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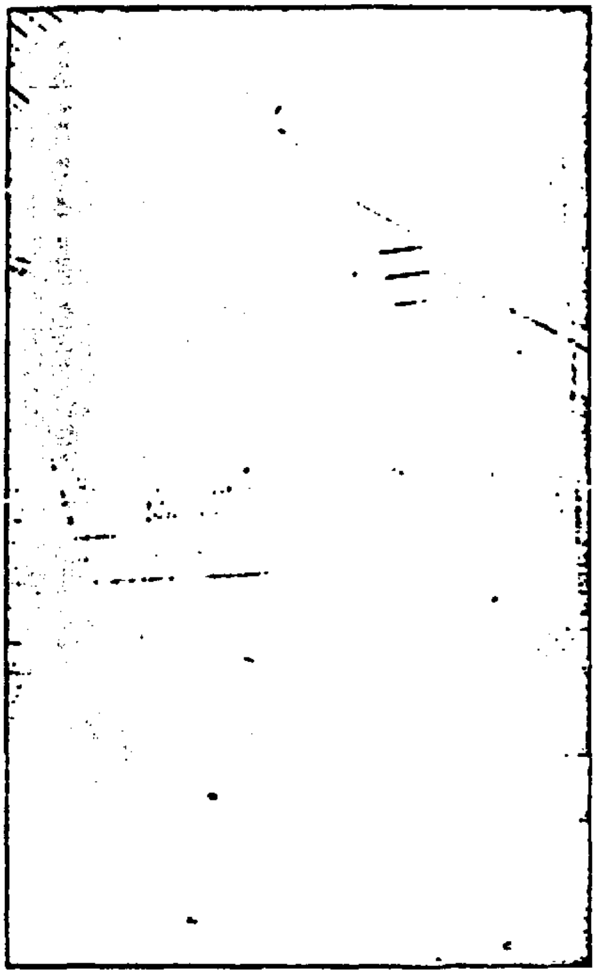
Living with VCM
How PVC Processors Can Cope

It may take some effort. And expense. But you should be able to protect your workers, comply with the new OSHA regulation and stay in business. This comprehensive report is intended to help guide you through the provisions of the new rule and suggest approaches to meeting its requirements in your individual plant situation. By Matthew H. Naitove, Associate Editor



General Tire & Rubber Co.

As this issue reaches you, the countdown will have already begun toward the Jan. 1 deadline of the most critical challenge yet to face the plastics industry. Hardly anyone involved in manufacturing or handling vinyl chloride monomer (abbreviated VC or VCM) or the PVC resin made from it is now unfamiliar with the dramatic chain of events which has led to the present crisis atmosphere. Some of the major links in that chain were:

- The announcement late last January by B.F. Goodrich Chemical Co. of the discovery of three deaths between 1968 and 1973 of long-time workers in a Louisville, Ky., PVC polymerization plant owing to a very rare cancer, angiosarcoma of the liver. (Subsequent intensive search in the U.S. and Europe revealed a total of over two dozen cases of this disease among monomer and polymer production and PVC fabrication workers.)
- Publication in the Federal Register on April 5 of an OSHA Emergency Temporary Standard limiting employee exposure in VCM and PVC production and processing plants to a 50 parts-per-million ceiling, one-tenth the prior limit. The standard also required regular workplace monitoring of airborne VCM by no later than April 22.
- First public reports in June of two angiosarcoma deaths associated with PVC processing and another two such deaths of persons living a few miles from PVC processing operations in Connecticut.
- OSHA hearings in June and July which produced voluminous testimony from representatives of industry, labor, medical science and others on possible health hazards from VCM and industry's ability to minimize these hazards.
- Announcement last Oct. 1 of the permanent OSHA standard on VCM, effective Jan. 1, the major thrust of which is to limit exposure to 1ppm averaged over 8 hrs and to maximum excursions of 5 ppm averaged over 15 min.

Where are we now? OSHA's Jan. 1 deadline leaves a scant matter of weeks before the effective date of a standard that some monomer producers and most PVC makers say is impossible to meet with any known technology short of putting men into respirators—an alternative fraught with its own large difficulties.

As for the PVC processor, whose only possible exposure is from the relatively small amounts of residual monomer trapped in the resin, the burden of the standard on him is assumed by its authors to be relatively light. In fact, the industry consensus seems to be that most, if not all, processors should be able to keep the majority of worker exposures within allowable limits by instituting certain engineering changes—mainly, increased ventilation—or work-practice modifications at reasonable cost. Most experts agree that the major problem for the processor under the new standard may be its ultimate effects on resin availability and cost. (See also p. 25.)

SPI and about 10 chemical firms have gone to court in hopes of having the standard sent back to OSHA for revision, and have appealed to OSHA for a stay in making the rule effective. Whatever the chances of some relief being granted, either by the end of this month or later, tighter restrictions on VCM are here to stay, and the PVC processor would be well advised to understand the new rule and know in advance what is required of him for compliance.

This is advisable both to minimize a health risk whose full extent is still only guessed at and because of the new and closer look OSHA is taking at processing operations. While the plastics industry has not until recently been considered a prime target for compliance inspections, an OSHA standards official in Washington says that firms

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manufacturing VCM and PVC "can plan to get to know an OSHA inspector in the near future." And the word from the compliance section is ditto for PVC fabricators. While in one sense the standard may be said to be aimed mainly at monomer and polymer production, where workers are subject to greater potential exposures, OSHA also has its eye on processors, who employ the great bulk of those potentially exposed—an estimated 350,000 vs. some 6500 workers in VCM and PVC chemical operations. So be prepared.

