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HAZARDS CONTROL
QUARTERLY REPORT NO. 13

Livermore, California

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HAZARDS CONTROL
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(April - June 1963)

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Lawrence Radiation Laboratory, University of California
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RELATIVE ACTIVITY FROM RADIOIODINES FOLLOWING
FISSION OF U^{235}

Radioiodines are produced both directly from fission and as daughters of other fission nuclides. Thus, the fraction of total iodine activity contributed by a given iodine nuclide will change with time. Since the total energy release and specific activity differs for each fission radioiodine, it is important to know the proportions of these nuclides so that biological hazards can be accurately assessed.

Figure 1 provides the means of determining the relative activity of the various fission radioiodines as a function of time after fission. The curves are based on thermal fission of U^{235} and were plotted from data given by Bolles and Ballou.¹ Several individual points on each curve were confirmed by calculation from the fission product yield data of Katcoff.² Because I^{136} is produced only as a direct fission product and has an 86-second half-life, it was not included.

The relative dose contribution can be determined by multiplying the relative activity by the dose constant for the nuclide under consideration. Dose constants can be calculated by the expression

$$R = \frac{2.1E}{m\lambda}$$

where R is the dose constant, expressed as total integrated thyroid dose in rads per microcurie uptake, E is the effective absorbed energy in MeV, m is the mass of the thyroid (taken as 20 grams), and λ is the effective decay constant (hours⁻¹).

¹ N. C. Bolles and N. E. Ballou, USNRDL-456 (1956).

² S. Katcoff, Nucleonics 16, 78 (1958).

Fig. 1. Relative activity from radioiodines following fission of U^{235} .

The above expression is derived in the Appendix of UCRL-7345.³ Total integrated thyroid doses, in rad per microcurie uptake, are:

I^{131} - 6.3 rad,
 I^{132} - 0.23 rad,
 I^{133} - 1.8 rad,
 I^{134} - 0.11 rad,
 I^{135} - 0.54 rad.

Values for E, m, and λ can be obtained from the ICRP report.⁴

The above method can be used to determine MPC's for mixtures of gaseous fission iodines and thyroid doses following inhalation or ingestion. These data can also be used to determine the proportions of the various radioiodines in milk from fallout.

HIGH EXPANSION FOAM FIRE CONTROL SYSTEM FOR GLOVED BOXES

Introduction

Considerable effort has been directed toward techniques for extinguishing fires in gloved boxes which contain radioisotopes or other hazardous chemicals. Gloved box fires are infrequent and many that do occur are self-extinguishing. However, any gloved box fire is of serious concern, because the interior of the box is not accessible to conventional fire fighting equipment without destroying the total enclosure feature of the box. If the box is opened or the integrity of the enclosure is lost due to fire damage, the spread of contamination may ultimately be of more concern than the fire. Operations involving pyrophoric metals are frequently conducted in gloved boxes. Once ignited, these burning metals cannot be controlled with water. Such fires can be extinguished by covering the burning metal with Met-L-X, but to be effective this fire extinguishing material must usually be applied by hand.

Automatic gas blanketing systems using carbon dioxide, nitrogen, or argon have been investigated with some success. However, failure to extinguish fires by this technique is usually due to the inability to keep the blanket gas in intimate contact with the fire. Out-breathing of contaminated air through leaks in the enclosure may result if the box is pressurized by a

³R. L. Kathren, W. C. Day, D. H. Denham, and J. L. Brown, UCRL-7345 (1963), pp. 29-30.

⁴International Commission on Radiation Protection Committee II Report, Health Physics 3, 1 (1960).

rapid introduction of inert gas. Also, with inward air leaks, even infinite purge periods may not reduce the oxygen content below the level which will sustain metal fires.

The fire control system described here uses high expansion foam produced from argon gas and a one-percent aqueous solution of ammonium lauryl sulfate. We have attempted to make better use of inert gas by incorporating it in a stable, tough foam blanket which will remain in intimate contact with the fire source. The heat capacity of the gas blanket has been increased by adding water as a thin film around the gas bubbles which provides effective cooling without excessive water damage.

