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DEVELOPMENT OF AN AUTOMATED READER FOR ANALYSIS AND STORAGE OF PERSONNEL DOSIMETER BADGE DATA

by

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ABSTRACT

The collection and archiving of data from personnel dosimeters has become increasingly important in light of the lowered threshold limit values (TLV) for hydrazine (HZ), monomethylhydrazine (MMH), and unsymmetrical dimethylhydrazine (UDMH). The American Conference of Government Industrial Hygienists (ACGIH) lowered the TLV from 100 parts per billion (ppb) to 10 ppb and has caused increased concern over long term exposures of personnel to trace levels of these hypergols and other potentially harmful chemicals. An automated system of reading the exposure levels of personnel dosimeters and storing exposure data for subsequent evaluation has been developed.

The reading of personnel dosimeter badges for exposure to potentially harmful vapor concentrations of hydrazines or other chemicals is performed visually by comparing the color developed by the badge with a calibrated color comparator. The result obtained using visual comparisons of the developed badge color with the comparator may vary widely from user to user. The automated badge reader takes the variability out of the dosimeter reading by accurately comparing the reflectance obtained from a colored spot on the badge with a reading on the same spot prior to any exposure to chemical vapors. The observed difference between the reflectance values is used as part of a calculation of the dose value for the badge based on a stored calibration curve.

The badge reader also stores bar-code data unique to each badge, as well as bar-code information on the user, as part of the permanent badge record. The start and stop exposure times for each badge are recorded and can be used as part of the calculated concentration, in ppm, for each badge logged during a recording period. The badge reader is equipped with a number of badge holders, each of which is unique to a specific type of personnel dosimeter badge. This gives the reader maximum flexibility to allow for the reading of several different types of badges. Test results of the badge reader for several different types of personnel dosimeter badges are presented within the body of this paper.

INTRODUCTION

BACKGROUND

The Bacharach/GMD 2-spot dosimeter badge is currently used by personnel at both the Kennedy Space Center (KSC) and Cape Canaveral Air Station (CCAS) to monitor the toxic levels of hydrazines such as HZ and MMH. These badges operate on the principal of chemisorption and change color when exposed to vapors containing the hydrazines. The color is produced by the reaction of the hydrazine in the vapor sample with a chemically treated paper tape attached to the badge. The observed color of the tape on the badge is a measure of the

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dose exposure of the badge. Comparison of the color present on the badge tape with a color wheel allows a user to estimate the dose exposure.

Recently, the Toxic Vapor Detection Laboratory (TVDL) developed a dosimeter badge which measures the dose of dimethylethoxysilane (DMES) obtained by personnel involved in waterproofing operations on the shuttle. In addition to the development of the dosimeter badge, a reader system was fabricated which stores information on each badge and its user by means of bar coding. The fabrication of additional badge holders has aided in the reading of HZ, MMH, UDMH, and nitrogen dioxide (NO_2) badges using the same basic hardware/software. The remainder of this paper discusses the development of the hardware and software associated with the badge reader along with data collected using the badge reader under both laboratory and field conditions.

APPARATUS

Minolta Chroma Meter

The Minolta Chroma Meter is a compact tristimulus color analyzer which measures the reflective colors of various surfaces. The CR-200 Meter used for testing of dosimeter badges employs diffuse illumination and a zero degree viewing angle to take accurate color measurements of a wide variety of subjects. The mixing chamber of the Chroma Meter contains a pulsed xenon arc lamp which provides even, diffuse illumination over the surface of the sample. Photocells are used by the meter's double-beam feedback system to measure both the incident and reflected light. Both absolute measurements or color differences can be measured. Data can be converted between several color systems or between absolute and difference measurements by the built-in microprocessor. A printed copy of the data is generated at the end of the measurement cycle. In addition, the collected data can be sent to an external computer by means of an RS-232 cable link. The basic Minolta CR200 measuring head is shown in figure 1.

