PROGRESS IN VINYL CHLORIDE CONTAINMENT

A Report By
The B.F.Goodrich Company

B.F.Goodrich

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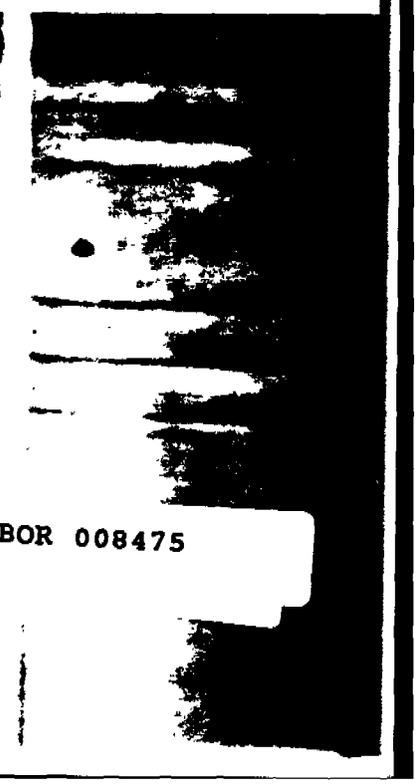
BACKGROUND

The B.F.Goodrich Company was faced with a number of serious and difficult decisions when we discovered, in January, 1974, that three of our employees who had worked for many years in our Louisville, Ky., polyvinyl chloride plant had died from a rare form of liver cancer, angiosarcoma. Subsequently, additional cases were identified and reported among polyvinyl chloride production workers in plants of various companies in the United States, Canada, Europe and Japan.

In all these plants polyvinyl chloride (PVC), a solid resinous polymer which is the base material for the vinyl plastic industry, is produced from vinyl chloride (VC), a reactive gaseous monomer. Goodrich has produced PVC since 1937. Prior to 1974, its programs to provide a safe work environment in keeping with known scientific data already had reduced the concentration of VC gas exposure to an average of less than 100 parts per million (ppm). The angiosarcoma discovery, however, added a new dimension to the problem of VC confinement.

The Company took immediate action. We informed our employees, appropriate government officials, customers, others in industry and the public of all pertinent facts. We searched medical records and medical examination reports of all employees who could have been exposed to vinyl chloride to ascertain the existence of physical abnormalities. We began immediately to reexamine our manufacturing operations — to explore, in the light of the technology that was then available or could be developed in the short term, all possible ways to confine VC inside equipment and prevent its escape.

With faith in our technological ability and with great concern for worker safety, the Company made the decision to continue both with PVC production and with plans for expansion at the Louisville Plant.



In May, 1974, the Company announced it had undertaken the most intensive research and development program in its history, involving more than 130 scientists, engineers and technicians, with the aim of containing vinyl chloride gas. To date, these company technologists have devoted 425,000 man-hours to these projects. This does not include the thousands of hours devoted by plant and support personnel on monitoring, training, medical examinations and other aspects of finding solutions to these problems.

We now estimate that the total capital expense required to comply with VCM standards of the Federal Occupational Safety and Health Administration and the expected Environmental Protection Agency vinyl chloride standards will amount to an estimated $42 million over the period 1974 to 1977, inclusive. This is the figure we estimated one year ago. It may be possible to meet our goals and reduce the $42 million figure by 10 to 15 per cent through technological developments resulting from our research, development and engineering programs.

Goodrich Programs

Today, The B.F.Goodrich Company can report considerable progress in these programs.

While all goals have not yet been fully achieved, the Company is operating its five U.S. PVC plants, as well as its VC monomer manufacturing facility at Calvert City, Ky., well within the strict regulations established by OSHA. It is also supplying PVC resins with such a minute content of residual vinyl chloride monomer (RVCM) that the possibility of VC exposure from their use is virtually eliminated.

The Company is confident, based on extensive sampling data, that it will be able to operate its plants in compliance with expected requirements of the Environmental Protection Agency (EPA) regulating VC emissions to the environment. We also expect to continue supplying PVC compounds for wide usage in food packaging which can meet proposed standards for approval by the Food and Drug Administration (FDA).

