies will be provided to other appropriate Federal agencies for their comments.

Pursuant to sections 6(c) and 8(c)(3) of the Williams-Steiger Occupational Safety and Health Act of 1970 (84 Stat. 1596, 1599; (29 U.S.C. 655, 657)), and Secretary of Labor's Order No. 12-71 (36 FR 8754), 29 CFR Part 1910 is amended by adding thereto a new § 1910.93q to read as set forth below. In addition, pursuant to section 4(b)(2) of the Act (84 Stat. 1592; (29 U.S.C. 653)), the standard in the new § 1910.93q is determined to be more effective than the corresponding standards now in Subpart B of Part 1910, in Parts 1915, 1916, 1917, 1918, and 1926 of title 29, Code of Federal Regulations, and in Part 50-204 of Title 41 of the Code of Federal Regulations. Therefore, these corresponding standards are superseded by the new standard in § 1910.93q.

1. In 29 CFR Part 1910, § 1910.93 is amended by deleting from Table G-1 the line: "* * * C Vinyl chloride * * * 500 * * * 1300".

2. Part 1910 of Title 29 of the Code of Federal Regulations is amended by adding thereto a new § 1910.93q to read as follows:

§ 1910.93q Vinyl chloride.

(a) *Scope and application.* (1) This section applies to any area or operation in which vinyl chloride (chloroethene), Chemical Abstracts Service Registry Number 75015, is manufactured, reacted, handled, processed, released, repacked, or stored.

(2) This section does not apply to the handling, storage, or other use of vinyl chloride polymers and copolymers in the form of fabricated products.

(b) *Permissible exposure.* The occupational environment shall be controlled so that no employee is exposed to vinyl chloride at a concentration in excess of 50 parts per million (ppm) (127.0 mg/cum).

(c) *Monitoring*—(1) *Initial monitoring.* As soon as possible but not later than April 22, 1974, every employer of an employee working in an area or operation in which vinyl chloride is manufactured, reacted, handled, processed, released, repacked, or stored shall begin monitoring the ambient air of the area to determine whether it contains vinyl chloride in concentrations in excess of 50 ppm.

(2) *Frequency.* Monitoring of a sufficient number of employees so that a representative sample of exposures to vinyl chloride may be determined shall be accomplished not less frequently than weekly until all results for three consecutive weeks are at or below 50 ppm. Thereafter, monitoring shall be conducted not less frequently than monthly so long as the concentrations of vinyl chloride do not exceed 50 ppm. If a monitoring sample reveals vinyl chloride in concentrations in excess of 50 ppm, weekly monitoring shall be resumed until all results for three consecutive weeks are at or below 50 ppm.

(3) *Method of monitoring.* Personnel monitoring shall be accomplished by collecting samples by suitable devices worn by the employee. The samples shall be analyzed by gas chromatography or by any other method which is of equivalent sensitivity. The analytical procedure shall be sensitive to 5 ppm of vinyl chloride in air with an accuracy of ±20 percent for a ten minute air sample.

(4) *Employee observation of monitoring.* Employees working in an area or operation whose ambient air is monitored, or their representatives, shall be given a reasonable opportunity to observe the personnel monitoring required by this section.

(5) *Recordkeeping.* The results of all monitoring shall be recorded in writing. The records shall be retained for at least 5 years and shall be made available for inspection and copying by representatives of the Assistant Secretary of Labor for Occupational Safety and Health and the Director of the National Institute for Occupational Safety and Health (NIOSH).

(6) *Employee access.* Each employee and former employee shall have access to such records of the results of monitoring required by this section as will indicate his own exposure to airborne concentrations of vinyl chloride.

(7) *Employee notification.* Each employer shall promptly notify any employee who has been or is being exposed to vinyl chloride in concentrations in excess of 50 ppm, and shall inform him of the corrective action being taken.

(d) *Compliance.* (1) Whenever any monitoring sample reveals vinyl chloride at a concentration in excess of 50 ppm, or whenever any accident, such as rupture of equipment or spillage, indicates the likelihood of a greater than usual release of vinyl chloride into the ambient air, all employees exposed to such concentrations shall be withdrawn to a safe area and shall not be permitted to reenter the work area unless they wear either Type C continuous flow or pressure demand air supplied respirators or self-contained breathing apparatus.

(2) Work which may reasonably be expected to release vinyl chloride in concentrations in excess of 50 ppm, such as repair, maintenance or cleaning of reactors or other equipment containing vinyl chloride, shall be accomplished only by employees wearing Type C continuous flow or pressure demand air supplied respirators or self-contained breathing apparatus.

(3) In any case covered by paragraphs (d)(1) or (d)(2) of this section, in addition to providing the required respirators, the employer shall examine and analyze the source of the excessive concentrations of vinyl chloride in order to determine feasible engineering or operational controls appropriate to reduce the airborne concentrations to the permissable level. Such controls shall be implemented as quickly as possible.

(4) Periodic tests shall be conducted for equipment leaks and for emissions of vinyl chloride which may result from work practices.

3. In 29 CFR Part 1910, § 1910.19 is revised to read as follows:

§ 1910.19 Special provisions for air contaminants.

(a) *Asbestos dust.* Section 1910.93a shall apply to the exposure of every employee to asbestos dust in every employment and place of employment covered by § 1910.12, § 1910.13, § 1910.14, § 1910.15, or § 1910.16, in lieu of any dif-

ferent standard on exposure to asbestos dust which would otherwise be applicable by virtue of any of those sections.

(b) *Vinyl chloride.* Section 1910.93q shall apply to the exposure of every employee to vinyl chloride in every employment and place of employment covered by § 1910.12, § 1910.13, § 1910.14, § 1910.15, or § 1910.16, in lieu of any different standard on exposure to vinyl chloride which would otherwise be applicable by virtue of any of those sections.

Effective date. These amendments shall become effective on April 5, 1974.

(Secs. 4, 6, and 8, 84 Stat. 1592, 1596, 1599 (29 U.S.C. 653, 655, 657); Secretary of Labor's Order No. 12–71, 36 FR 8754.)

Signed at Washington, DC., this 2d day of April 1974.

JOHN STENDER,
Assistant Secretary of Labor.

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