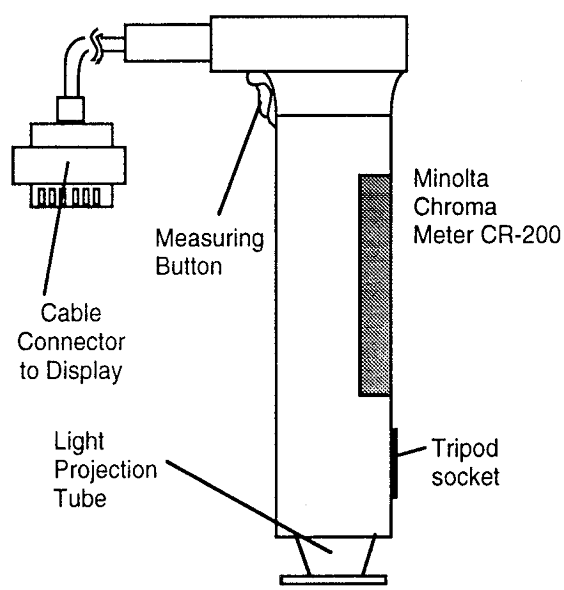

Figure 1 - Minolta Chroma Reader

RESULTS AND DISCUSSION

The dose received by a personnel dosimeter badge is usually obtained by matching the observed color on the badge with a calibrated color comparator or "dose estimator." Depending on the manufacturer of the color comparator, the dose value may read out in units such as ppb-hours (hrs) or TLV-hrs. Variations in the value for the dose received by the badge are commonplace due to individual differences in the perceived color.

During development of a personnel dosimeter for the monitoring of DMES, the Minolta Chroma Meter was used to obtain the dose value for each badge. No color estimator was available since a precise determination of the relationship between color and dose for DMES had not been determined. A 2-spot dosimeter badge manufactured by Bacharach/GMD for silane determination was evaluated and found to be acceptable for the determination of DMES (figure 2). The attenuated dosimeter spot on this badge is used to monitor for concentrations above the range of the bottom spot. The addition of an additional porous layer over the top of the dosimeter paper slows down the migration of chemical vapors to the reactive dosimeter paper. The dosimeter badge color gradually changed from white to gray and eventually black as the concentration of DMES in the vapor stream increased. The Minolta Chroma Meter CR-200 series has the ability to measure absolute chromaticity in one of five different color systems. The Commission Internationale de l'Eclariage (CIE) $L^*a^*b^*$ color system, which more closely parallels the sensitivity of the human eye to color, was used to obtain the total color difference, $d\,E^*_{ab}$, according to the following formula:

$$d\,E^*_{ab} = [\,(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\,]^{1/2}$$

The values for ΔL^*, Δa^*, and Δb^* are the differences between the baseline and final measured colors. A typical graph of dose (ppm-min) versus the d E values obtained from the Minolta is shown in figure 3. The ppm concentrations used to calculate the dose values were obtained from Fourier Transform Infrared (FTIR) data taken during badge calibration. The FTIR gas cell sampled the same vapor stream which was used to expose the dosimeter badges.

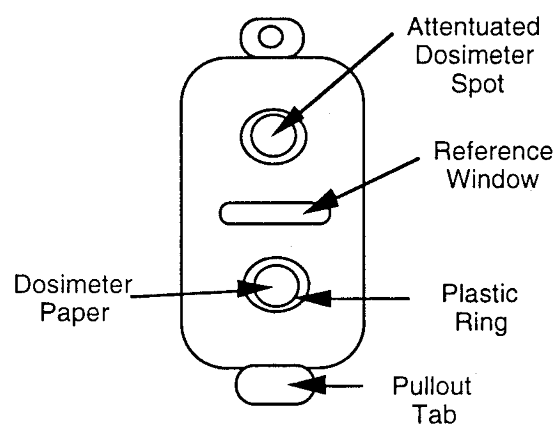

Figure 2 - DMES 2-Spot Dosimeter Badge

DOSIMETER BADGE HOLDER

In order to make the reading of the dosimeter badge more consistent and independent to positional variations with respect to the Minolta Chroma Meter and the badge, a dosimeter badge holder was fabricated. This holder was designed to firmly position the CR200 measuring head directly above a dosimeter badge and allow easy measurement of the badge color. The measuring head sits in a cavity with the meter baseplate approximately 1/16 inch above an inserted badge. The badge itself sits in a drawer just below the baseplate of the Chroma Meter. Individual drawers have been fabricated to hold a variety of badges in such a way that the center of a spot to be measured is directly below the center of the light projection tube of the Minolta. A small detent was placed along the sides of a badge drawer in order to be able to stop the drawer and measure the second spot on badges such as the GMD 2-spot HZ/MMH dosimeter. The Chroma Meter/badge holder shown in figure 4 was attached to a bracket that slipped over the display position of the Minolta hardware. This movable bracket provided accessibility to the Minolta keyboard when needed for operations such as power. In the case where calibration of the Minolta meter was required, the badge holder drawer could be completely removed and replaced with the white Minolta calibration plate.

