

INTERNAL CORRESPONDENCE

VC - AutoChromo

CHEMICALS AND PLASTICS

P. O. BOX 8261, SOUTH CHARLESTON, WEST VIRGINIA 25303

Copy To: Mr. D. L. Garrison  
Mr. R. C. Lawrence  
Mr. W. R. Manning  
Mr. R. V. Sealey  
Mr. R. N. Wheeler ←  
Mr. G. L. Baker  
Mr. R. E. Reiter

Date April 20, 1976

Originating Dept. Engineering

Subject Approval of technical manuscript for presentation at American Industrial Hygiene Conference

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Gentlemen:

Attached is a copy of the manuscript titled "Automatic Systems For Monitoring Vinyl Chloride in Working Atmospheres" authored by Messrs. G. L. Baker and R. E. Reiter. This final draft of the manuscript is being forwarded to you for approval for submission to the program committee of the 1976 Industrial Hygiene Conference. If approved, the paper will be presented by Mr. Baker at the 1976 Industrial Hygiene Conference on May 21, 1976 at the Marriott Hotel in Atlanta, Georgia. The American Industrial Hygiene Association Journal also reserves first-call publication rights on all papers presented at this conference.

The manuscript must be submitted prior to the start of the conference, which is May 16th. Therefore, a note of approval sent to me in Building 740, Room 1318 by May 7, 1976 would be greatly appreciated.

If you find any aspect of the manuscript questionable or objectionable, please contact me at extension 5333 or Mr. Baker at extension 4482.

Thank you for assisting us in maintaining Union Carbide's position as a leader in "state-of-the-art" technology throughout our industry.

Sincerely yours,

*J. H. Brubaker*

J. H. Brubaker  
Measurement and Control Technology  
CHEMICALS AND PLASTICS

JHB:ks

Attachment

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APR 22 1976

R. N. WHEELER, JR.

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ROUGH DRAFT

AUTOMATIC SYSTEMS FOR MONITORING VINYL CHLORIDE  
IN WORKING ATMOSPHERES

G. L. BAKER

R. E. REITER

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ABSTRACT

The drastic reduction in the allowable exposure of workers to vinyl chloride monomer (VCM) brought about by the Occupational Safety and Health Administration led Union Carbide Corporation (UCC) to develop automatic monitoring systems for use at production facilities which process VCM. This paper describes what these systems consist of, how they function, and how well they perform.

The present monitoring systems evolved during a project lasting for approximately one year. During the first phase of the project, the analyzers were installed. Each analyzer is a chromatograph equipped with a strip chart recorder, a 20 point stream selector, and a sampling system which includes automatic introduction of a calibration sample on one stream. The measuring range is 0-25 ppm VCM.

During the second phase of the project, data acquisition and processing systems were developed and installed. These systems compute and print out raw data and shift, daily, and monthly averages for each sample point, and the averages for the entire unit. They also compute an estimated maximum employee exposure to VCM, based on the average amount of time each employee spends near each sample point.

The systems are performing very well and are now considered essential operating tools at several UCC production units.

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### INTRODUCTION

Early in 1974 evidence was found indicating that prolonged exposure to high concentrations of vinyl chloride monomer (VCM) may be harmful to human health. The Occupational Safety and Health Administration immediately published an Emergency Temporary Standard for Exposure to Vinyl Chloride<sup>(1)</sup> which reduced the allowable 8-hour average exposure of workers from 500 ppm to 50 ppm VCM. Several months later, the allowable 8-hour exposure was reduced further to 1 ppm<sup>(2)</sup>.

At Union Carbide Corporation (UCC), a high priority program was initiated to obtain automatic monitors which would provide personnel protection and also aid operating personnel in determining sources of VCM emissions at the vinyl resins manufacturing facilities. The UCC Special Instrumentation Department (SID) conducted a survey of instrumentation available to monitor VCM, and prepared a recommendation with a cost estimate. This was completed and approved by the business manager within ten days. Within another ten days, the first monitor was installed and operating. Four more were delivered to preselected plant sites within five weeks after the project began.

Even before the monitors were selected, it was felt that an automatic method of tabulating data would be needed eventually. Soon after the first monitor was installed, this anticipated need was confirmed. Late in 1974, the decision was made to obtain data acquisition and printing capability for all the monitors. This final phase of the project was completed before the end of 1975.

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#### Selection of Monitoring Systems

The first step in obtaining automatic monitoring systems was to investigate the available methods for measuring VCM at low ppm concentrations. The initial measuring range desired was 0-100 ppm, but it was anticipated that eventually a 0-10 ppm range might be required (the range is now 0-25 ppm). This was an important consideration in the selection of instruments. Other important factors considered were reliability, specificity, ease of maintenance, delivery times and cost. It was fortunate that high sensitivity was considered initially to be one of the important requirements, because now the users desire both accuracy and reproducibility to be within  $\pm 0.1$  ppm.

The investigation of methods which could meet the measuring requirements quickly narrowed to two: infrared spectrometry and gas chromatography. Total hydrocarbons analyzers (THA's) were eliminated from serious consideration because many different organic compounds were known to be present in the vinyl resins operating areas, and a THA could not distinguish between VCM and most of these other compounds. Other types of analyzers, such as those which convert organic chlorides to hydrogen chloride and measure conductivity of an aqueous solution containing HCl were also eliminated because of lack of specificity.

Finally, infrared spectrometry was eliminated. Low cost infrared analyzers (\$3,000-\$10,000) lacked the desired sensitivity and specificity. More sophisticated systems such as the EOCOM Model FMS-7200 were acceptable except for the high cost (>\$100,000). Gas chromatographs were also acceptable, and cost only about \$5,000 to \$10,000. All these costs are for only the analyzers; stream selector, data acquisition, and installation costs are additional.

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Although the EOCOM Model FMS-7200 was not selected for the VCM measurement, it would be seriously considered for a problem where several pollutants were to be monitored at the same location. This system is capable of measuring several compounds at a time, even at ppb concentrations, while a chromatograph could measure only one or two with adequate resolution. Therefore, it would become more cost effective where several compounds were being measured in a single area being monitored.

Chromatographs manufactured by various reliable instrument manufacturers were considered for this project. However, a small, special purpose (Model 1200) chromatograph manufactured by Union Carbide for its own use was available for immediate delivery, and at lower cost than the commercial units. In addition, several of these were already in use at the UCC plants where vinyl resins are manufactured, so parts were stocked and instrument technicians were trained to service them. Therefore, the Model 1200 was chosen for the VCM project.

The auxiliary equipment included with each chromatograph was a 20 point electromechanical stream selector, and a strip chart recorder with an adjustable high level alarm, all mounted on a 24 by 52 inch panel. A stream switching station, including a sample pump and stream switching valves, was also provided with each system.