Recognizing the urgent need of many of those affected for guidance and advice, this article will try to provide answers to frequent questions on how the standard applies to the PVC processor, how he determines whether he has a VCM problem in his plant and what to do about it if he has. The information presented here has been gleaned from interviews with Government officials, health researchers, major PVC suppliers and their customers, makers of analytical equipment and independent testing laboratories. In viewing what's still a fast-changing situation, this article tries to pinpoint, where possible, what's presently known and, in other cases, tries at least to warn where the question marks remain.

The people in the know Before turning to specifics, here are some general remarks about two important sources of information regarding VCM—OSHA itself and your resin supplier.

First and most important, no PVC processor should be without a copy of the actual standard. Reprints from the Federal Register should be available free from your regional or area OSHA office; or else you can write to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. (request Part II of the Federal Register of Oct. 4, 1974). Reprints of the OSHA standard cost $.75 per copy.

Two additional documents should be issued by OSHA before Jan. 1. One is the Program Directive, which instructs regional and area personnel in how to conduct compliance inspections; it is intended to bring as much uniformity as possible to nationwide enforcement of the standard. The other is a Sampling Data Sheet intended to instruct field personnel in a uniform method of sampling for VCM in air. This will likewise be of interest to the PVC processor because it indicates how an inspector will judge compliance. Both documents will be publicly available from regional and area offices.

If you want direct answers to individual questions about the standard or its application to a given work situation, a recommended starting point is the Div. of Occupational Health Programming, Washington, D.C.

And for down-to-earth advice on what to do in your own plant, your PVC resin supplier is probably your best bet. Not only has he been living with the problem longer and thus has experience in monomer detection and air analysis, but he's likely to have his own processing facility as well and so be intimately acquainted with your problem. Resin suppliers have been keeping their customers informed through letters, bulletins and other means and, in many cases, have done actual monitoring in customer facilities.

First, know the law The initial statement regarding scope of the new VCM standard (29 CFR Part 1910, Section 1910.93q) reads in part: "This section applies to the manufacture, reaction, packaging, repackaging, storage, handling or use of vinyl chloride or polyvinyl chloride [homopolymer and copolymers], but does not apply to the handling or use of fabricated products made of polyvinyl chloride."

"Fabricated product" is said to mean product "which does not require further processing at temperatures, and for times, sufficient to cause mass melting of the polyvinyl chloride resulting in the release of vinyl chloride."

While OSHA apparently neither has closely defined "mass melting" nor intends to do so, it feels that the limits of what is covered are pretty clear. According to Grover Wrenn, chief of the Div. of Health Standards Development, the standard is specifically not intended to regulate certain processes that involve only partial heating of a fabricated material, such as thermoforming, heat-sealing, embossing, shrink-film or blister packaging.

Opinion in Washington seems to be that scrap is exempt "fabricated product"—at least until it's subjected to further melt processing. Coverage of the standard in this area still looks questionable, though not if virgin is reextruded or molded together with the scrap. But even if scrap is reprocessed alone, it would be prudent to monitor for VCM, though technical experience to date indicates that little or no vinyl chloride monomer release is likely from this source.

Another basic principle of the standard is that it aims at regulating individual worker exposures, not absolute concentrations in air. That is, it is primarily concerned with amounts of VCM actually in the worker's breathing zone (defined, "without regard to the use of respirators") and not those in nonwork areas, such as inside a storage silo or just adjacent to an injection machine nozzle. Furthermore, the regulation applies on an individual-by-individual basis. One worker may be exempted from its provisions while another at a different job or location in the same plant may not.

What's more, the standard provides an extra incentive to achieve low VCM levels by promulgating the key concept of an "action level," set at a 0.5-ppm time-weighted average. (TWA is a measure of what levels an employee was exposed to for how long in various work stations.) "The purpose of the action level," according to the preamble, "is to minimize the impact of the standard on the employers who have attained exposure levels well below the permissible limit. Thus . . . employers may, in effect, be exempted from some provisions of the standard." Or, as one industry observer puts it, "The complexity of life increases geometrically above 0.5 ppm."

Turning now from general principles to specific duties of employers in processing plants, the new OSHA regulation calls for the following actions in specified situations:

• Monitoring is required at least to determine initial exposure levels. (Monitoring done before Jan. 1 reportedly will be accepted.) Since moni-

Table 1—EMPLOYER REQUIREMENTS*

	Exposure Level, ppm		
	≤0.5	>0.5≤1.0	>1.0
Monitoring Program	None	Quarterly	Monthly
Medical Surveillance	No	Yes	Yes
Medical Records	No	Yes	Yes
Regulated Areas	No	No	Yes
Roster of Authorized Persons Entering Regulated Areas	No	No	Yes
Respirators	No	No	Yes
Warning Labels on Storage Containers	Yes	Yes	Yes
Training	Yes	Yes	Yes

*Data supplied by Diamond Shamrock Chemical Corp.

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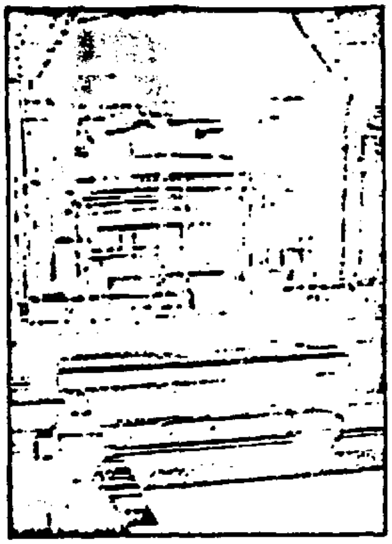

Local exhaust hoods over calender rolls and other process equipment are a major means of lowering VCM exposures.

toring need not be continued for any employee whose exposure is found to be at or below the action level ("unless changes have been made in production, process, control, type of resin, etc."), just what constitutes sufficient initial monitoring remains an important question of interpretation, at least until the Program Directive comes out. Though this point is interpreted by some to mean only one 8-hr TWA determination per worker for a clean bill of health, this may not necessarily be so. Said one OSHA standards official, "Speaking as an industrial hygienist, I'm not sure I would accept a single run-through. At least the points where highest exposures might be expected should be repeated."

