CONOCO

Interoffice Communication

To C. E. Gremillion

From J. J. Hall

Date November 19, 1975

Subject Feasibility of Automated VCM Monitoring System

Attached is the final report on the feasibility of installing an automated fixed-point system for monitoring personnel exposure to VCM. It contains a brief explanation of the concept of automated personnel monitoring, the results of the system calibration, a break-down of typical system costs, and recommendations.

As the report indicates, it appears that automated personnel monitoring is technologically and economically feasible and could result in significant reductions in not only laboratory workload but also the paperwork and recordkeeping required by OSHA.

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AUTOMATED MONITORING SYSTEM

PREPARED FOR

THE

CONTINENTAL VCM PLANT
WESTLAKE, LA.

November 19, 1975

BY

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OUTLINE

FIGURES

INTRODUCTION

The objective of this report is to describe and assess the feasibility of an alternative method for monitoring personnel exposure to vinyl chloride (VCM).

The current OSHA Standard on Exposure to Vinyl Chloride places stringent requirements on the manufacturer of VCM in the area of evaluation and control of personnel exposures. Legal requirements outlining the frequency of personnel monitoring, the minimum accuracy levels, and the maintenance of appropriate records place a tremendous burden on the VCM manufacturer. Moreover, because of the provision that monitoring data, engineering design improvements, and access rosters must be maintained for a thirty year period, the added expense of personnel monitoring must be considered long-term rather than temporary.

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CURRENT MONITORING TECHNIQUE

The existing system of personnel monitoring for organic vapor (including VCM) involves the use of dosimeters. The dosimeter is a small portable device which, when carried on the person of an employee, integrates his average exposure to VCM throughout the work-day. The device consists, briefly, of a small battery-powered air pump which draws a measured volume of air from the breathing zone of an employee, through a tube filled with activated charcoal. Any organic vapor present will adsorb to the charcoal. The amount of VCM adsorbed is measured (by gas chromatography) so that the average atmospheric concentration at the breathing zone can be calculated.

This technique represents the state of the art in industrial hygiene and is entirely adequate in classical monitoring applications. For example, the evaluation of an occupational exposure to a toxic substance generally consists of the following sequence.

First, an adequate number of samples are taken, ideally representing a "typical" work experience. The sampling results give an indication as to whether a potentially hazardous exposure exists. If the exposure is excessive, steps are taken to control the exposure. Repeated monitoring discloses the effectiveness of the controls. When exposures have been reduced to "safe" levels, continued personnel monitoring is generally unnecessary.

For this type of monitoring, the use of dosimeters is ideal. The sample is drawn directly from the breathing zone of the worker eliminating many of the sources of error in estimating his exposure.

However, the system does have its disadvantages. It is cumbersome for the employee who must wear the dosimeter. It requires a significant amount of laboratory analysis time. And it necessitates scheduling and training of employees in the proper care of the dosimeters. Compliance with the new OSHA standards requires the acquisition of tremendous amounts of data. Personnel monitoring becomes a continuing program rather than a matter of taking a few occasional samples. Compliance with OSHA standards using dosimeter monitoring methodology can impose a tremendous workload in laboratory analysis time and record keeping man-hours.

Automated Concept

A system for monitoring personnel exposures to VCM in compliance with the OSHA standard should meet the following criteria:

1) Effectively measure personnel exposures to VCM, meeting the requirements of the OSHA Standard for Exposure to Vinyl Chloride (29CFR 1910.93q).

2) Impose a minimum workload on laboratory and administrative personnel.

3) Possess alarm capabilities which could alert employees in the event that VCM concentrations exceed a preset value.

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4) Be capable of assisting in the control of access to regulated areas and compiling records of authorized personnel who have entered the area.

5) Be technologically and economically feasible.

The search for an improved technique for meeting these criteria for VCM monitoring had, as its ultimate goal, the elimination or at least reduction of the manual processing time. Such a search naturally gravitates toward methods of automating the monitoring "system". A monitoring system to measure time-weighted average (TWA) exposure to VCM must have the capability to measure and correlate three basic input variables: (1) ambient VCM concentrations in various plant areas, (2) employee locations, and (3) time of exposure.