After the first system was installed and performing satisfactorily, it was found that manual tabulation and manipulation of the data from 720 analyses per day from each analyzer consumed too much time of the operating personnel. Therefore, the decision was made to obtain data acquisition and reduction systems. To provide a basis for the selection of data systems, operations personnel

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representing each of the vinyl resins units described the type of data they needed. Then a survey was begun by SID to select a reasonably priced data acquisition system which would meet the requirements.

A small inexpensive microcomputer based on the Intel MCS-8 system had just been developed by Union Carbide. It was selected when the survey revealed that it was the least expensive system available at that time which met the data requirements and could be easily programmed by SID personnel. (Commercial systems can now be obtained for about \$10,000-\$20,000, without programming).

Operations and SID personnel collaborated to define the data requirements more explicitly. This process was very tedious but important. The nature of a data processor is such that once the basis for a program has been established, it is very difficult to change certain aspects without going back and starting over. In spite of the fact that considerable effort was made by UCC to identify all the requirements before beginning programming, an important requirement was overlooked initially, and major reprogramming was required to overcome the deficiency. The point overlooked was that data pertaining to personnel working on a five day per week daytime schedule could not be obtained from the data logged according to the regular four rotating shifts. Therefore, the systems had to be reprogrammed to allow for a "fifth shift". This oversight cost several thousand dollars in programming time to correct.

Soon after the data systems were selected for the first analyzers, five additional vinyl chloride monitoring systems, complete with data systems, were ordered. Figures 1 and 2 show one of the latest systems, including data acquisition. These new monitoring systems are functionally the same as the

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original systems except that the stream selection logic is provided by the microcomputer rather than by the electromechanical stream selector.

#### General System Description

In general, the VCM monitoring system's operation is as follows:

Sample from each of 19 sample points located throughout the production unit is brought to the chromatograph by a vacuum pump connected to the sample lines via a manifold and solenoid valves. Sample selection is brought about by the microcomputer sequentially energizing the solenoid valves, one every two minutes. The sample flows through an air cooler to drop out moisture, and then a 0.5 cc aliquot is injected into the chromatograph. As soon as the sample is injected, the microcomputer starts the next stream purging, to ensure that a fresh sample is available. The VCM concentration obtained by the chromatograph is immediately printed out on a locally mounted strip-chart recorder. It is also stored by the microcomputer for printout at the end of the analyses of all nineteen sample points and check sample, and for calculation of various data summaries. The data summaries include the average VCM concentration and standard deviation for each sample point and for the entire unit, the total of the number of times the VCM concentration exceeded a selected level, and an estimate of the average VCM concentration to which each employee was exposed. The microcomputer can also activate alarms when: (1) the VCM concentration at any point exceeds a preselected level, (2) the check sample analysis is out of range, or, (3) the sample flow is insufficient. A detailed description of the system's components follows.

#### Sampling System

The goal was to monitor as much of a production unit as possible with each analyzer, but without an excessively long time between analyses of different areas. It was decided that there should normally be no more than

40 minutes between checks of each individual area. The chromatograph requires two minutes per analysis, so each analyzer could monitor 20 sample points. Since one sample per cycle was check gas, this meant that 19 areas could be monitored. Production unit personnel determined the areas with the greatest potential for VCM leaks and it was at these locations that the sampling stations were installed. Each sampling station (Figure 3) consists of a cartridge filter protected with an inverted 6 inch funnel as a rainguard, and each is connected to the monitor via 1/4" Type 304 stainless steel tubing.

The tubing from each sample point was connected to a stream switching station, controlled by the microcomputer, which sequentially delivers sample from the 19 individual sample points, and check sample, to the analyzer. As soon as a sample is injected into the chromatograph, the next sample is started purging through the entire system. In applications where there are lines that are too long to be satisfactorily purged within the two minute cycle time (i.e., over 200 feet), a dual pump is used. One side continuously pulls sample from all of the longer sample lines. The other side of the pump delivers the sample the remaining short distance to the analyzer. It also delivers sample directly from the shorter sample lines. Whether a single or dual pump is used, the amount of sample necessary to thoroughly flush the line is in excess of what is required by the analyzer. This excess is vented outdoors.

Stream switching is accomplished through the use of 3-way solenoid valves. In the de-energized state, each solenoid valve connects a sample line to a manifold connected to the "purge" side of the pump. In the energized state, the sample line is connected to the side of the pump which delivers the sample to the chromatograph. The microcomputer allows an operator to select one of three different modes of stream switching:

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- (1) Automatic progression from Sample Point No. 1 through Sample Point No. 20.
- (2) Repeated analysis of any one desired sample point.
- (3) Automatic progression through all sample points while alternately selecting a single sample point, e.g., a sample progression of 1, 4, 2, 4, 3, 4, etc.

The latter mode extends the flexibility of the system because it allows a trouble spot to be monitored more frequently and the effects of corrective action observed without neglecting the rest of the production unit. However, it does lengthen the time required to sample all the points.

#### Chromatograph

The Union Carbide Model 1200 chromatograph is a compact process analyzer equipped with solid state circuitry, including an electronic automatic zero. It is equipped with a flame ionization detector (3, 4) which is very sensitive to most organic compounds including vinyl chloride. It is purged with air and provided with a purge-power safety interlock system permitting safe operation in operating areas which can sometimes be hazardous (Class 1, Group D, Division 2).

A sample valve in the analyzer injects a 0.5 cc sample into a three-column system (Figure 4) every two minutes. The first column separates the vinyl chloride from the high-boiling compounds, such as vinyl acetate, which might be present in the sample. A column valve diverts the unwanted compounds to vent, and at the proper time, diverts the vinyl chloride to the

second column where it is separated from most remaining interferants. A second column valve diverts these interferants to vent, and at the proper time diverts the vinyl chloride to the third column, where the final separation is made. (Some of the analyzers located where few interfering compounds are present, contain only two columns).

The first two columns contain 20 percent Igepal CO-880 on a Chromasorb P support. The third column contains 20 percent Octoil S on a Chromasorb P support.

Calibration sample for the chromatograph is 10 ppm VCM in a nitrogen matrix, prepared by the partial pressure technique and kept in a steel cylinder. It can be introduced manually for calibration, and is automatically introduced as Sample No. 20 during normal operation. The microcomputer is programmed to verify that Sample No. 20 is always in range.

#### Data and Alarm System

Each monitor is equipped with a potentiometric strip-chart recorder located on the analyzer panel, but the heart of the data system is the Union Carbide Model 2800 Microcomputer, which is used in conjunction with a GE TermiNet 300 Printer. The Model 2800 was developed by Union Carbide for in-house use. It is designed around the Intel MCS-8 Microcomputer System. It is an 8-bit parallel processor with a typical instruction cycle time of 12.5 microseconds, and is capable of addressing 16,384 eight-bit words of memory. The GE TermiNet 300 prints at a rate of 30 characters per second.