At any rate, in cases where above-action-level exposures are found, monitoring must be continued at least quarterly when below the permissible limit and at least monthly when above the limit, until two successive readings no less than five working days apart confirm exposures below the action level.

• Regulated areas must be established in processing plants wherever PVC is "stored, handled or used" and exposures exceed permissible limits. This means restricting access to "authorized persons" and keeping daily rosters of those entering the regulated areas. Such areas, which need not be physically walled in, might consist of the work space around a piece of processing equipment, as long as requirements for access control and keeping of rosters are met.

• Respiratory protection must be supplied if exposures exceed 1- and 5-ppm limits. Though the employer must provide respirators for all who are thus exposed, until Dec. 31, 1975, employees may choose to forego such protection as long as exposures don't exceed 25 ppm (defined as a 15-min ceiling). Anyone choosing not to wear a respirator "shall be informed at least quarterly of the hazards of vinyl chloride and the purpose, proper use, and limitations of respiratory devices."

• Provisions for employee training about the hazards of VCM apply to all PVC processors, regardless of exposure levels at their plants. Compliance officials offer no precise definition for any such a program: it could employ lectures, slides, demonstrations, pamphlets, etc. Where respirators are used, proper instruction in use and maintenance is required as per Section 1910.134 of OSHA regulations. Some review of the training program must be given annually.

• Medical surveillance of anyone exposed over the action level involves a specified yearly examination (or equivalent, as determined by a physician), provided at no cost to the worker. An OSHA-sponsored study by Foster D. Snell, Inc., Florham Park, N.J., estimates cost of such surveillance at $140-160/employee, requiring a minimum of 1½ hrs of his time. It may be discontinued, as with monitoring, after exposures have been reduced below the action level. (A firm offering package medical programs specially tailored to this standard is Health Evaluation Programs, Inc., Park Ridge, Ill.)

• Containers of PVC resin—including bags, boxes, loaded railcars, trucks and silos—and regulated areas must display specified signs or labels warning of a "cancer-suspect agent."

• All records of monitoring, medical exams and rosters of persons entering regulated areas must be maintained for at least 30 years.

• Within a month after establishing a regulated area, reports must be submitted to your OSHA area director, citing plant location and number of employees in the regulated area. Each employee exposed to more than permissible levels (whether wearing a respirator or not) must be informed in writing within 10 days of monitoring results.

A simplified roster of employer duties related to VCM levels is presented in Table 1, opposite.

Next, find out if you have a problem

With regard to monitoring—the first step toward compliance—industry observers note that a large proportion of processors are already behindhand in this area. Not only have a good many PVC processors ignored the vinyl chloride monitoring requirement of the emergency temporary standard which has been in effect since April, but some have even indicated they will wait until the last minute before confronting the situation.

Of course, other processors have more than met their obligations. For instance, one custom molder, Ball Plastics Div., Ball Corp., Evansville, Ind., had been monitoring for the presence of organic vapors for several years before it recently began testing for VCM in particular. And several firms, particularly the larger ones, say they intend to continue monitoring regularly even though they find no VCM exposures in their plants amounting to the action level.

By and large, those who have monitored found they had little to fear. Interviews with companies in practically all areas of PVC processing—including extrusion, calendering, injection, blow and rotational molding—indicate many processors will find they have been operating with virtually undetectable levels all along. This is confirmed by the experience of two independent laboratories, DeBell & Richardson Testing Institute and Gollob Analytical Services, which monitored for vinyl chloride in a total of about 50 PVC processing operations and found few major exposure problems that didn't seem correctable with improved ventilation.

This is not to say that common problem areas don't exist or that you ought not anticipate such and pay special attention to these aspects of your operation. Experience has shown what common sense would predict: that highest exposures are generally associated with materials handling and storage and occur around hot-processing equipment, particularly in the case of intensive mixing units. Moreover, the chances of encountering unacceptable VCM levels can be related to whether one handles raw resin or compound, powder or pellets, plasticized or unplasticized material as discussed below.

Wherever resin is stored is a place to watch. According to Diamond Shamrock studies, area monitoring of trucks loaded with resin showed levels above 15 ppm, air space in a bulk railcar after four days' storage measured over 40 ppm and the inside of a silo, 1 ft above the resin surface, had more than 120 ppm. Granted that these were spot samples of areas where

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employees either don't work at all or for only short times, you nonetheless should be alert to possible exposures of workers unloading a truck, sampling a railcar, maintaining a silo dust filter, and opening up bags or boxes of material.

According to Gollob sources, poorly ventilated warehouses can contain a few ppm, with some sites going as high as 25 ppm. The contribution to a worker's TWA would depend, of course, on the amount of time he spent near the stored resin.

Processing at elevated temperatures also tends to liberate residual monomer from the resin. Most experiments show that by far the greatest amounts are released during dryblending, and that relatively little is given off during subsequent extrusion, molding, etc. For example, investigators reportedly have found insignificant VCM levels right over extruder dies. And the Diamond Shamrock data showed exposures to operators of extruders, injection and blow molding machines to be rarely above permissible or action levels, while monitoring of mixing operations indicated the need for much greater care to avoid unacceptable levels.

By this reasoning, processors handling compounds are expected to encounter less airborne monomer by an order of magnitude, especially if the compound has been produced by high-intensity mixing. Rigid pellets, according to some sources, may release more VCM than powder compounds, depending on how each was manufactured. Finally, flexible compounds, whether powder or pellets, reportedly should give lower exposures than rigids, as the plasticizer is said to displace the monomer during compounding.