The generator is integrally mounted to the enclosure and foam production is automatically started when a temperature rise inside the box is detected by a thermal switch. The system was designed to provide fire control protection during off-hour unattended periods. When energized, the thermal switch also sounds an alarm at the Central Fire Station, so that fire protection personnel can be present soon after receiving the alarm.

Description

Components of the system are shown in Fig. 2. These consist of: (1) a Fenwall thermal switch adjusted to trip at a temperature of about 140°F; (2) a source of argon gas under pressure; (3) a solenoid valve; (4) a Venturi nozzle; (5) a foam concentrate reservoir; (6) a foam generating chamber; (7) a conical cotton net; and (8) a pneumatically operated closure between the foam chamber and the interior of the gloved box.

Operation

When the temperature within the box exceeds the set point of the thermal switch (about 140°F) this switch opens the solenoid valve (see Fig. 2) allowing argon gas to flow through the Venturi nozzle. Through a parallel line, argon pressure simultaneously energizes a pneumatic operator which opens the closure port. Passage of argon through the Venturi nozzle draws foaming agent into it where thorough mixing between argon and foaming agent occurs. This mixture is forced as a fine spray against the conical cotton net. Once this net is wet, a foam of uniform bubble size is produced. Foam is forced through the chamber plenum and enters the gloved box through the port.

Fig. 2. Components of gloved box Hi Expansion Foam Generator.

Argon pressure at the Venturi nozzle is 30 psi. Foam flow is about 10 cfm. The volume of foam to be generated can be varied by changing the volume of foaming agent, and the rate at which the foaming agent is delivered can be varied by adjusting the nozzle. Once energized, the system produces foam until the foam reservoir is empty; after that argon gas continues to flow until it is manually turned off or the argon supply is depleted. A latching relay was added to the circuit to prevent the thermal switch from closing after the solenoid is initially energized. Without this relay, foam in contact with the thermal switch could cool the switch to its cutoff temperature and stop the foam before the box was filled.

Figure 3 shows the back of one of our metal boxes fitted with a prototype of the foam generator. Figure 4 shows the front of the box 30 seconds after the solenoid was energized. The Fenwall thermal switch can be seen inside the box at the upper right. From the Magnehelic gage it can be seen that introduction of foam did not pressurize the box.

Fire Extinguishing Tests

Acetone and kerosene fires were so easily extinguished with foam that magnesium chip fires were selected to provide a more difficult fire control problem. A 5-gram sample of magnesium chips on a metal screen was placed within a Transite enclosure. The magnesium was ignited and allowed to burn about one minute. The enclosure was then filled with foam. The fire was extinguished without metal splattering. Unburned metal chips were evident upon examination of the ash. As an additional demonstration of the ability to control a magnesium fire, a volume of foam was applied just sufficient to cover the burning magnesium. Burning subsided and the fire was controlled, but as soon as the foam bubbles were thermally broken, the magnesium reignited. A second application permanently extinguished the fire.

Fig. 3. Foam generator installed on rear of LRL metal gloved box.

GL3-6-6-3810

Fig. 4. Front view of gloved box equipped with foam generator - foam volume after 30 seconds of operation.

DETERMINATION OF DILUTION OF VAPORS IN CALIBRATION BOTTLES BY INFRARED ANALYSIS

Introduction

Tables are available giving the concentrations of vapors in calibration bottles for the general case.^{5,6} For a three-bottle system, such as we constructed, the dilution equation is:

$$C_3 = C_0 \exp\left(-\frac{V}{V_0}\right) \left[1 + \left(\frac{V}{V_0}\right) + \frac{1}{2} \left(\frac{V}{V_0}\right)^2\right], \quad (1)$$

where

C_0 = the original concentration,

C_3 = the residual concentration in the third bottle,

V_0 = the volume of the bottle in liters, and

V = the volume withdrawn in liters.