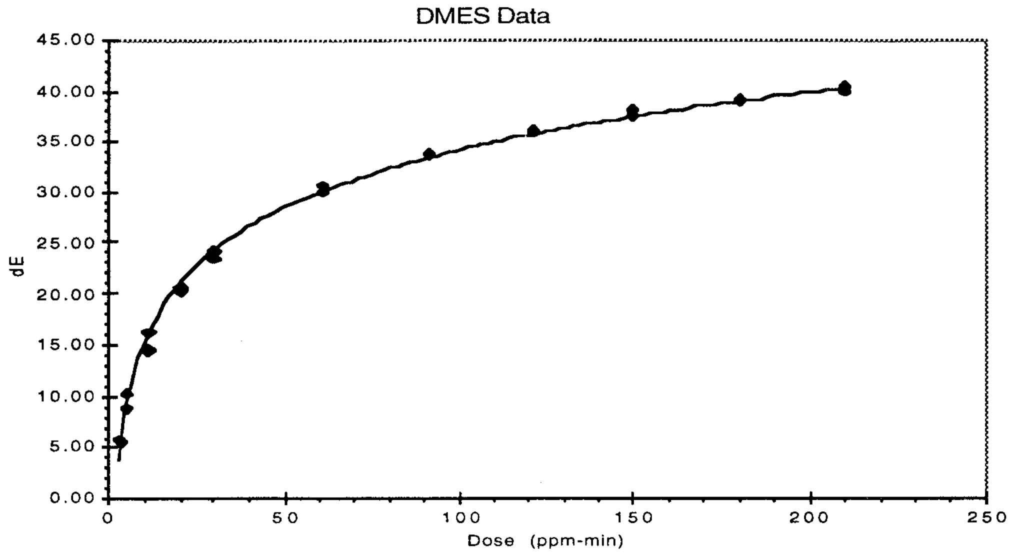

Figure 3 - Plot of Dose versus d E (Minolta)

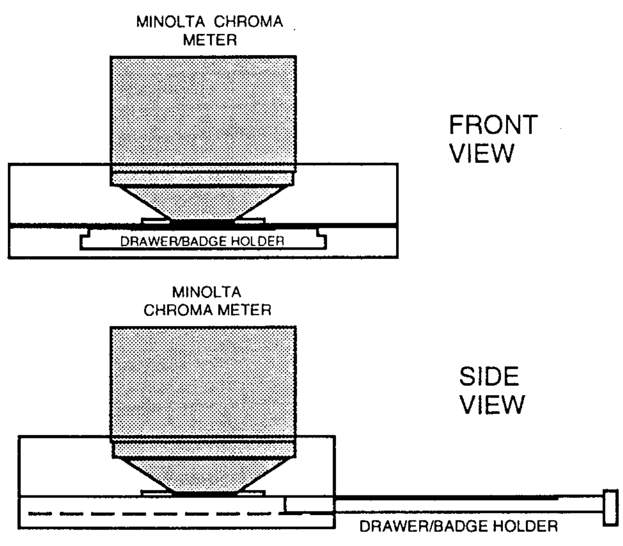

Figure 4 - Dosimeter Badge Holder

BAR-CODED DOSIMETER BADGE AND READER

The Bacharach/GMD 2-spot dosimeter badge has a bar-code label placed on the backside of the badge. The DMES badges were modified so that the bar-code information was visible on the front side of the badge (figure 5). This placement of the bar-code strip did not require an operator to read both sides of the badge; one side for bar-code information and the reverse side for color information relating to the dose. In addition, having the bar-code on the same side as the dosimeter measuring spots allows for future implementation of a combination bar-code/badge reader. This option is discussed as part of the recommendation section of this paper.

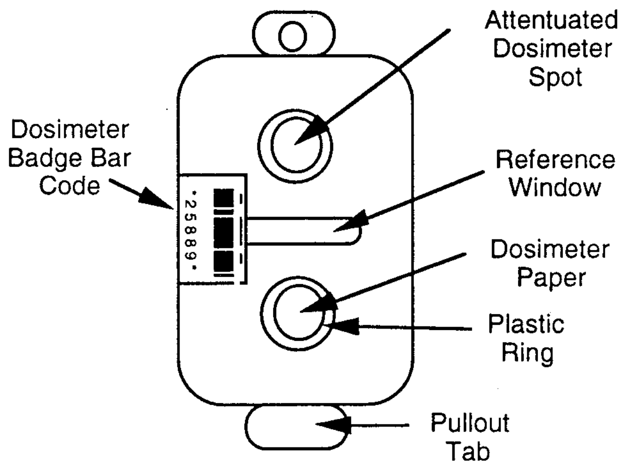

Figure 5 - Bar-coded Dosimeter Badge

A scan of the KSC personnel badge associated with each dosimeter badge was also made in addition to bar-code information on a dosimeter badge. These two pieces of bar-coded data (dosimeter badge and personnel I.D. badge) form the basis for a historical log of badge information. All of the bar-code information was read by a CODESCAN 3000 host system and PSC Hand-Held Laser Scanner.