Monitoring technique: no simple matter Probably no aspect of the VCM standard has aroused more intense discussion than the monitoring technology itself. Considerable research and innovation in analytical techniques have been fostered by the attention to this issue during the past year, and new equipment offerings have greatly expanded the choices available.

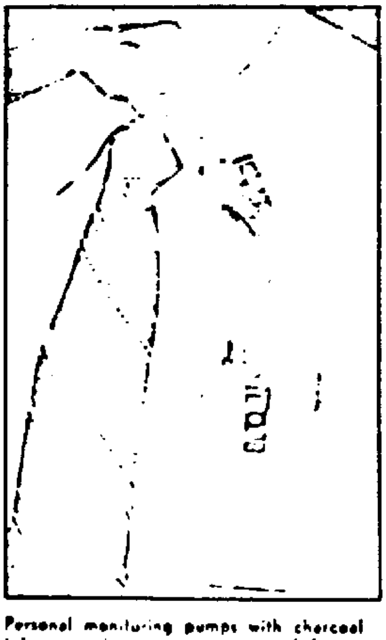
However, one of the biggest questions remains, What will satisfy OSHA? The standard requires only that "individual employee exposure levels be determined"; in fact, OSHA officials say they mean to allow employers a certain amount of freedom as to exact method of compliance so long as that intent be fulfilled. (The Program Directive should supply more information regarding criteria.)

The standard's preamble expressly permits both area and personal (or "personnel") monitoring. Area monitoring of a specific plant location is said to offer the advantage of convenience; personnel monitoring of actual breathing zones gives more direct determination of the time-weighted averages, in which the regulation is expressed.

For instance, a 1-ppm TWA could result from breathing exactly 1 ppm for 8 hrs, or 2 ppm for 4 hrs, or 4 ppm for 2 hrs; or it could mean, for example, breathing 1.5 ppm for 4 hrs, followed by 0.5 ppm for another 4 hrs.

Some sources believe that area monitoring can give accurate determinations of TWA's without having the worker carry a personal monitoring device around with him for long periods. One way this might be done is by area-monitoring all work stations and then calculating by computer the amount of time each worker spent in each location.

Another approach to figuring TWA might be to combine area and personal monitoring. That is, once personal monitoring had established exposure below the action level, area monitoring could watchdog the operation to warn if exposure changed. Besides allowing immediate warning of high-level excursions, as personal monitoring does not, area monitoring has been determined by some company health officers to be far more economical over the long term with regard to manpower requirements.



Personal monitoring pumps with charcoal tubes are the most common tool for determining worker exposures. [Courtesy, Anatole J. Sipin Co.]

What will OSHA use? The VCM standard makes reference to only one specific monitoring and analysis method, described by the National Institute for Occupational Safety and Health in the *NIOSH Manual of Analytical Methods*. This method will be used by OSHA inspectors and is also the most widely employed in the industry to date. A copy of the procedure, "Vinyl Chloride in Air" (P&CAM #178), can be obtained from the NIOSH Office of Technical Publications in Cincinnati.

The basic monitoring tool for this method is a personal sampling pump, a battery-powered device of the size and shape of a transistor radio, with a flexible tube attached (see photo, below). The pump draws air in the flexible tube and through a glass tube containing activated coconut-shell charcoal used to adsorb any VCM present. Pumps weigh from as little as 10 oz up to about 2 lbs and may be carried in a shirt pocket or clipped to a belt. The end of the flexible tube is clipped someplace like the shirt collar to give a representative sampling of the breathing zone.

To analyze monitoring results, the glass tube is removed from the pump, the charcoal emptied from the tube and shaken together with carbon disulfide solvent to desorb the VCM. Then a sample of the CS_2/VCM solution is run through a gas chromatograph, which separates the VCM from other chemicals present, to a flame ionization detector, which indicates how much VCM is present. From the sample one can calculate the total amount of VCM adsorbed by the charcoal from a known volume of air (pump flow rate having been accurately calibrated) during a measured time period—thus obtaining a TWA.

Though the NIOSH charcoal-tube method is only suggested and not required, it has raised numerous questions and objections. One concerns the length of the sampling period deemed sufficient to establish an 8-hr TWA. Must one sample continuously for 8 hrs for each worker, or would several shorter sampling periods suffice?

Industry opinion on this point ranges from those who feel an 8-hr sampling gives the only definitive answer to advocates of periods as short as 15 min, the latter stipulating of course that samples be made during times of expected peak exposure.

The NIOSH manual recommends a

pump flow rate of 50 cc/min, with total volume sampled not to exceed 5 liters for the standard charcoal tube. This recommendation is made in order to avoid overloading the tube's adsorbent capacity, which would result in false readings. At this flow rate, and with the normal range of sampling volume reportedly 1-5 liters, tubes must be changed every 20-100 min (1 liter equalling 1000 cc). Thus, for practicality, a DeBell & Richardson consultant recommends monitoring each worker for at least ½ hr every 2 hrs, or 4 samples/shift, even though full 8-hr monitoring might be theoretically preferable.

But this same source says that innovations in pump design now permit "a whole new philosophy of personal monitoring." Now that lower operating ranges of pumps have recently dropped from 50 to as low as 5 cc/min, a worker reportedly can use a single tube throughout an entire shift. The consultant therefore recommends using a pump with a suitable operating range, for instance 10-50 cc/min, permitting full 8-hr monitoring with a few tubes at low flow rates; he also suggests taking a few short-time samples at the higher rate during periods of expected peak exposure to satisfy the 5-ppm 15-min ceiling. Here, high flow rates would be better for maximum accuracy since they concentrate as much VCM as possible on the charcoal.