Goodrich programs have been designed to reduce vinyl chloride escape, however it may occur, to the very lowest achievable levels, and to assure a wide margin of safety for our employees, workers in customers' plants, and ultimate users of PVC products. These programs are in three major categories:

1. Reduction or elimination of possible exposure to employees in plants.
2. Reduction of residual vinyl chloride monomer in PVC resins and compounds leaving its plants, to lower the possibility of exposure in transportation, in customers' processing plants and in finished products.
3. Reduction of VC emissions in air and water from its plants.

Reduction of Plant Exposures

Because of primary concern for employee safety, the reduction of exposures in plants was the first area of concentration. Before January, 1974, the Company already had reduced exposure levels in its plants far below the then-existing government standards (500 ppm) and the levels recommended by the American Conference of Governmental and Industrial Hygienists (ACGIH), which were 200 ppm. By the time OSHA issued its new temporary standard of 50 ppm in April, 1974, the Goodrich plants were operating below this level and the Company had made decisions on programs designed to reduce exposure levels still further.

The permanent standard *proposed* by OSHA as published in the Federal Register on May 10, 1974, could, in the opinion of B.F.Goodrich, have led to a shutdown of the PVC industry. This was also the viewpoint of the industry, as expressed through the Society of the Plastics Industry (SPI). Reasons behind the opinion were practical ones, as follows:

1. The proposed standard was ambiguous in its establishment of "nondetectable" levels. As written, these

could have been interpreted as indicating permissible exposure of 1.0 ppm or 0.5 ppm, or as requiring no exposure whatsoever.

2. The four types of respiratory equipment listed as acceptable for protection against vinyl chloride were all to be self-contained. Such equipment would have been totally impractical because weight and bulk of tanks, hoses, etc. would have severely limited worker mobility. Further, the limited air supply in self-contained equipment, enough for only 30 minutes, would have required resupply so frequently that these systems also would have been impractical.
3. Protective clothing called for in the proposed standard would have placed additional unacceptable restraints on worker mobility. This clothing also would have exposed the wearer to severe heat stress, particularly when worn in confined areas and where the work required substantial physical effort.

Within established Federal procedures, and in open hearings and in open records, Goodrich and industry experts provided extensive technical information on control of industrial gases under pressure and work practices, and realistic information on the possibilities for engineering controls.

The permanent OSHA standard issued on October 5, 1974, is stringent, but is more realistic and much less ambiguous, and sets forth detailed specific parameters for industry action. It requires that worker exposures be no more than 1 ppm on a time-weighted average for 8 hours, and no more than 5 ppm for any 15-minute period. Under the standard, respirators are made available to all workers. Until April 1, 1976, their use is optional up to 25 ppm, but is required at higher levels. After April 1, 1976, respirators are mandatory for exposures above the 1- and 5-ppm levels.

As one of the first steps in its intensified program, Goodrich quickly developed monitoring systems to measure ambient VC levels in work atmospheres on a continuing basis. These systems have been continuously improved and now are very accurate and reliable.

Portable monitoring devices were required to enable engineers to locate quickly leaks or sources of vinyl chloride in plants. Since VC gas is continuously under pressure in the PVC manufacturing operations, even the smallest apertures in the hundreds of valves, flanges or similar equipment in plants can release the gas into the work atmosphere.

Another of the first tasks was to locate all these sources and make them as leakproof as possible. In many cases, this required the development or special procurement of new, more highly engineered pumps, flanges and gasketing materials, and also extensive re-engineering of piping systems to reduce the number of possible leak sources.

Still another step was the installation of new ventilation systems in buildings in which PVC operations are conducted. This substantially reduced VC in work areas where it was most likely to concentrate. Automatic alarm systems were installed to indicate if VC concentrations should reach levels requiring respirators, or evacuation of personnel until an emergency situation can be corrected.