Measurement of System Parameters

The first parameter, ambient VCM concentrations, is currently being monitored by two process gas chromatographs located in the plant control room. Each of these chromatographs sequentially monitors ten fixed plant locations in the plant. Therefore, ambient VCM concentrations at twenty fixed point locations are monitored throughout the day. Each point is measured at approximately ten-minute intervals. Output from the chromatographs is recorded on strip charts in the control room and maintained on file.

The two remaining parameters, employee location and time of exposure can be measured by any one of several techniques.

Motion and Time Study. One classical method for predicting personnel locations involves the use of motion and time study analysis. This technique could produce a chart for each job classification outlining location versus time for a typical work shift. A continuing work sampling plan could be employed to ensure that the actual work scheme for each job classification did not vary significantly from the initial sequence. This method could have application in plants where job tasks are repetitive and therefore predictable with a significant level of accuracy. However, in continuous chemical process operation, the job tasks of operations and particularly of maintenance personnel are so highly varied that a motion/time study analysis could not reliably predict location versus time charts for all employees.

Transmitter. An innovative approach to monitoring personnel location employs the use of miniature electronic transmitters, carried by each employee so that his exact position could be continuously monitored and recorded. While such a technique would obviously yield the ultimate in accuracy, it would be cost-prohibitive for most applications. In addition, employee reaction to a device whereby management could continuously monitor their whereabouts would doubtless be strongly negative.

Badge Readers. A third approach, utilizing a network of badge readers located at strategic points in the plant appears to be the most cost-effective technique. By locating badge readers at the entrances to critical areas of the plant (e.g., regulated areas) the time during which any employee might remain in an area with high ambient VCM levels could be logged. Each employee would carry a unique identification card (existing ID cards could be used when appropriately punched) and would be required to "punch in" and "punch out" upon entering and exiting regulated areas.

Data Compilation and Reduction. Data from two of the sources outlined above (i.e., gas chromatographs and badge readers) are required to calculate TWA personnel exposures. First, the ambient VCM concentrations as a function of time in various plant areas are measured by the gas chromatographs and recorded. Second, personnel location data are generated by the badge reader network. The data from both sources must be compiled correlated and reduced to generate daily TWA exposures for plant employees. The TWA exposure for an individual is calculated using the following equation:

$$\text{T.W.A.} = \frac{\sum_{i=1}^{n} (T_i)(C_i)}{\sum_{i=1}^{n} (T_i)}$$

where: C_i = concentration in ppm

T_i = time exposed at that concentration

Such voluminous calculations are best automated to be practically useful. It would seem then, that the most appropriate system for the Conoco VCM Plant would be one which would utilize the existing chromatographs, coupled with a network of strategically placed badge readers and centered around a minicomputer to compile and reduce the data to useful form (see Figure 1).

Proposed System

Several firms currently market systems utilizing badge reader networks similar to that outlined in Figure 3. Preliminary quotes indicate that TANO Corporation of New Orleans offers the most cost-effective approach. TANO's VCM monitoring package employes a Digital PDP-11 minicomputer to continuously monitor the two input variables. Any measured concentration higher than a preset limit would cause an alarm system to activate. Each person entering the plant would be issued a unique badge number and a wallet-sized card. Upon entering one of the designated areas, employees would insert their card into the badge reader. A background ambient concentration level is used for individuals not registered into one of the designated areas. At the end of each shift VCM concentrations compiled from chromatograph input, coupled with badge reader inputs are integrated into TWA exposures for each employee. These data are used to produce reports such as:

1) A daily report of VCM exposure for each person in the plant during the preceding twenty-four hours.

2) A letter individually addressed to each person exposed to VCM levels higher than the permissible limit (an OSHA requirement).