Another stumbling block in interpreting the monitoring provisions has been the requirement that whatever measurement used shall have a minimum accuracy, "with a confidence level of 95%," of ±50% at 0.25-0.5 ppm, ±35% at 0.5-1.0 ppm and ±25% over 1 ppm.

The detection method offered in the NIOSH manual currently reads, "Precision: Unknown," but fuller evaluation by NIOSH is reportedly due by Jan. 1. OSHA says it will accept this method as meeting its accuracy requirements—which the agency considers to be quite loose—and the unofficial word is that it will prove more accurate than called for.

In any case, most observers agree that the NIOSH method isn't for amateurs. Among the various sources of error, or "interferences," to which the method is reportedly subject are batch-to-batch variations in charcoal, affecting its adsorptive and desorptive efficiency. High humidity is also said to be particularly bad for accuracy. Inexact pump calibration is another source of error, as is contamination of the carbon disulfide (itself a highly toxic chemical), besides numerous possible testing discrepancies on the part of the laboratory analyst.

Table 2—VCM MONITORING AND ANALYSIS SERVICES*

Aetna Life & Casualty Co., Hartford, Conn.
Airco Industrial Gases, Murray Hill, N.J.
Anderson-Nichols, Boston
Boehringer Laboratories, Wynnewood, Pa.
Chemetrics Laboratories, Inc., Park Ridge, Ill.
George D. Clayton & Associates, Southfield, Mich.
Crobaugh Labs, Cleveland
DeBell & Richardson Testing Institute, Enfield, Conn.
Denver Research Institute, University of Denver, Denver
Diamond Shamrock Corp., Environmental Laboratories, Painesville, Ohio
Gollob Analytical Service, Inc., Berkeley Heights, N.J.
Gulf Research & Development Co., Pittsburgh
LFE Corp., Environmental Analysis Laboratories, Richmond, Calif.
National Loss Control Service Corp., Long Grove, Ill.
Pollution Control Science, Inc., Miamisburg, Ohio
Charles M. Shapiro & Son, Brooklyn, N.Y.
Ten Eck Environmental Consultants, South Bend, Ind.
University of Cincinnati Medical Center, Kettering Laboratory, Cincinnati
U.S. Testing Co., Hoboken, N.J.

*Partial listing.

A number of modifications of the NIOSH method have appeared recently. Scientists at Western Electric's Research Center in Princeton, N.J., developed a new type of sampling tube containing porous polymer adsorbent in place of charcoal. Together with thermal desorption of the VCM, instead of carbon disulfide extraction, the method is said to be one or two orders of magnitude more sensitive and is believed to be more accurate than charcoal tubes; also, the new tubes are reusable. Western Electric also uses a mass spectrometer, reportedly giving the most precise identification of VCM presence of any instrument, though it costs in the neighborhood of $100,000, is expensive to operate and requires highly trained personnel. The company is said to be planning to license the new technology and an "improved" area-monitoring method in the near future.

Still another method which has attracted considerable attention is the use of plastic bags instead of sampling tubes for personal monitoring. Now that some pumps are available which can be operated in both a pressure and a suction mode, they can be used to fill a bag with air samples.

Bags of aluminized Mylar, Tedlar, Teflon and saran are said to have proved acceptable. They reportedly come in 1-7 liter sizes and may be clipped to a belt or carried in a small knapsack. A 2-liter bag measures about 8 x 16 x 2 in. thick when inflated. The bags require a septum for withdrawing a sample with a gas syringe or a valve which can be directly coupled to the gas chromatograph inlet port.

Bag sampling is attractive for its simplicity. Because air is merely collected and then analyzed directly, there are fewer opportunities for error, and whatever gc reading is obtained is an actual TWA for the contents of the bag. Some knowledgeable sources vouch for bag sampling as inherently more accurate than adsorbent tube methods.

Should you buy equipment? Regardless of all the above considerations, probably the main objection to the NIOSH method, from the point of view of a great many processors, is that gas chromatographs are sophisticated instruments, generally costing several thousand dollars and at least requiring supervision by a trained analytical chemist. Numerous smaller, simpler, less expensive versions of these and other types of instruments are being advertised. Their manufacturers claim to supply them fully calibrated for push-button operation by relatively untrained personnel.

But experienced technical personnel at PVC resin companies tend to be skeptical of such claims, reasoning that analyzing for any gas in the range of ½ ppm involves considerable uncertainties and that in the case of VCM, the stakes are too high to permit a casual approach.

Thus resin suppliers are generally cautioning their customers against hastily jumping into large equipment purchases. They feel most processors won't be involved in monitoring over a long term. In fact, many fabricators may find that they only need perform initial monitoring and very little thereafter. Most others should be able to get below the action level and stay there.

Consequently, resin suppliers recommend that most processors begin by consulting an independent analytical laboratory (see Table 2, above). These groups provide various services, including complete monitoring and analysis, processing of samples taken by the customer himself and equipment rental. A spot-check indicates that fees commonly run $10-30/sample, depending on number and type of samples, volume discounts being generally offered.

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Table 3—VCM MONITORING and ANALYSIS EQUIPMENT SUPPLIERS*