The result of each analysis is immediately printed out on the strip-chart recorder at the same time the VCM is "seen" by the detector.

Referring to Figure 5, the wide bars are the sample point identification bars; the length of each is proportional to the sample point number it represents. The line above the sample point identification bar indicates the VCM concentration at that sample point.

The microcomputer accepts the raw analysis data from the analyzer, performs two checks to determine that the data is valid, and then stores the data for printout and for calculating a number of statistical summaries to provide information on probable employee exposure. These summaries are provided on work shift, daily and monthly bases (Tables I - III).

One of the checks the microcomputer makes before storing a piece of data is to see whether the sampling system flow switch is actuated (i.e., sample flow is insufficient). If it is, an alarm is actuated and the word "FLOW" is printed out instead of raw data for that sample point, and the value is not included in calculating the statistical summaries.

The other check is performed following each analysis of the check sample. If the result obtained for the check sample does not lie between two preselected values, an alarm is actuated and the message "CHECK GAS" will appear on the next printout. Subsequent analyses values will be printed out but not stored for use in calculating the statistical summaries until the result for the check sample returns to an acceptable value.

A printout of results occurs upon completion of analysis of all twenty sample points. The time of day is printed out with each line of data. At the end of each work shift, day and month, a summary of the data is printed (Table 1).

Each shift summary (Table I) consists of the average of the past eight hours' analyses for each point, a total of the number of times the overall average VCM concentration exceeded a preset value, and a calculated average exposure by job-type. The job-type averages are time-weighted averages for up to 16 different job types, which are based on the estimated average percent of time a worker doing a particular type of job spends in the vicinity of each sample point being analyzed. They are calculated from the eight-hour averages.

The daily summary (Table II) consists of two sections: 1) a summary of the past 24 hours in the form of averages for each point and for the entire unit, and the number of times each point and the entire unit exceeded the preset limit; and 2) a month-to-date summary which consists of the average and standard deviation of all data accumulated to date for the current month, the total number of times each point exceeded the preset limit, and the average number of times per day each point exceeded the limit.

The monthly summary (Table III) consists of six sections with the same format, one for each of the four shifts, one for day shift personnel, and one for the unit as a whole. Each section consists of a summary for the entire month and contains the average analysis value and standard deviation for each sample point and for the entire unit, the total number of times each sample point exceeded the preset limit, the average number of times per day each point exceeded the limit, an estimated average exposure and standard deviation by job-type as described in the 8-hour summary, and finally, a calculated probability that the employees of each job type were exposed to a concentration greater than the preset level.

If the amount of VCM in the sample is above either of the two adjustable alarm levels preset in the microcomputer, an alarm is actuated. In order to help it meet the regulations of April 1, 1976 and to eliminate the "lag time" involved when the control room operator has to relay alarm information to the field operators, some of the systems are utilizing an additional output circuit of the microcomputer to activate warning lights located in each of the monitored areas. The light stays on until subsequent analysis of that sample point shows the VCM concentration has returned to a safe level. Consideration has been given to utilizing this same circuitry to activate an annunciator which would automatically play a recording announcing which area is unsafe. An alarm can also be actuated if the flow switch in the sampling system detects a low flow (e.g., a plugged sample line) or if the check sample analysis is beyond the preset values.

#### System Performance

The performance of the monitoring system was checked to see how various environmental factors affected its response. Extensive tests were run with one of the analyzers to determine its reproducibility under both steady and unsteady-state ambient temperature conditions, and to determine the interference effect of the many different compounds sometimes present in the ambient air of the production units where VCM is monitored.

Under controlled ambient conditions, with the measuring range set to 0-10 ppm, the readings from a 5 ppm VCM calibration sample reproduced within  $\pm 0.05$  ppm for 24 hours (Figure 6). A sample containing no VCM and another containing 1.0 ppm reproduced slightly better.

In other tests, with the measuring range set to 0-25 ppm, the 1 ppm sample reproduced within  $\pm 0.1$  ppm for 24 hours.

The average VCM readings changed slightly as the ambient temperature changed. The results are shown in Figure 7.

Ambient temperature changes produced another effect which might in some circumstances have a small effect on the results. A rapid change in the temperature (3-4°C/min.) of the sample tubing near the analyzer can change the reading by as much as 20 percent of the VCM concentration. A sudden increase of temperature increases the normal response from the sample, while a sudden decrease of temperature decreases the response. This apparently results from a small amount of adsorption of sample on the tubing walls. This is not believed to be a serious problem for the existing applications, but if the effect occurs, it can be reduced by insulating the sample tubing near the analyzer to prevent rapid temperature changes.

Operating personnel at the vinyl resins units were questioned concerning what compounds might be present in the atmosphere at the units. Synthetic samples of these compounds and others which were known to elute near the VCM elution time were prepared and introduced into the analyzer to determine whether any of them would interfere with the VCM analysis. Methyl chloride produced the greatest interference of any of the compounds. 20 ppm methyl chloride produced a response equivalent to 1 ppm VCM. High concentrations of toluene were also found to cause some interference. 1000 ppm toluene produced a response equivalent to 6 ppm VCM. This response to toluene was not immediate; it showed up approximately 40 minutes after it was sampled. The complete results of the tests are shown in Table IV.

Tests were performed on two different sample lines installed in a plant. One was 400 feet of 1/4" Type 304 ~~stainless~~ stainless steel; the other, 125 feet of 1/4" polyethylene. No reduction in the response to a 1 ppm VCM sample was detected when pulled through the stainless steel line. Also, the full response was obtained within the two minute analysis cycle time. However, a loss of about 25 percent of the response to the same 1 ppm sample occurred when it was pulled through the polyethylene line, even after several minutes. ) 2

These test results and the poor mechanical properties of polyethylene tubing justified the recommendation not to use it for sample lines in spite of substantially lower installation costs.

In general, the monitors have required little maintenance and stay "on-line" greater than 99% of the time. Periodically, a microswitch or electromechanical relay has had to be replaced in the chromatograph, and solenoid valves have had to be replaced in the sampling systems. A number of problems were encountered with the printers shortly after each was started up, but once these were corrected, the printers have not required a great deal of maintenance.

### System Utilization

The most important service the VCM monitors have performed is in helping reduce VCM emissions by locating sources of leaks. It has helped engineers determine the perpetual trouble spots, which were remedied by equipment re-design or replacement, and it still helps shift personnel locate leaks due to equipment malfunction. Whenever the VCM concentration exceeds an acceptable value at any sample point, one of the shift personnel goes into the vicinity of the sample point with proper respiratory equipment and a portable organic vapor analyzer to locate the leak source.

In most cases, the estimated average VCM exposure of each employee calculated by the microcomputer agrees quite well with the data obtained by carbon-tube and Sipon pump worn by the employee. At one of UCC's vinyl resins units, agreement has been so good, they have done away with requiring personnel to wear carbon tubes, and rely solely on the monitor's data.