New Reactor Cleaning Technology

PVC manufacture from VC in existing plants is a batch operation in which reactors are charged, emptied and recharged repeatedly, and in which solid material normally deposits or builds up on reactor interiors during each batch reaction. Reactors are large, sealed pressure vessels in which vinyl chloride gas is converted (polymerized) into the solid polyvinyl chloride resin, or plastic. Reactor cleaning to remove this build-up between charges has, in the past, been a principal source of worker exposure to VC, because unre-

acted VC gas in the reactors is entrapped within the solid deposits. Before 1974 our efforts had been directed to reducing exposure from reactor cleaning. Goodrich then had already developed and patented, and was using in its plants and licensing others to use, its Hydraulic Reactor Cleaner (HRC). This equipment, by automated mechanical means, greatly reduced frequency and duration of reactor entry and manual cleaning.

We are now able to report that our research program has resulted in a further major accomplishment in preventing such exposure to an extent heretofore unattainable. This is the invention, development and proving out in production plants of what is called the Goodrich "Clean Reactor Technology". It involves the combination of new processes, techniques and materials for treating interiors of used or new reactors to prevent solid deposits and build-up even after a large number of charges. This new technology, with related improvements and practices, includes continued use of HRC's but after many charges instead of after each charge, and more complete evacuation of vapors in reactors before they are opened. It virtually eliminates the possibility of worker exposure to VC from reactor emptying and cleaning operations.

Our goal is a completely closed, automated and essentially leak-proof reaction system which will require no reactor opening or entry except for periodic maintenance.

Goodrich is now operating its PVC plants, as well as its vinyl chloride monomer plant, with levels of VC in the work area of between 1 and 3 ppm. These are average levels, and exposure to employees as measured by personal monitoring is considerably lower. With the use of respiratory equipment when required, worker exposure can be kept below the levels called for by the OSHA standard.

Respirator Use and Employee Education

The Company also has made advances in the technology and use of respirators. All available types were tested to make sure that inhalation of any VC could be prevented, and to select types which would cause the least discomfort and inconvenience to workers. At this time, the Company has adopted air-fed respirators for use in most operations when necessary. Other types, such as air-packs, are provided for special situations.

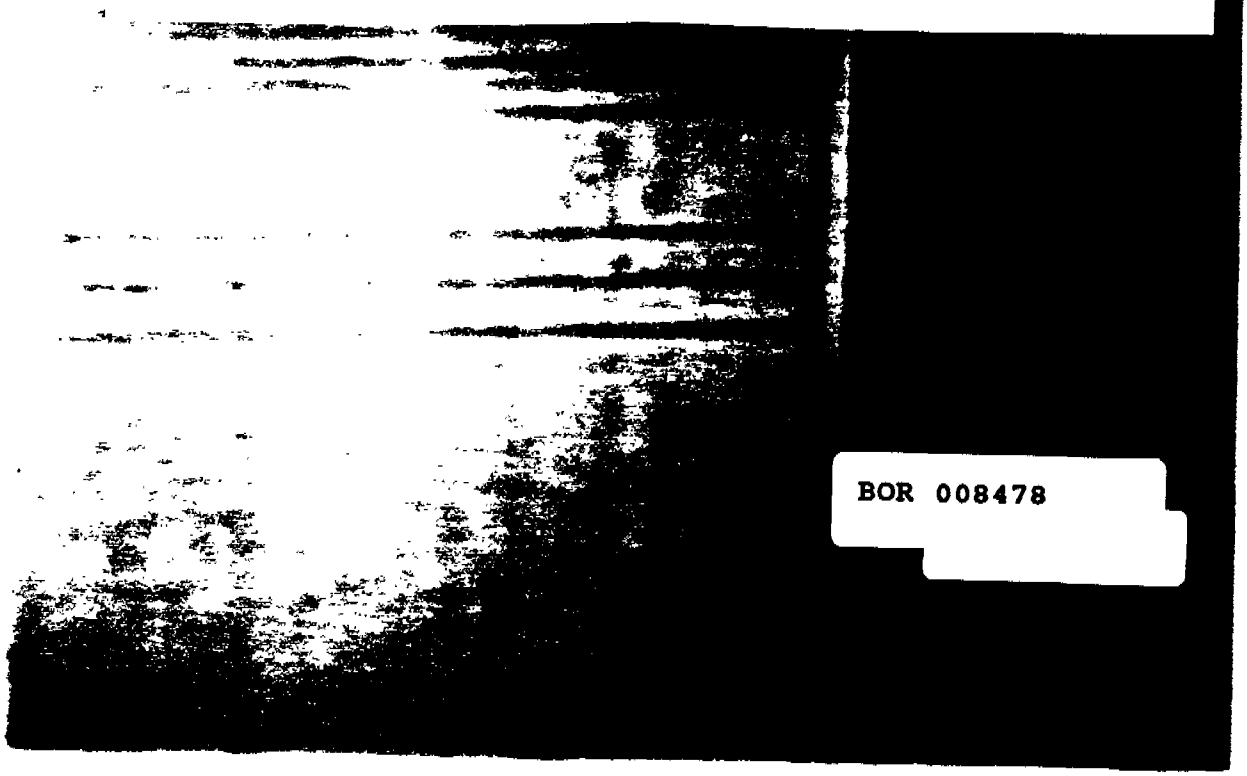
The OSHA standard calls for employee education and training on precautionary measures relating to reduced exposure to vinyl chloride. Goodrich has carried on such training programs at its Calvert City vinyl chloride monomer plant and all five PVC manufacturing plants. Programs were built around on-the-job training sessions and special slide films and educational bulletins, and have received praise from Federal and state agencies for thorough coverage and effective presentation.