A.E.D., Inc., Chicago
Alltech Associates, Arlington Heights, Ill.
Analytical Instrument Development, Inc., Avondale, Pa.
Applied Automation, Inc., Bartlesville, Okla.
Arcas, Inc., Houston
Bacharach Instrument Co., Pittsburgh
Baseline Industries, Inc., Lyons, Colo.
Beckman Instruments, Inc., Process Instruments Div., Fullerton, Calif.
Beckman Instruments, Inc., Scientific Instruments Div., Irvine, Calif.
Bendix Corp., Environmental Science Div., Baltimore
Bendix Corp., Process Instrument Div., Ronceverte, W. Va.
E. D. Bullard Co., Sausalito, Calif.
Byron Instruments, Inc., Raleigh, N.C.
Calibrated Instruments, Inc., Ardsley, N.Y.
Carle Instruments, Fullerton, Calif.
Century Systems Corp., Arkansas City, Kans.
Devco Engineering Inc., Fairfield, N.J.
Empire Technology Inc., Clifton Park-Elnora, N.Y.
Environmental Compliance Corp., Pittsburgh
Environmental Measurement Systems, div. of Western Marine Electronics, Seattle
Eocom Corp., Irvine, Calif.
Gow-Mac Instrument Co., Madison, N.J.
Hewlett-Packard, Avondale, Pa.
Honeywell Inc., Process Analyzer Center, Houston
Ion Track Instruments, Inc., Waltham, Mass.
Matheson Gas Products, E. Rutherford, N.J.
Microchemical Specialties Co., Berkeley, Calif.
MDA Scientific, Inc., Park Ridge, Ill.
Mine Safety Appliances Co., Pittsburgh
National Environmental Instruments, Warwick, R.I.
Perkin-Elmer Corp., Norwalk, Conn.
Anatole J. Sipin Co., N.Y.C.
SKC Inc., Pittsburgh
TC Systems, Inc., Houston
Varian Associates, Palo Alto, Calif.
Wilks Scientific Corp., S. Norwalk, Conn.

*Partial listing.

Individual needs will of course differ. Smaller processors have already shown some preference for outside consultants, while larger operations, particularly those associated with a resin producer or other technical-backup source, have installed sophisticated equipment systems. General Tire & Rubber Co., for instance, has a $10,000 gas chromatograph in each of its 12 PVC processing plants (used for a variety of purposes) and a mass spectrometer at its Akron research center.

A shopper's guide If you are considering equipment purchases, you'll quickly find there's a bewildering array of instruments now being advertised to the plastics industry—and they cover every level of price and sophistication.

The following brief overview of some of the basic approaches to vinyl chloride detection and measurement provides an indication of costs and representative suppliers (see also Table 3, right):

• ***Personal monitoring pumps.*** These, already discussed above, are offered for $300-350 by such firms as Sipin, SKC, Bendix, Mine Safety Appliances and Calibrated Instruments. Charcoal tubes, at 40¢ apiece, are available from SKC and other pump suppliers as well as various distributors. Sampling bags may be obtained from Alltech Associates, Calibrated Instruments and other pump suppliers. They cost as much as $6 each but are reportedly reusable.

• ***Gas chromatography.*** Equipment here encompasses a wide variety of types, from laboratory analytical models for analyzing personal monitoring samples to on-line process monitors for continuous sequential sampling of one to 30 remote locations, as well as units that combine both capabilities. Prices also range all over the map, with large, sophisticated lab models selling for $5000-10,000 or more and simplified, portable units costing around $1000-$5000. Suppliers include Perkin-Elmer, Hewlett-Packard, Varian, Beckman, Bendix, Gow-Mac, Baseline Industries, Century Systems, Arcas, Applied Automation, and Analytical Instrument Development.

• ***Infrared absorption analysis.*** This technology has been attracting considerable attention as an alternative to gas chromatography for both personal and area monitoring. Units range from battery-powered portable types (under $3000) to computerized multipoint monitoring systems ($10,000 and over). Two firms which have shown particular interest in VCM detection are Wilks Scientific and Eocom.

• ***Colorimetric methods.*** These appear to be another promising alternative. MDA Scientific has developed several models that employ a chemically impregnated paper tape which changes color as VCM is drawn into the sampling port. An optical sensor then measures concentration according to depth of color change. System reportedly offers extremely simple operation and sensitivity to 0.01 ppm. Continuous area-monitoring unit with paper-tape cassette costs $2900 with chart recorder; spot-sampling model is $500. MDA is also developing a personal monitor to be worn by workers ($650 plus $950 for the tape reader); device will give both TWA and continuous profile of worker exposure. For a simplified colorimetric approach to manual spot sampling, Bendix supplies glass tubes containing a reactive absorbent medium said to be highly specific to VCM. Sample from a hand pump is injected into a tube, with length of stain produced indicating concentration. Method reportedly can measure 0.5 ppm with ±5-10% accuracy. (Cost is $85-90 for 10 tubes and sampling pump.)

• ***Total hydrocarbon or organic vapor analyzers.*** This approach to area monitoring, as the term suggests, isn't specific to VCM and so is more suitable for showing where VCM doesn't exist than where it does. Suppliers such as Bendix, Bacharach and Century Systems provide units from portable direct-reading types to stationary, remote multipoint monitors. Prices range from around $600 to over $6000.

Various other analytical approaches to portable and stationary area-monitoring are available. Examples include a detection system based on the differing physiochemical adsorptive forces of different compounds, supplied by Environmental Measurement Systems; an electron-capture detector system from Ion Track Instruments; systems from Devco Engineering based on identifying VCM by its dielectric constant, and an electrolytic-cell gas sensor from Bullard. (Prices vary with the unit.)

But whichever way you decide to monitor, keep the OSHA inspector and the method he's using in mind. As a major PVC supplier puts it, "We want to be damn sure our results match up with his."

What about respirators? Another equipment question which has been causing some confusion is that of respirators. While it's hoped and expected that very few workers in processing plants will ever need to wear one, at least one informed source doubts whether all purchasers of uncompounded resin will be able in the short term to get below permissible VCM limits in certain plant areas, such as mixing rooms. Furthermore, a senior OSHA official says that sampling of incoming railcars might well be classified as a "hazardous operation"—defined, in part, as a situation in which accidental overexposures might reasonably occur—and thus require respiratory protection.