This employee exposure calculation has also been put to use in a slightly different way. At one plant location, personnel are trying to determine if one of their buildings can be de-regulated. They have entered all the sample points in that building as one "job", so the microcomputer prints out an easily referred to set of data on the building, along with the printout of employee exposure data.

#### CONCLUSION

The VCM monitoring systems which have been started up and debugged have performed very well. The data have been obtained and logged on permanent records without consuming valuable operator time. The systems have been valuable in rapidly detecting VCM emissions into the working environment so that immediate corrective action can be taken and employee exposure minimized. These or equivalent monitoring systems are essential to the vinyl resins units in meeting the existing regulations affecting personnel exposure to VCM.

The systems are very sensitive, accurate and relatively maintenance free. VCM concentrations can be read to the nearest 0.1 ppm, and very few compounds affect the VCM readings. Several built-in system checks, such as sample flow and the automatic introduction of calibration gas help to ensure that the data obtained is accurate and reliable.

Union Carbide considers the VCM monitoring systems to be completely successful, and preferred to other approaches for dealing with the VCM emission and employee exposure problems. Similar systems would be useful in monitoring other volatile compounds which are suspected to be harmful to human health.

#### References

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3. Caldecote, H. F.: Ion Production and Removal in Flames. Presented at the Eighth Symposium (International) on Combustion, Pasadena, California, August 29 - September 2, 1960.
4. Sternberg, J. D., Galloway, W. S., and D. T. L. Jones: "The Mechanism of Response of Flame Ionization Detectors." ISA Proceedings 1961 International Gas Chromatography Symposium.