SYSTEM INTEGRATION

The integration of the bar-coded dosimeter badge, Minolta Chroma Meter, and badge holder into an automated data acquisition system was accomplished by means of program written in LabView®. This multi-functional software package was developed by National Instruments and can be used for wide variety of applications.

The incident and reflected light from the surface of the dosimeter badge are measured and compared to values obtained during calibration of the badge to verified vapor samples. Using the measured values for the incident and reflected light both before and after exposure, the embedded LabView® program calculates the dose to which the badge had been exposed. The output value for the dose is in ppm-min. In addition, the data collected by the Chroma Meter is archived along with a bar-code number for an individual badge and a bar-code ID for the user.

The operation of the integrated dosimeter badge reader system accomplished through the use of user-friendly menus. The menu shown in figure 6 occurs at the top level of the program and contains options to issue and collect a dosimeter badge, calibrate the Minolta, and stop collecting data. When a new badge is issued a request is made for bar-code information on both the user and the dosimeter badge. Baseline data on the color of the badge is transmitted from the Minolta Chroma Meter to a PC via an RS232 link. A database file is subsequently updated with the bar-code information, the current time/date, and the acquired baseline color parameters. The collection portion of the software reads the bar-code information on a badge along with the current parameters for color, and calculates the exposure dose value based on parameters from an internal calibration curve. This dose value is output to the screen along with a warning if the acquired dose is above the allowable limit based on the TLV. The software is designed to list any outstanding badges which remain at the end of a collection period. The bar-code information for each outstanding badge is listed on the screen. Calibration of the Minolta, the third menu option, is completed by following a set of step-by-step procedures which are listed on the screen. The last menu option, to stop collecting data, will halt the software program. During data collection the software will prompt the user if an attempt is made to read the color from a badge which has no baseline data; i.e., has never been issued.

FIELD TESTS

The automated dosimeter reader and badge holder were field tested during two waterproofing operations on the Orbiter Processing Facility (OPF) High Bays. The data collected by the automated reader is comparable to FTIR data taken at five fixed locations surrounding the shuttle during the same waterproofing operations. Table 1 displays the data collected for five DMES dosimeter badges during the second field test.