System components and preliminary price quotes are listed below:

PDP-11 Computer w/32k Processor
7 Badge Readers
TDAC Interface
RSX11-M System Software
Application Software
Installation
Dual Cassette

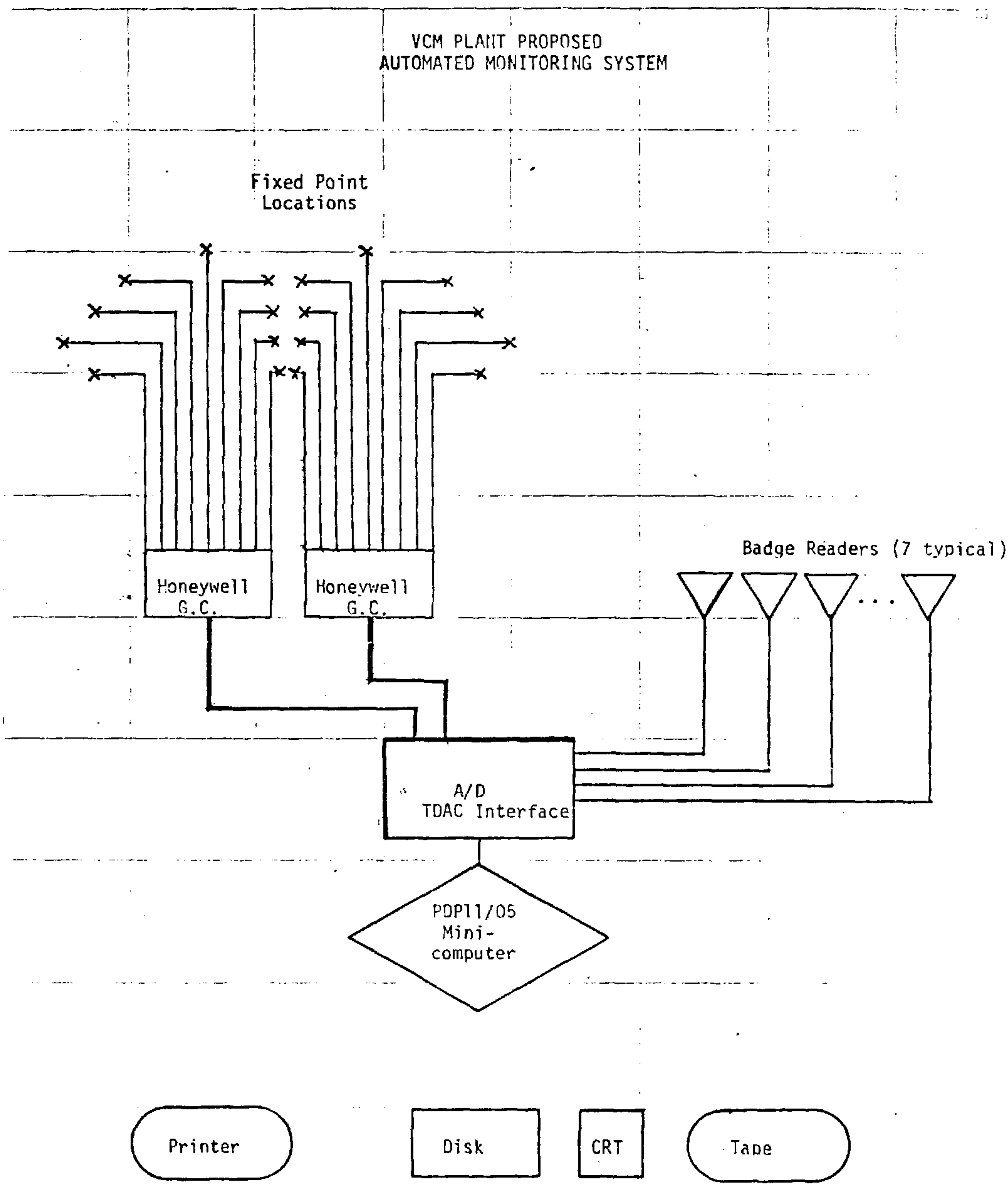

Figure 1

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Disk
1A36 Printer
Bootstrap Casette Loader

System Price \$58,000
Additional Badge Readers (\$1650 ea.)