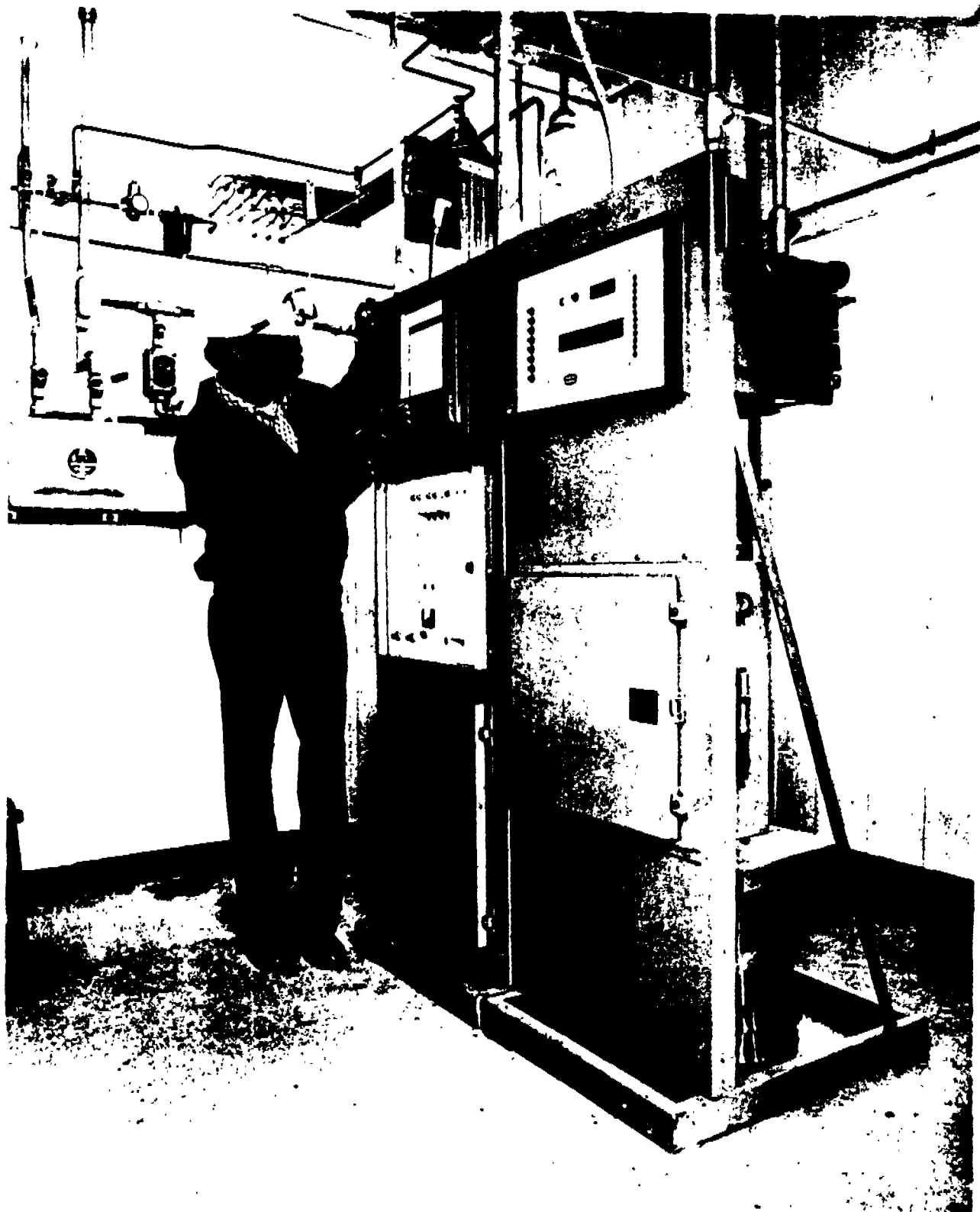


FIGURE 1. TYPICAL VCM MONITOR INSTALLATION

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FIGURE 2. GENERAL ELECTRIC TERMINET 300 PRINTER



FIGURE 3. TYPICAL SAMPLING STATION

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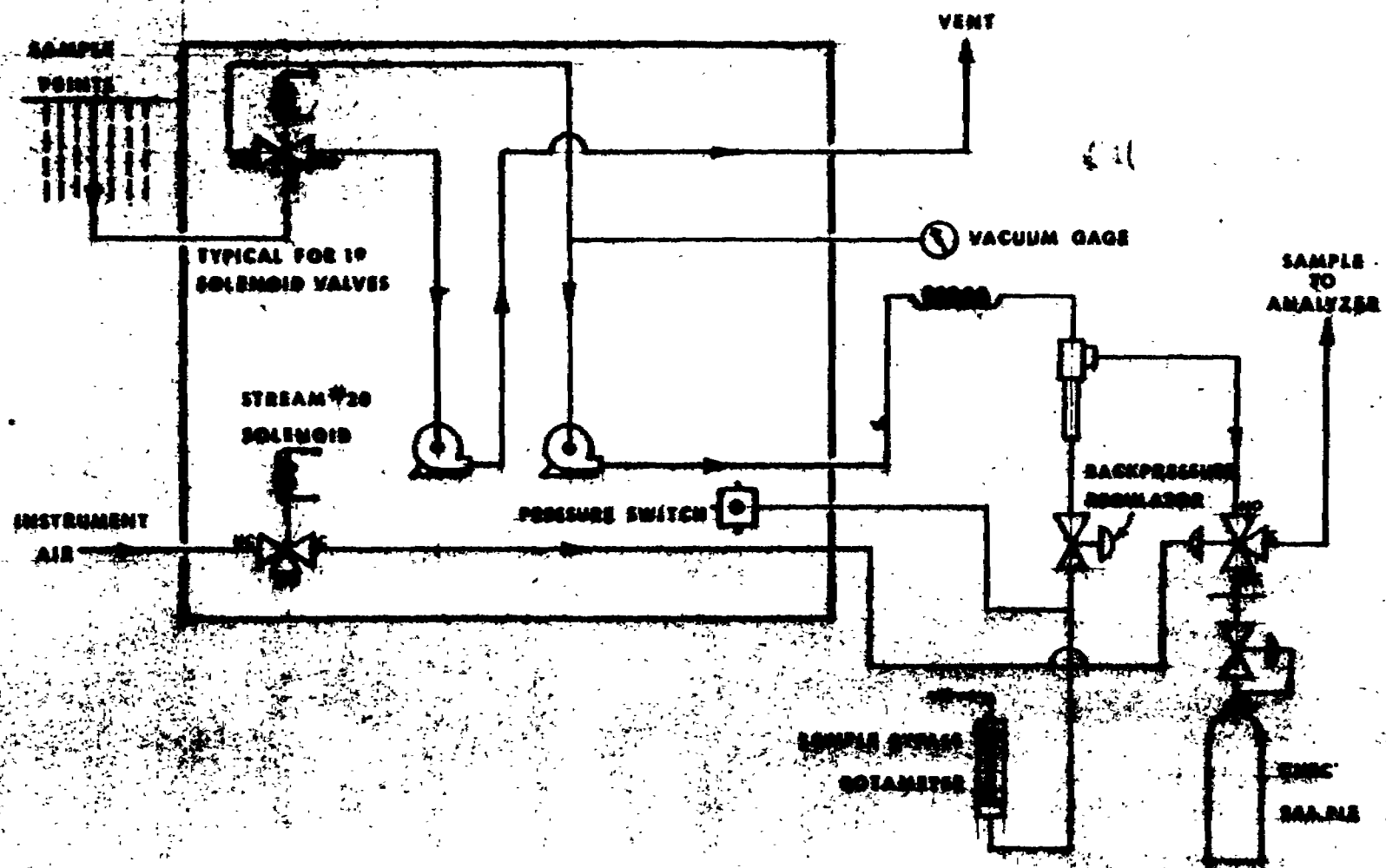


FIGURE 4. SAMPLING SYSTEM SCHEMATIC DIAGRAM

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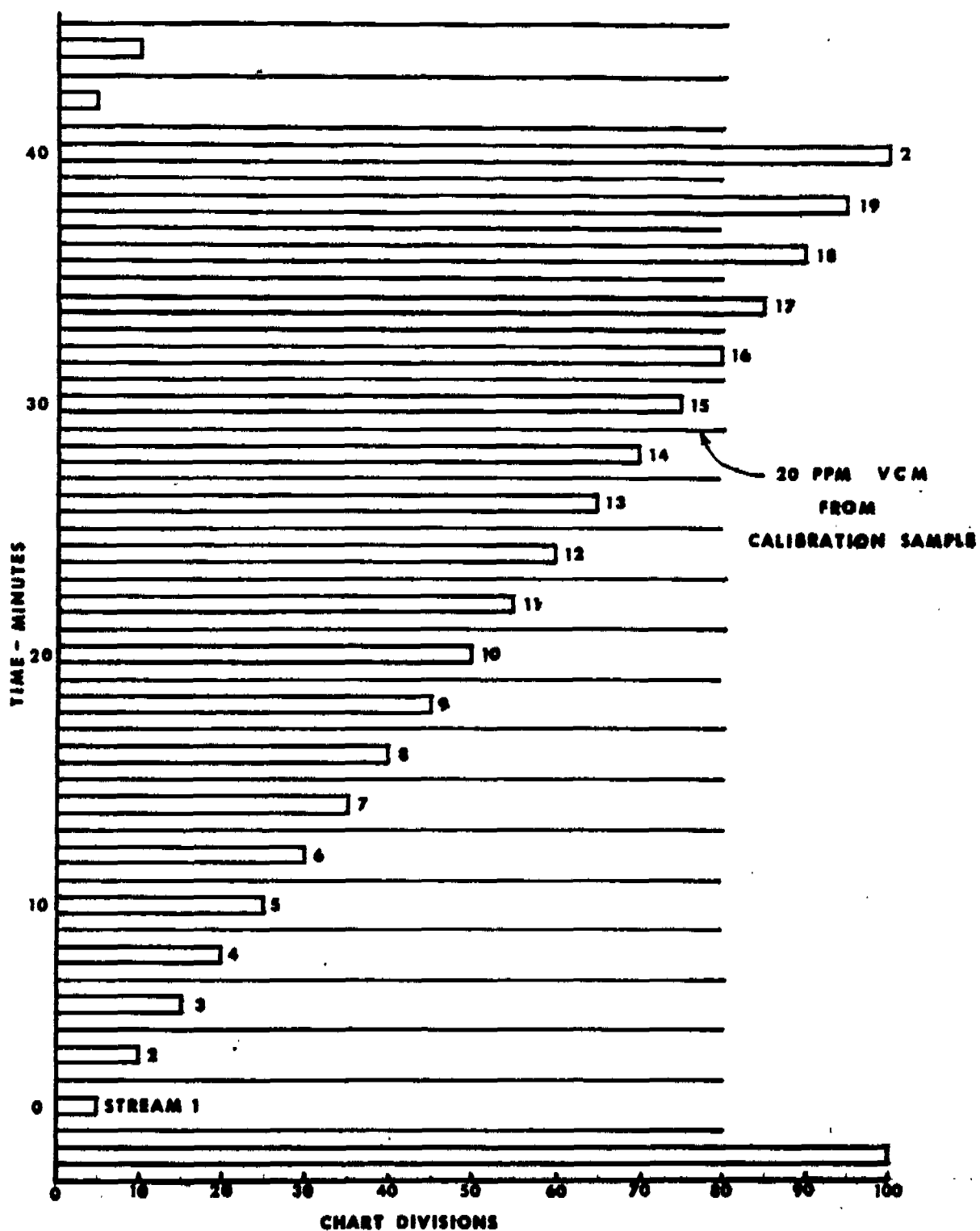