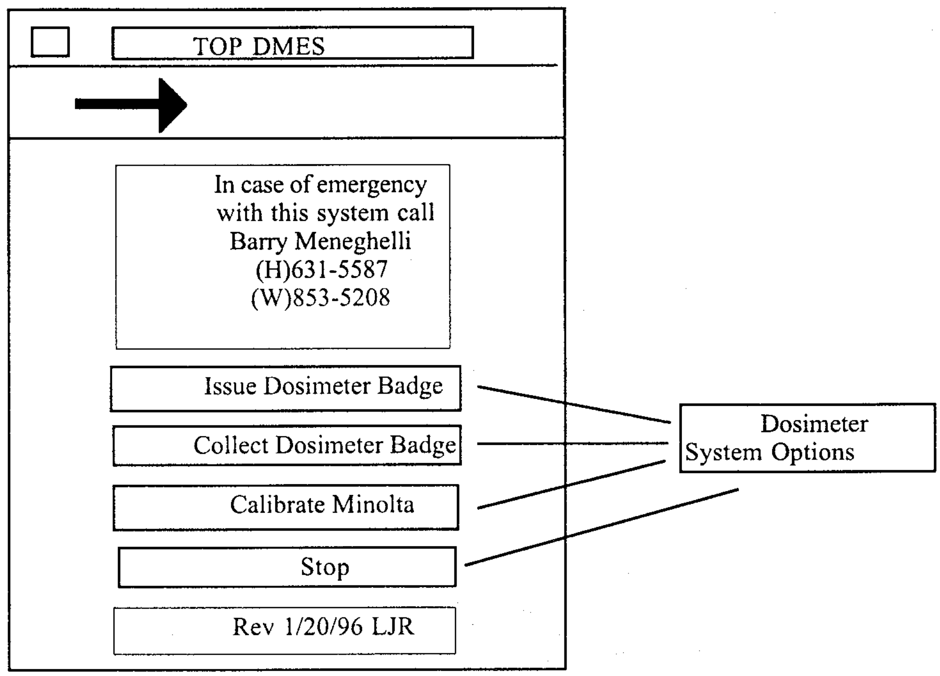

Figure 6 - Automated Reader Main Menu

Table 1 - Dosimeter Badge Data

Badge ID	Personnel ID	Date/Time (Start)	L (Start)	a (Start)	b (Start)	Date/Time (End)	L (End)	a (End)	b (End)	Elapsed Time (sec)	Dose (ppm-min)
30454	3224196	2/4/96 0902	92.60	-0.78	1.11	2/4/96 1511	91.81	-1.01	3.52	22143	3.95
30367	3224198	2/4/96 0900	92.78	-0.84	1.07	2/4/96 1512	91.83	-1.09	3.69	22270	4.09
30185	3224198	2/4/96 0901	92.96	-0.76	1.11	2/4/96 1512	91.91	-0.95	3.61	22246	4.04
30256	3224198	2/4/96 0901	93.01	-0.70	1.20	2/4/96 1514	91.96	-0.87	3.28	22380	3.84
30140	3224198	2/4/96 0859	92.81	-0.77	1.02	2/4/6 1514	91.76	-1.02	3.44	22497	4.01

BACHARACH/GMD 2-SPOT DATA

The para-dimethylaminobenzaldehyde (PDAB) and Vanillin spots of the Bacharach/GMD 2-spot dosimeter change colors to shades of orange and yellow, respectively, as they are exposed to vapor samples containing HZ or MMH. Small modifications to the software involving the calibration curve parameters and fabrication of a drawer to hold the dosimeter would allow the automated reader to collect and store information on these badges. The responses for a series of badges are shown in figure 7 for comparative purposes.

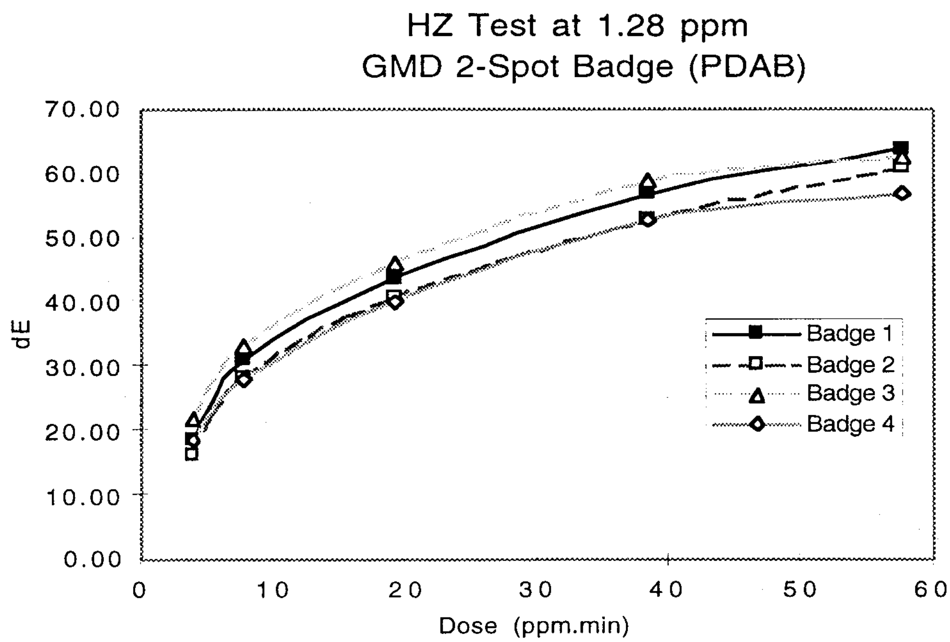

Figure 7 - GMD 2-Spot Dosimeter Data

SUMMARY

An automated reader has been developed which can be used to collect and store personnel dosimeter data. Minor software modifications along with the fabrication of badge-specific holders allows the automated system to be used with a variety of dosimeter badges. The use of an automated dosimeter badge reader provides a vehicle for more consistent data collection and storage by means of a historical database. The use of bar-code information for both dosimeter badges and personnel identification allows for precise cross-referencing of information using a minimum of input data.

RECOMMENDATIONS

- Embed a bar-code reader within the badge holder which will automatically read the code on the badge as the drawer is closed and automatically initiate the collection of dosimeter badge data.
- Employ a less expensive color reader in place of the Minolta.
- Replace the hand-held bar-code with a slot reader for transmission of the personnel ID information.

PRESENT WORK

- Evaluation of the Colortron from LightSource as a replacement for the Minolta Chroma Meter is currently in progress.

ACKNOWLEDGMENTS

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