Reduction of VC in Product

The second major category of progress is the reduction of residual vinyl chloride monomer in PVC resins and compounds produced in Goodrich plants. In the past, chiefly because of the comparatively large size and other properties of the molecules in PVC, very small amounts of unreacted vinyl chloride have remained entrapped in the resin, or polymer. These amounts are reduced when resins are mixed with other ingredients to make compounds, and then are reduced still further during processing into finished products in customers' plants.

The OSHA standard extends to processor plants. Goodrich, in cooperation with many customers using its various PVC resins and compounds, has measured vinyl chloride release to the air around processing equipment. Levels were found to be very low compared with those in PVC production plants and have been lowered markedly in the past year.

Both OSHA and the National Institute of Occupational Safety and Health (NIOSH) have stated that they saw no



problem with VC exposure from finished goods. However, a question has been raised about the possible migration of vinyl chloride into food from packaging materials made of PVC compounds.

In September, 1975, the Food and Drug Administration proposed new regulations affecting the use of PVC in a number of food-contact applications. Under these proposals, PVC resins and compounds fabricated into bottles, blister packs, boxes, and other semi-rigid and rigid packaging that comes in contact with food would no longer have FDA approval. The regulation would continue to permit PVC use in pliable film-type wraps, gaskets, cap liners, pipe, tubing and packaging coatings.

It should be noted that the FDA action to date is only a proposal, not a final regulation, and comments on the proposal are being received for consideration. Two comments are worth special mention in this regard.

First, as we announced last May, our Company is producing new PVC bottle compounds containing significantly less than one part per million (ppm) of VC. The Company has been unable to detect vinyl chloride, by analytical methods sensitive to 50 parts per billion (ppb), in food-simulating solvents when the package is fabricated from compounds containing 1 ppm or less of residual vinyl chloride.

Secondly, the FDA proposal leaves the door open for suppliers or users of PVC packaging materials to submit food additive petitions and secure FDA approval if their supporting data demonstrates there would be no reasonable expectation that vinyl chloride would become a component of the packaged food. Should the present proposed regulations become final, Goodrich believes that packaging materials fabricated from its new PVC compounds will meet this criterion for approval.

New Stripping Columns Developed

A major factor in our Company's ability to produce PVC compounds that are extremely low in vinyl chloride content has been the development of a new improved continuous method of stripping vinyl chloride from PVC resin during its manufacture, as announced by the Company on August 26. In the new process, resin made in slurry form from VC in a group of reactors is continuously fed into the top of an especially designed stripping column countercurrent to steam fed at the bottom of the column. As the column is operated under controlled conditions, the steam rises to the top, picking up almost all the VC in the resin flowing downward. The VC is collected and recovered for reprocessing, while the stripped slurry is removed at the bottom. Virtually all the remaining VC is removed in drying of the slurry.

Goodrich is now installing the new stripping columns in all of its PVC plants and, as a result, we are producing general purpose resins with an ultra-low residual VC monomer content — in ranges below 1 ppm. It is believed that processors and fabricators using these resins will not have to establish regulated areas in their plants under the OSHA regulations. Regulated areas are those in which the time-weighted average in the work area is greater than one-half part per million (0.5 ppm).