FIGURE 5. ANALOG DATA PRESENTATION

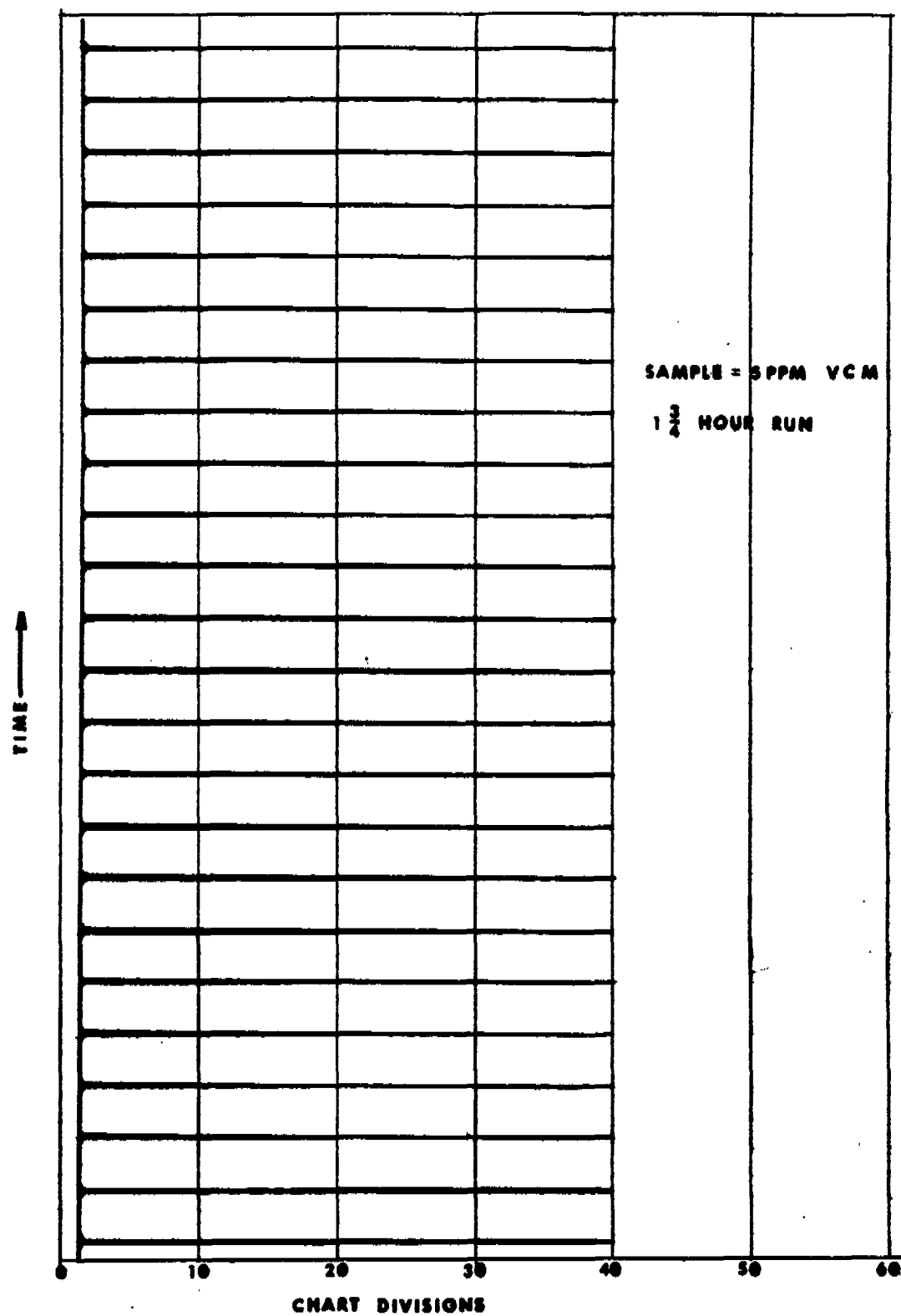


FIGURE 6. VCM MONITOR REPRODUCIBILITY

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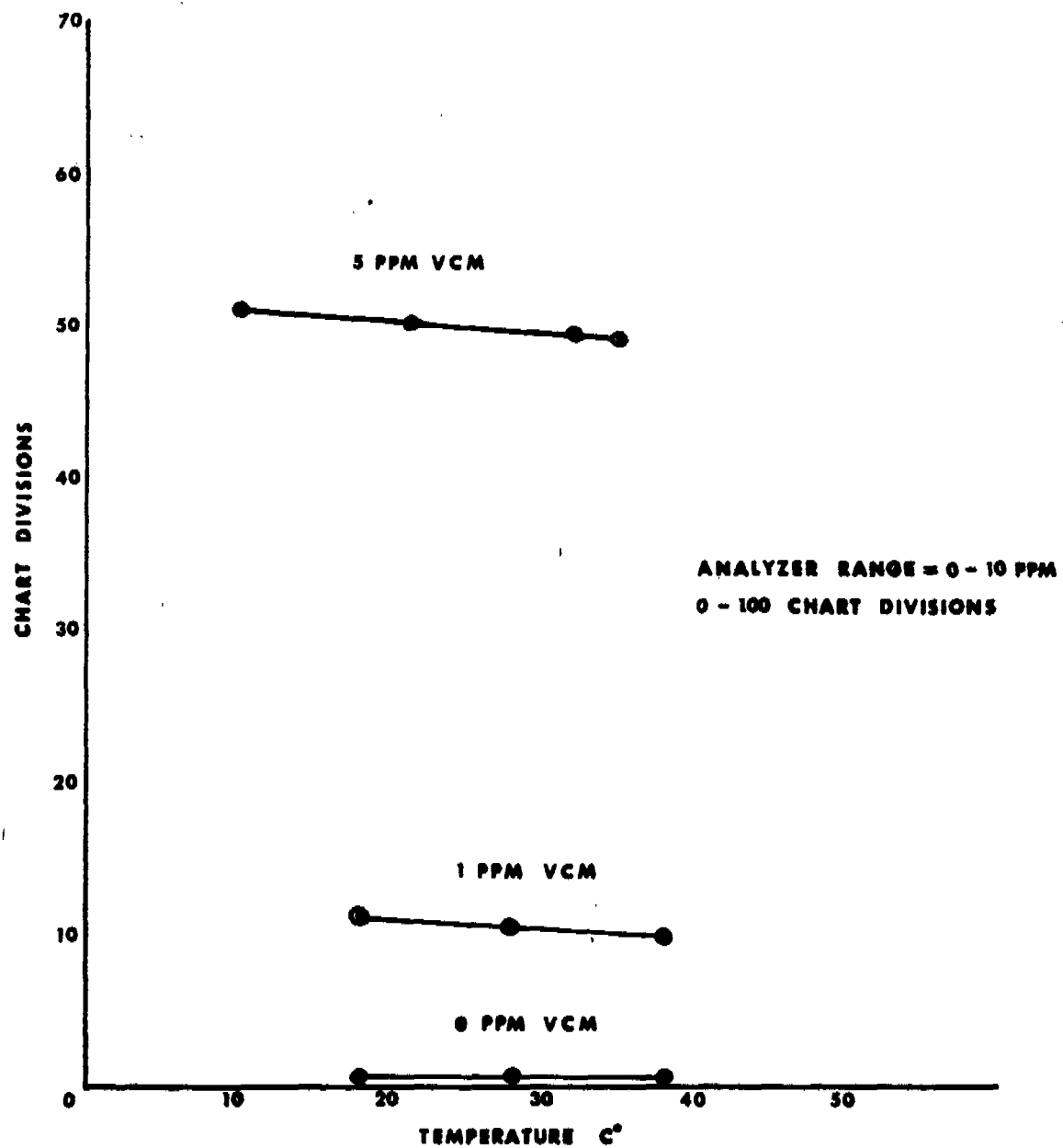