VCM maintenance personnel would provide materials (wire, conduit, etc.) and labor for installation of badge readers and equipment. Expertise for system "hook up" is included in quoted price.

Accuracy Verification

Accuracy Requirements

The automated monitoring system, as proposed by TANO Corporation appears to meet the requirements initially established for an automated monitoring system with one possible exception--accuracy. The accuracy of personnel monitoring via fixed point monitors has not been verified.

Paragraph 1910.93q (c) (4) of the OSHA VCM standard states:

> The method of monitoring and measurement shall have an accuracy (with a confidence level of 95 percent) of not less than plus or minus 50 percent from 0.25 through 0.5 ppm, plus or minus 35 percent from over 0.5 ppm through 1.0 ppm, and plus or minus 25 percent over 1.0 ppm.

If an automated monitoring system is to be used to demonstrate compliance with the OSHA regulations, then some technique is needed to verify the accuracy of the system.

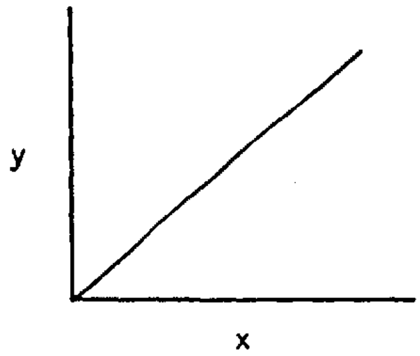
One way to gauge the results obtained from an automated monitoring system is to compare the system output to the results obtained by the recongized monitoring technique (personnel dosimeters). If the data derived from monitoring an individual via an automated system are indeed valid, they should compare very closely with the results from monitoring that same individual with a personnel dosimeter.

Regression Analysis

Regression is the mathematical technique used to measure and quantify the relationship between two or more variables. In this application there are two variables; x, the value obtained from monitoring an individual with a dosimeter and y, the value obtained by monitoring that same individual via the automated system. Ideally, the two values would be exactly the same if a large number of samples were taken, the relationship between x and y would be expressed as

$$x=y$$

In which case the regression line would be a straight line, starting from the origin and extending at an angle of 45 degrees.



In actuality, due to the cumulation of error from many sources, the relationship will be something other than a sample x = y. However, if a consistent relationship exists, its parameters can be determined through a regression analysis and a "calibration curve" for the automated system can be derived.

Experimental Procedure

Data Collection. During the month of June 1975 each employee who was scheduled to be monitored via personnel dosimeter was also issued a time chart (see Figure 2) and requested to maintain a record of his/her whereabouts during that shift with particular interest to the plant regulated areas. The objective of this time chart was to obtain the same data that would be collected by the badge reader network, if it were installed and operational. That is, the time charts would provide information as to when and how long the employee was in the critical areas of the plant.

This worker location information was then used in conjunction with the strip chart output from the fixed point gas chromatographs to calculate a TWA exposure for each employee (using equation (1)). The data thus calculated represented a simulation of the data that would be obtained from an automated monitoring system and represents the "y" variable in the regression. The results from the dosimeter testing on each individual represent the "x" variable in the regression analysis.

Mathematical Analysis. Any linear relationship between two variables can be expressed in the form:

$$y = a + bx$$

In a linear regression the unknowns in this equation ("a" and "b") can be computed using the Method of Least Squares. The formula are shown below:

$$b = \frac{\sum_{i=1}^{n} (x_i - \overline{x})\ (y_i - \overline{y})}{\sum_{i=1}^{n} (x_i - \overline{x})^2} \qquad (2)$$

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$$a = \bar{y} - b\bar{x} \qquad (3)$$

where: b = point on the regression line on vertical axis.

a = point on the regression line on horizontal axis.

x_i = represents each concentration value in ppm.