Plant Environment

The Goodrich stripping technology is also a key to progress in the third category of reduction of VC losses, that is, escape to the environment. Since the stripping operation continuously recovers and recycles all but traces of the VC present in the PVC resin as it comes from the reactors, there is a substantial reduction in the amount of VC which could be discharged to the environment with the air from the dryer or with effluent from other downstream operations.

In other respects, progress in reduction of VC in the work place has been achieved, while avoiding forcing the VC out of the plant into the surrounding environment. Goodrich environmental engineers at each plant, as well as the corporate environmental staff, have carefully analyzed in-plant control measures for their effect

on VC concentrations in air and water effluents. Steps have been taken where appropriate to collect exhaust air and remove even small amounts of contained VC, and VC has been stripped and recovered from effluent process water. Control of leaks in equipment has, of course, reduced losses in venting air from the plants as well as in work areas.

The air surrounding the Goodrich VC plant and PVC plants has been sampled scientifically, with regard to meteorological conditions and other factors, and tested for VC content at periodic intervals. Levels have been much lower than in the work place, due to the rapid mixing of exhaust air with the much greater volume of ambient air, and also the actual breakdown of VC molecules when released to the atmosphere.

At present, the levels of VC in the outside air at points adjacent to Goodrich plants are of the order of a few hundredths of one part per million. Effluents leaving the plants contain only a few parts per million. As the new stripping technology is installed in all PVC plants and technological improvements are incorporated in the VC monomer plant at Calvert City, emissions of VC will become even lower.

At about the same time Goodrich environmental engineers began concentrating on reduction of VC in the environment, the technical branch of EPA started a study of the possible establishment of federal emission standards under the authority of the Clean Air Act. At the request of EPA, Goodrich has worked closely with its experts in supplying emission data, setting up atmospheric testing areas and procedures and providing engineering and economic data on possible control technology.

Availability of Technology

Even though the technology we have developed is proprietary, and could give Goodrich a competitive advantage, the Company considers it our responsibility to make it available on an unrestricted basis to all competitors in the PVC and vinyl chloride industry in the United States and abroad. Modest license fees will partially offset Goodrich's large research, development and engineering costs.

Several license agreements have already been signed on the stripping column technology, and considerable interest has been shown by producers, here and abroad, in the newer clean reactor systems. We are also supplying new containment technology to licensees, worldwide, of our vinyl chloride monomer processes.

The Future of PVC

The Company has stated several times that capital expenditures, operating costs, research and development costs and maintenance connected with VC control, plus continuing medical surveillance, has added to the production costs of its PVC materials. As the new technologies are adopted in all production operations and further experience is gained, greater efficiency and reductions in unit operating costs should be significant.

Because of the versatility and comparatively low price of PVC, it is the second largest plastic in sales volume in the U.S. It is estimated that U.S. industry capacity will exceed 5 billion pounds in 1975, and 7 billion pounds in 1980.

We are now confident that, with the employment of the new VC confinement technologies, the use of PVC will continue to grow, and Goodrich intends to maintain its leadership position in this industry.

VC containment programs have, at least for the present, somewhat reduced capacity at existing Goodrich PVC plants. However, new capacity at the Louisville, Ky., plant, which will start production in January, will more than make up the difference and provide capacity to meet increased customer requirements for the next few years.

These new facilities embody all the improved technology for VC loss reduction

which the Company has developed. With the use of very large reactors, the number of valves, pumps, flanges and other former leak sources has been substantially reduced. New stripping columns, reactor cleaning systems and many other new developments are being installed. Goodrich engineers believe that this new facility will be as good as or better than any other PVC plant in the United States in prevention of employee exposure or escape of VC into the environment, or residual VC in product.

We intend to continue our efforts to reduce VC exposure resulting from all our operations and products, and to continue our research and development efforts to refine our techniques and develop new ones. We face the possibility that, because of the long latency period, we will see other cases of angiosarcoma resulting from heavy exposure in the past.

But we now feel sure that the chances are extremely remote of this disease resulting from VC exposure in our current operations.

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