FIGURE 7. EFFECT OF AMBIENT TEMPERATURE ON ANALYZER RESPONSE

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TABLE 1  
FORMAT FOR RAW DATA AND SHIFT SUMMARY

VINYL CHLORIDE BY CONTINUOUS MULTIPPOINT GAS CHROMATOGRAPHIC ANALYSIS  
EXPERIMENTAL UNIT--NO TOWN, USA  
06/29/75

|                                             | SAMPLE POINT |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|---------------------------------------------|--------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| TIME                                        | 21           | 22  | 23  | 24  | 25  | 26  | 27  | 28  | 29  | 30  | 31  | 32  | 33  | 34  | 35  | 36  | 37  | 38  | 39  | 40  |
| <b>A SHIFT</b>                              |              |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 00:12                                       | 0.0          | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 00:52                                       | 0.0          | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 01:32                                       | 0.0          | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 02:12                                       | 0.0          | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 02:52                                       | 0.0          | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 03:32                                       | 0.0          | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 04:12                                       | 0.0          | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 04:52                                       | 0.0          | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 05:32                                       | 0.0          | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 06:12                                       | 0.0          | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 06:52                                       | 0.0          | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 07:32                                       | 0.0          | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 10. |
| <b>B HOUR AVERAGES A06/30/75</b>            |              |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|                                             | 0.0          | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| <b>NUMBER OF TIMES EXCEEDING 5.0 PPM: 0</b> |              |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

AVERAGE EXPOSURE BY JOB TYPE

JOB00: 0.0 JOB01:21.3 JOB02: 0.0 JOB03:20.3 JOB04:13.7 JOB05:25.0 JOB06:12.9 JOB07:25.6  
JOB10:19.3 JOB11: 0.0 JOB12:14.8 JOB13:12.8 JOB14:12.9 JOB15:15.2 JOB16:12.8 JOB17: 0.0

**B SHIFT**

|                                             |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|---------------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 08:12                                       | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 08:52                                       | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 09:32                                       | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 10:12                                       | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 10:52                                       | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 11:32                                       | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 12:12                                       | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 12:52                                       | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 13:32                                       | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 14:12                                       | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| 14:52                                       | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.7 | 0.1 | 0.0 | 0.0 | 10. |
| 15:32                                       | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10. |
| <b>B HOUR AVERAGES B06/30/75</b>            |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|                                             | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 10. |
| <b>NUMBER OF TIMES EXCEEDING 5.0 PPM: 0</b> |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

AVERAGE EXPOSURE BY JOB TYPE

JOB00: 0.0 JOB01:21.6 JOB02: 0.0 JOB03:20.6 JOB04:13.8 JOB05:25.4 JOB06:13.1 JOB07:26.1  
JOB10:19.3 JOB11: 0.0 JOB12:15.2 JOB13:13.0 JOB14:13.0 JOB15:15.2 JOB16:13.0 JOB17: 0.0

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TABLE II

DAILY SUMMARY FORMAT WITH NON-FACTUAL DATA

## VINYL CHLORIDE BY CONTINUOUS MULTIPPOINT GAS CHROMATOGRAPHIC ANALYSIS

EXPERIMENTAL UNIT--NO TOWN, USA

## SUMMARY FOR 06/30/75

| SAMPLE POINT                                   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      | ENTIRE |
|------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|--------|
| 21                                             | 22  | 23  | 24  | 25  | 26  | 27  | 28  | 29  | 30  | 31  | 32  | 33  | 34  | 35  | 36  | 37  | 38  | 39  | 40   | UNIT   |
| 24 HOUR AVERAGES                               |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |        |
| 0.0                                            | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.3 | 0.0    |
| NUMBER OF TIMES EXCEEDING 5.0 PPM (EACH POINT) |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |      |        |
| 0                                              | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0    | 0      |

## MONTH-TO-DATE SUMMARY

## AVERAGE FOR MONTH

0.4 0.3 0.1 0.1 0.5 2.6 0.4 0.4 0.3 1.0 0.1 0.3 0.2 0.3 0.2 2.2 0.3 1.3 0.2 10.1 0.6

## STANDARD DEVIATION OF AVERAGE

1.7 1.6 0.5 0.5 1.6 6.4 0.9 1.1 0.6 2.9 0.4 0.8 0.7 0.9 1.1 6.3 0.9 3.7 0.9 0.6 2.5

## NUMBER OF TIMES EXCEEDING 5.0 PPM (EACH POINT)

14 8 0 1 20 137 10 7 3 38 0 5 6 7 5 106 7 78 8 460

## AVERAGE NUMBER OF TIMES PER DAY EXCEEDING 5.0 PPM (EACH POINT)

1 1 0 0 2 17 1 0 0 4 0 0 0 0 0 13 0 9 1 57

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DAY SHEET

TABLE III

| MONTHLY SUMMARY FORMAT WITH NON-FACTUAL DATA                   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|----------------------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| AVERAGE FOR MONTH                                              |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 0.3                                                            | 0.3 | 0.2 | 0.1 | 0.4 | 2.4 | 0.3 | 0.3 | 0.2 | 0.6 | 0.1 | 0.2 | 0.2 | 0.3 | 0.2 | 2.2 | 0.3 | 1.3 | 0.3 |
| STANDARD DEVIATION OF AVERAGE                                  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 0.7                                                            | 1.2 | 0.3 | 0.3 | 0.9 | 5.1 | 0.6 | 0.6 | 0.4 | 1.1 | 0.2 | 0.6 | 0.4 | 0.5 | 1.6 | 6.3 | 0.7 | 2.8 | 1.2 |
| NUMBER OF TIMES EXCEEDING 5.0 PPM (EACH POINT)                 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 1                                                              | 2   | 0   | 0   | 2   | 48  | 1   | 0   | 0   | 3   | 0   | 0   | 0   | 0   | 1   | 35  | 1   | 31  | 5   |
| AVERAGE NUMBER OF TIMES PER DAY EXCEEDING 5.0 PPM (EACH POINT) |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 0                                                              | 0   | 0   | 0   | 0   | 6   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 4   | 0   | 3   | 0   |