$\bar{x}$ = represents the mean value of all readings of x_i.

y_i = represents each concentration value in ppm.

$\bar{y}$ = represents the mean value of all readings of y_i.

Since the relationship is not strict, i.e., there is some variance of the data from the regression line, the confidence limits for "a" and "b" can be calculated using the following formula:

Confidence limits for "b":

$$b \pm t\alpha/2;\ n-2 \quad \frac{Sx/y}{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2}} \qquad (4)$$

where: $t\alpha/2;\ n-2$ = the t statistic for n-2 d.f. and $\alpha/2$

$$Sx/y = \frac{(y_i - \bar{y})^2 - b\ (x_i - \bar{x})\ (\bar{y}_i - \bar{y})}{n-2}$$

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Confidence limits for "a":

$$a \pm t_{\alpha/2;\, n-2} \quad S_{x/y}\sqrt{1 + \frac{1}{n} + \frac{\bar{x}^2}{(x_i - \bar{x})^2}} \qquad (5)$$

Figure 3 graphically displays the results of these calculations. The confidence limits for typical "y" values are shown. The Upper Confidence Limit line is the line representing the "x" values associated with the upper confidence limit of any given value of "y".

To use the graph, find the "y" value obtained from monitoring an individual using the automated system. If the "x" value associated (through the UCL line) with the "y" is less than or equal to 1, then we are 95 percent confident that that individual was not excessively exposed. For example, if, in this case, the "y" value is less than or equal to 0.88 ppm, we are confident that exposure was not excessive.

Conclusions

The results of the regression analysis show that there is a predictable relationship between the results obtained with dosimeter monitoring and those obtained through a simulated automated technique. An automated system, properly designed and installed, could be used to demonstrate, with 95 percent confidence, that employees are not exposed to VCM in excess of the permissible limit.

In this limited study, the resulting absolute accuracy of the system did not meet the stringent OSHA requirements outlined previously. However, several actions are available which could reduce the confidence interval. For example, the method of tracing employee position in this experiment (by means of the time chart) was admittedly crude. With a badge reader network actually installed, the data obtained would be much more precise. Consequently, a more precise calculation of an individual's TWA exposure would be possible.

Additionally, after the installation of the system, the computing power afforded by the PDP-11 minicomputer would enable the operator to select the most appropriate input data to match dosimeter results.

In summary, it is felt that an automated system for VCM monitor, when properly designed and installed can be used to effectively evaluate personnel exposure to VCM vapors. There is no reason why the automated concept could not be successfully applied to other environmental monitoring problems.

VCM Plant Personnel Dosimeter Time Chart

Organization: Maintenance **Date:** 5/20/75 **Name:** G. Linscombe

TWA 0.08

Time	Maintenance Shop/ Office	Control Room	Block I (except req. area	Regulated Area Block I	Block II	EDC Tank Tops	Loading Racks	Vent Recovery Unit	VCM Loading Pumps	VCM Transfer Pumps	Lab Regulated Area	Comments
7:00	.05											
7:15		.10										
7:30			.30									
7:45	.05											
8:00			.00									
8:15			.00									
8:30	.05											
8:45			.10									
9:00	.05											
9:15	.05											
9:30		.00										
9:45	.05											
10:00	.05											
10:15			.10									
10:30	.05											
10:45	.05											
11:30	.05											
11:45			.20									
12:00				1.1								
12:15	.05											
12:30			.10									
12:45				.43								
1:00			.00									
1:15	.05											
1:30				.10								
1:45			.00									
2:00		.00										
2:15				.28								
2:30	.05											
2:45	.05											
3:00			.00									
3:15				.35								
3:30	.06											