One major question concerns what

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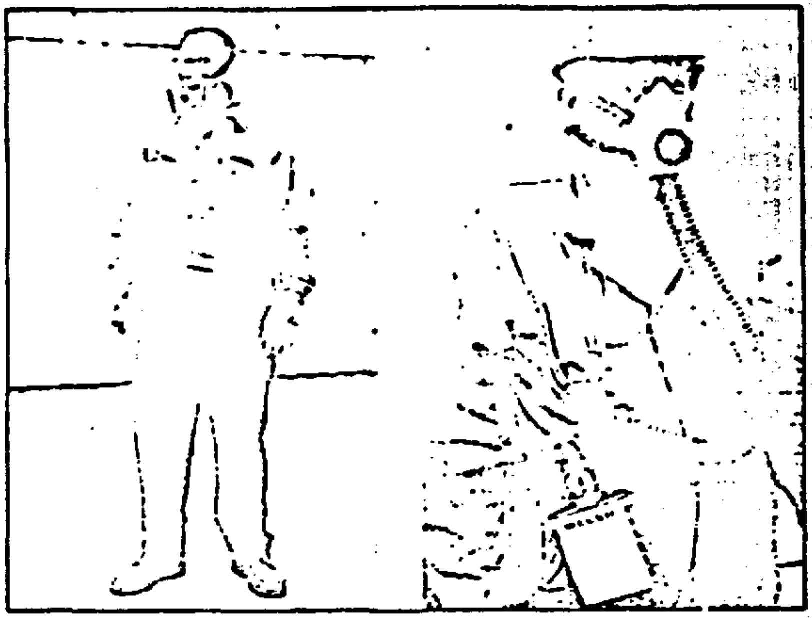
type of respirator is legal and practical to use. The standard lists specific types of respirators as permissible in certain maximum VCM ambient concentrations; the equipment for the higher levels is generally more expensive. Basic types include:

- Air-purifying masks, which filter ambient air through cartridges or canisters containing adsorbent media. Cartridge types reportedly run $10-12, canisters about $50 and "powered" (blower-equipped) types around $200. Replacement cartridges are $3-6 and cans $10-15. Cartidge masks are permitted for up to 10 ppm and canisters for up to 25 ppm, probably as much as would be found in a processing plant.
- Air-supplied masks, which are fed through a hose from an outside source. Masks themselves cost $80-85: the least expensive method of supplying air would be to connect with the plant's compressed-air system and add a low-pressure purifier (about $1000). As issued, the standard permits air-line respirators without auxiliary supply in up to 100 ppm; but the list omits what's said to be actually the most common respirator type. The list is being amended so that, for not over 1000 ppm, OSHA reportedly will permit a Type C supplied-air, continuous-flow respirator with full or half mask, helmet or hood, which costs approximately $60-80.
- Self-contained compressed-air bottles, which, depending on type, can be used in all environments. For a 15-min supply, these units start at $350-400. Combination air-line types with self-contained auxiliary supply would run $200. However, to refill compressed-air tanks requires a high-pressure purifier/compressor/cascade system costing $5000-$6000.•

If any respirator is used at all, clearly the most desirable for the processor in terms of cost and convenience of use are the air-purifying types. Unfortunately, to date no such respirators have been approved by NIOSH, as required by the standard. NIOSH reportedly only just completed testing protocols to begin evaluations and possible certifications of respirators this month. One important question still left hanging is whether NIOSH will insist on end-of-service-life indicators (the first of which is only recently rumored to have been developed) or will go along with OSHA's acceptance of "administrative controls" to make sure cartridges and canisters are replaced sufficiently often.

But even if all approvals are made immediately, it will be impossible to supply the industry with the required number of respirators by Jan. 1, according to an SPI petition for a delay of the standard. Some 25 000 respirators are reportedly already on order for VCM and PVC manufacturers alone, and SPI says today's supply is only 26% of current demand; with expeditious NIOSH approvals, supply would still be only 78% of demand.

But should lack of available respirators be the only factor keeping you from compliance, OSHA sources in Washington say application for a variance is always a possible avenue of relief.



Cartridge (l.) and canister (r.) type air-purifying respirators are least expensive and easiest to use, but must wait NIOSH approval.

Tips on engineering controls When asked what difficulty processors will have in lowering VCM levels in their plants, most informed sources replied that in the long run, getting rid of VCM would not properly be the processor's problem at all. Since his only exposure to VCM can be from unreacted monomer in the resin (PVC does not degrade to VCM), the most evident solution is for the resin supplier to remove as much of it as possible.

There is indeed a strong push by all resin suppliers to accomplish just that. Today's resins reportedly may contain anywhere from less than 1 ppm to over 1500 ppm of VCM, depending on method of manufacture, grade, particle structure and other factors. The initial goal, industry wide, seems to be to get averages below 50 ppm; some suppliers say they can achieve this consistently in certain grades or from certain production facilities Tenneco Chemicals even claims it has been able, on a pilot-plant basis, to produce resin with "no detectable" VCM remaining.

Meanwhile, the next best answer for the processor is said to be to remove as much VCM as possible, under controlled conditions, during the compounding process. Such an effort would leave that much less monomer to cause problems downstream. Substantial improvements in VCM removal reportedly have been shown possible with a new technology developed jointly by ICI's Plastics Div. and T. K. Fielder Ltd. in England, with the technology now made available in the U.S. and Canada through Werner & Pfleiderer Corp., Waldwick, N.J.

The system centers on the dryblending cycle, where most VCM is normally generated, and further enhances this effect while insuring that the VCM so produced is safely exhausted from the work area. In this way, it not only makes the resin more free of monomer for subsequent processing, but reportely also tends to yield lower VCM levels in the mixer work area.

Filtered air is continuously aspirated through the mixer head-space while small amounts of low-pressure air are also injected at or near the bottom of the mixer bowl. This air then flows through the material, stripping away additional VCM from the mix. Monomer-laden air is drawn from the mixer through a cyclone separator, where large particles are collected in a removable dust bin; it then moves on to a cloth filter to trap additional fines before passing through a turboblower and being exhausted from the work area. (See diagram.)