AVERAGE EXPOSURE BY JOB TYPE

|             |             |             |             |             |             |             |             |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| JOB00: 6.4  | JOB01: 33.7 | JOB02: 2.0  | JOB03: 25.9 | JOB04: 17.0 | JOB05: 45.3 | JOB06: 21.2 | JOB07: 47.2 |
| JOB10: 22.5 | JOB11: 0.4  | JOB12: 24.3 | JOB13: 16.5 | JOB14: 20.2 | JOB15: 17.7 | JOB16: 16.6 | JOB17: 3.6  |

STANDARD DEVIATION ON AVERAGE EXPOSURE

|            |            |            |            |            |            |            |            |
|------------|------------|------------|------------|------------|------------|------------|------------|
| JOB00: 3.3 | JOB01: 2.0 | JOB02: 3.6 | JOB03: 4.9 | JOB04: 4.6 | JOB05: 4.2 | JOB06: 6.6 | JOB07: 7.2 |
| JOB10: 4.4 | JOB11: 0.7 | JOB12: 2.7 | JOB13: 4.2 | JOB14: 7.1 | JOB15: 4.2 | JOB16: 6.6 | JOB17: 6.6 |

PER CENT PROBABILITY OF EXPOSURE GREATER THAN 1.8 PPM:

|             |             |             |             |             |             |             |             |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| JOB00: 91.9 | JOB01: 99.9 | JOB02: 51.7 | JOB03: 99.9 | JOB04: 99.9 | JOB05: 99.9 | JOB06: 99.7 | JOB07: 99.9 |
| JOB10: 99.9 | JOB11: 2.5  | JOB12: 99.9 | JOB13: 99.9 | JOB14: 99.3 | JOB15: 99.9 | JOB16: 98.7 | JOB17: 60.3 |

UNIT

|                                                                |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|----------------------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| AVERAGE FOR MONTH                                              |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 0.4                                                            | 0.3 | 0.1 | 0.1 | 0.5 | 2.6 | 0.4 | 0.4 | 0.3 | 1.0 | 0.1 | 0.3 | 0.2 | 0.3 | 0.2 | 2.2 | 0.3 | 1.3 | 0.2 |
| STANDARD DEVIATION OF AVERAGE                                  |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 1.7                                                            | 1.6 | 0.5 | 0.5 | 1.6 | 6.4 | 0.9 | 1.1 | 0.6 | 2.9 | 0.4 | 0.8 | 0.7 | 0.9 | 1.1 | 6.3 | 0.9 | 3.7 | 0.9 |
| NUMBER OF TIMES EXCEEDING 5.0 PPM (EACH POINT)                 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 14                                                             | 8   | 0   | 1   | 20  | 137 | 10  | 7   | 3   | 38  | 0   | 5   | 6   | 7   | 5   | 106 | 7   | 78  | 8   |
| AVERAGE NUMBER OF TIMES PER DAY EXCEEDING 5.0 PPM (EACH POINT) |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 1                                                              | 1   | 0   | 0   | 2   | 17  | 1   | 0   | 0   | 4   | 0   | 0   | 0   | 0   | 0   | 13  | 0   | 9   | 1   |

AVERAGE EXPOSURE BY JOB TYPE

|             |             |             |             |             |             |             |             |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| JOB00: 6.9  | JOB01: 35.1 | JOB02: 2.1  | JOB03: 26.1 | JOB04: 17.2 | JOB05: 47.1 | JOB06: 22.0 | JOB07: 49.2 |
| JOB10: 22.7 | JOB11: 0.4  | JOB12: 24.5 | JOB13: 17.2 | JOB14: 20.2 | JOB15: 17.7 | JOB16: 17.0 | JOB17: 4.0  |

STANDARD DEVIATION ON AVERAGE EXPOSURE

|            |            |            |            |            |            |            |            |
|------------|------------|------------|------------|------------|------------|------------|------------|
| JOB00: 7.4 | JOB01: 7.8 | JOB02: 4.8 | JOB03: 5.4 | JOB04: 6.1 | JOB05: 5.9 | JOB06: 3.9 | JOB07: 7.0 |
| JOB10: 5.9 | JOB11: 1.1 | JOB12: 5.2 | JOB13: 6.5 | JOB14: 6.9 | JOB15: 5.5 | JOB16: 2.5 | JOB17: 2.1 |

PER CENT PROBABILITY OF EXPOSURE GREATER THAN 1.8 PPM:

|             |             |             |             |             |             |             |             |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| JOB00: 74.9 | JOB01: 99.9 | JOB02: 51.7 | JOB03: 99.9 | JOB04: 99.3 | JOB05: 99.9 | JOB06: 99.9 | JOB07: 99.9 |
| JOB10: 99.9 | JOB11: 10.9 | JOB12: 99.9 | JOB13: 99.1 | JOB14: 99.5 | JOB15: 99.7 | JOB16: 99.9 | JOB17: 85.1 |

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TABLE IV  
Response of VCM Monitor to  
Compounds Other Than VCl  
(Analyzer Range - 25 ppm Full Scale)

| <u>Compound</u>     | <u>Concentration, ppm</u> | <u>Response, as ppm VCM</u> |
|---------------------|---------------------------|-----------------------------|
| acetaldehyde        | 25                        | None                        |
| acetone             | 10,000                    | None                        |
| butadiene           | 100                       | None                        |
| n-butyl acrylate    | 1,000                     | 1*                          |
| 1-butyne            | 100                       | None                        |
| chlorine            | 100                       | None                        |
| ethyl chloride      | 100                       | None                        |
| ethylene oxide      | 100                       | None                        |
| hydrogen chloride   | 100                       | None                        |
| isobutane           | 100                       | None                        |
| isobutylene         | 1,000                     | 0.2                         |
| isopropanol         | 1,000                     | None                        |
| methanol            | 1,000                     | None                        |
| methyl acetate      | 1,000                     | None                        |
| methyl chloride     | 20                        | 0.6                         |
| methyl ethyl ketone | 1,000                     | None                        |
| n-nonane            | 1,000                     | None                        |
| 1-pentene           | 100                       | None                        |
| toluene             | 1,000                     | 6*                          |
| trichloroethylene   | 1,000                     | None                        |
| vinyl acetate       | 1,000                     | None                        |
| methane             |                           |                             |
| ethane              |                           |                             |
| ethylene            |                           |                             |
| acetylene           |                           |                             |
| propane             |                           |                             |
| propylene           | 1,200 Total               | 0.6                         |
| allene              |                           |                             |
| propyne             |                           |                             |
| n-butane            |                           |                             |
| 1-butene            |                           |                             |
| cis-2-butene        |                           |                             |
| trans-2-butene      |                           |                             |

\* Interference does not appear immediately, but occurs approximately 20 samples later.

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