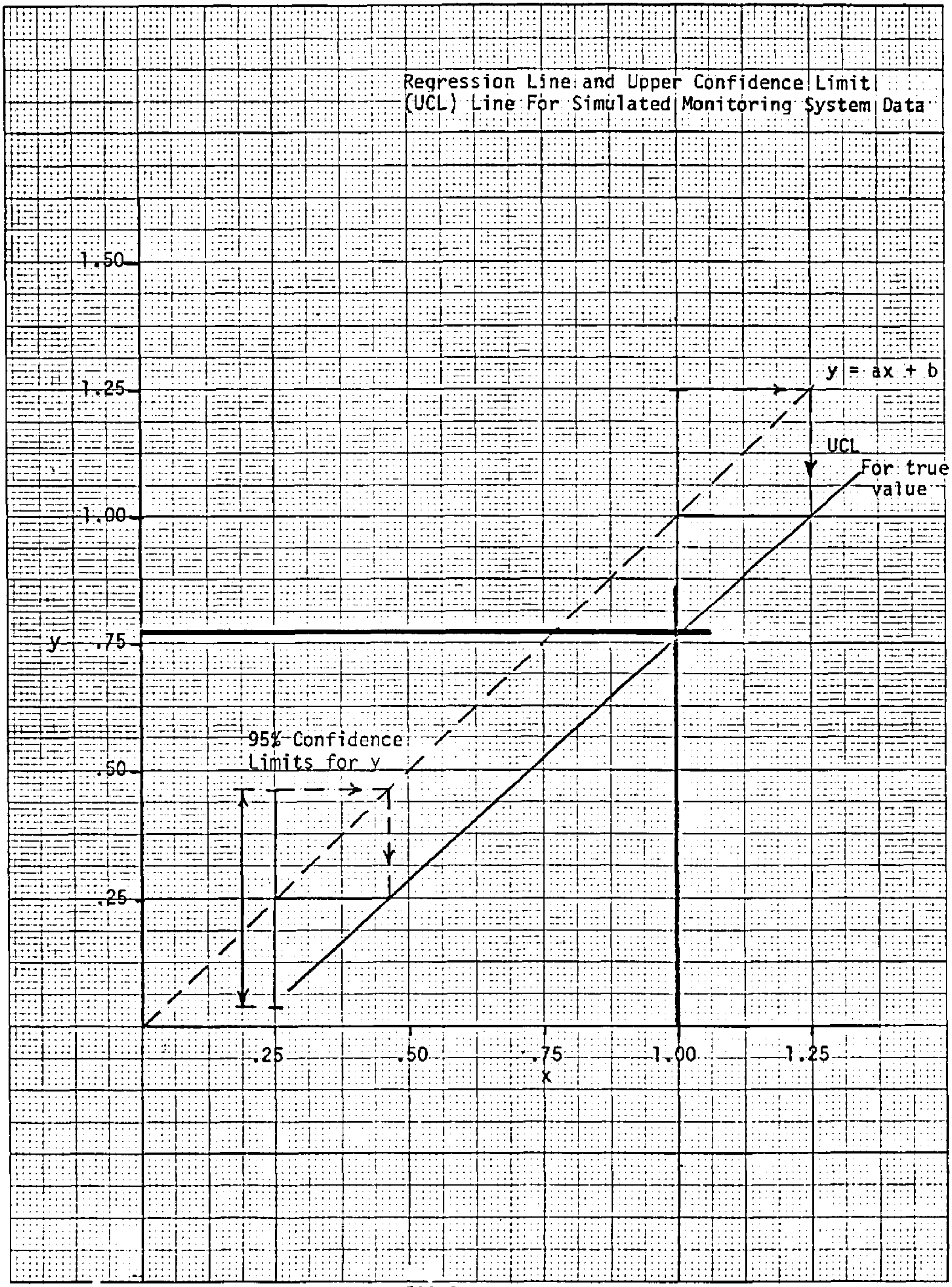
Regression Line and Upper Confidence Limit
(UCL) Line For Simulated Monitoring System Data
y = ax + b
UCL
For true
value
95% Confidence
Limits for y
1.50
1.25
1.00
.75
.50
.25
y
.25
.50
.75
1.00
1.25
x

FIGURE 3