With this Exorsta system, much more monomer reportedly can be removed, at lower temperatures than would otherwise be necessary. Company data show that residual VCM in finished dryblend can be halved by increasing mixing temperature from 250 F to 265 F, though even better results can be obtained at the lower temperature by adding headspace aspiration alone. With air stripping as well, monomer removal at 250 F is increased more than fourfold again. Thus the system is said to readily produce dryblends with only 5-10 ppm residual VCM vs. more than 100 ppm by conventional dry-blending techniques.

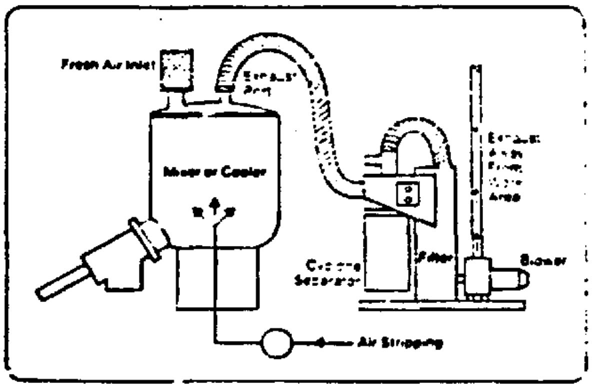
Werner & Pfleiderer supplies complete Exorsta systems, including engineering, training and installation services as well. The Exorsta system is a self-contained design with cyclone separator, filter and exhaust mechanisms and is said to be readily adaptable to retrofitting all existing dryblend units. It costs $3000-6000 installed, depending on size and type of mixing equipment.

Considerable work is being done in monomer-extraction techniques. Process Control Corp., Atlanta, reports it also has been retrofitting mixer units with its own aspiration systems. And Werner & Pfleiderer is developing technology for using vented twin-screw compounding extruders to remove even more monomer. A goal which it hopes to accomplish soon is to produce compound with as little as 1 ppm residual VCM.

Among other techniques for minimizing VCM exposures in processing plants, automated bulk materials handling is certainly a step in the right direction, as it eliminates exposure from opening bags or boxes or from stored material in warehouses. But remember that what happens in a pneumatic feed line is reportedly something like air stripping in a mixer; that is, there will be plenty of entrained monomer and possible leaks are a factor to consider.

For this reason, Process Control Corp. engineers have been recommending vacuum rather than pressure systems. Pressure and friction reportedly can make feed lines quite hot (180-200 F) while vacuum lines are cooler (100-120 F) and thus cause less monomer to be released. What's more, Process Control's vacuum-conveying systems feature closed-loop designs that both exhaust monomer outside the plant and reportedly avoid particle-size classification problems said to be common in closed-loop pressure systems.

Process Control is working on other materials-handling approaches to minimize worker exposures in mixing areas. Here part of the problem is said to be that usually only major compound ingredients (such as resin and plasticizer) are metered automatically to the mixer while from six to 13 "microingredients" (additives which together add up to no more than 10% of the total) are added by hand. The company recommends instead that these microingredients be masterbatched together with enough resin to dilute the whole to a sizeable volume from which portions could be automatically dosed. Getting the operator away from the mixer as much as possible is thus a simple answer to reducing his exposure.



New system removes as much VCM as possible during dryblending, so less can escape downstream. (Courtesy, Werner & Pfleiderer Corp.)

But of all engineering controls applied to the VCM problem, ventilation is probably the most widespread and versatile. Moving large volumes of air to ventilate entire work areas is the most expensive and least efficient approach; in addition, winter weather will require that incoming air be heated, at considerable extra expense.

Locating exhaust hoods near processing equipment is by far the preferred approach, and many processors attribute their lack of exposure problems to doing this. In many cases, local ventilation had already been installed to remove plasticizer vapors and other fumes. (One plant even went to the novel length of entirely enclosing a calendering line.)

Proper ventilation is also advisable in warehouses where PVC resin is stored. Cost and airflow requirements can possibly be minimized by keeping all PVC segregated in one corner, perhaps in an actual enclosure, with local exhausting provided. Alternatively, in a warehouse with relatively good overall air movement, you might scatter the PVC in smaller lots so that lesser local VCM concentrations could accumulate. Amount of ventilation needed in a warehouse will partly depend on storage temperature, more monomer being liberated at higher temperatures. How long the resin is stored is also relevant; VCM emissions from bagged resin reportedly decline rapidly to negligible levels after a few weeks (though this is not necessarily true for pelletized PVC materials).

Some processors are spending several thousand dollars on ventilation in order to get below the action level. As this is a technically complex subject in itself, you may well want to consult a professional engineer before making such an investment.

Dr. Maurice Oberg of LFE Environmental Analysis Laboratories presented some of the complexities involved at a recent SPE meeting in N.Y.C. For example, distance of an exhaust hood from the VCM source is an important factor, with airflow requirements increasing proportionally to the square of that distance. Hood configuration is likewise important, since 25% less airflow reportedly can provide the same amount of control if the hood is flanged or if it's placed flush against a wall or other surface. One example Oberg cited was a hood over an extruder die, the hood flange contacting the die at roughly a 45° angle. Such an arrangement reportedly would provide efficient fume removal and avoid dripping condensed plasticizer, for instance, on the extrudate. A flexible metal duct would permit the hood to be moved for access to the die.

The above considerations, as well as shape of hood, fan blade configuration and duct geometry, are only some of the factors involved in designing the most efficient system for your money. (A professional manual on the subject is "Industrial Ventilation," published by the American Conference of Governmental Industrial Hygienists Committee on Industrial Ventilation, Lansing, Mich.) □□

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