Table I, which is derived from Eq. (1), gives some values for the average concentration of the portion withdrawn and the residual concentration from a three-bottle system. The purpose of this investigation was to check the agreement between our installation and the theoretical equation. We were especially interested in determining the degree of variation caused by connecting tubing, tubing bends, and the like.

An infrared spectrophotometer was used in this investigation as an in-stream vapor analyzer to record dilution rates in the bottles.

Isopropyl ether was selected as the test vapor because of its relatively low boiling point (68°C) and strong infrared absorption at 1128 wavenumbers. Solutions of isopropyl ether containing the equivalent concentration of 10 through 200 ppm in the bottles were prepared by diluting weighed quantities of the ether with carbon tetrachloride.

Description of Apparatus

Figure 5 shows a photograph of the assembled calibration bottles connected to the 10-meter, infrared spectrophotometer. The flow of air is measured with the wet test meter. The small pump attached to the 10-meter

⁵ A. N. Setterlind, Preparation of Known Concentrations of Gases and Vapors in Air, Am. Ind. Hyg. Assoc. Quart. 14, No. 2, 113 (1953).

⁶ F. M. Stead and G. J. Taylor, Calibration of Field Equipment from Air Vapor Mixtures in a Five Gallon Bottle, J. Ind. Hyg. Tox. (Nov. 1947).

Table I. Average concentration of portion withdrawn and residual concentration of each of three bottles connected in series calculated from Eq. (1).

Amount withdrawn; % of single bottle vol.	1st Bottle		2nd Bottle		3rd Bottle	
	Residual conc.	Av. conc. of volume withdrawn	Residual conc.	Av. conc. of volume withdrawn	Residual conc.	Av. conc. of volume withdrawn
0	100.00	100.00	100.00	100.00	100.00	100.00
10	90.48	95.24	99.53	99.76	99.98	99.99
20	81.87	90.78	98.25	99.26	99.88	99.95
40	67.03	82.69	93.85	97.59	99.21	99.74
60	54.88	75.57	87.81	95.24	97.69	99.28
80	44.93	69.29	80.88	92.45	95.26	98.20
100	36.79	63.73	73.58	89.35	91.97	97.22
120	30.12	58.80	66.26	86.06	87.95	95.95
140	24.66	54.42	59.18	82.72	83.35	94.42
160	20.19	50.52	52.49	79.36	78.34	92.68
180	16.53	47.03	46.28	76.04	73.06	90.76
200	13.53	43.91	40.59	72.79	67.65	88.83
220	11.08	41.11	35.46	69.66	62.27	86.51
240	9.07	38.58	30.84	66.64	56.96	84.25
260	7.43	36.30	26.75	63.76	51.86	81.95
280	6.08	34.24	23.10	61.02	46.94	79.61
300	4.98	32.36	19.92	58.41	42.33	77.38
320	4.08	30.67	17.11	55.95	38.03	75.06
340	3.34	29.11	14.70	53.63	34.00	72.80
360	2.73	27.69	12.56	51.44	30.25	70.52
380	2.24	26.39	10.72	49.37	26.92	68.32
400	1.83	25.20	9.15	47.43	23.82	66.19
420	1.50	24.13	7.80	45.63	21.03	64.12
440	1.23	23.09	6.64	43.91	18.55	62.12
460	1.005	22.15	5.63	42.29	16.26	60.19
480	0.82	21.28	4.76	40.76	14.20	58.34
500	0.67	20.48	4.02	39.33	12.40	56.55

Fig. 5. Calibration bottles in series with infrared cell and air mover.

cell and manometer acts as the air mover for the system. Figure 6 is a block diagram of the system.

Procedure

Air Flow Tests

Tests were made to determine the most rapid rate at which air could be drawn through the assembled apparatus and yet maintain a pressure not lower than one centimeter of mercury below atmosphere. With the tubing and valve fittings used in our system, this rate was found to be about 10 liters per minute. Above this flow, a partial vacuum is created in the 10-meter cell. Therefore, all dilution tests were conducted at air flow rates of less than 10 liters per minute.

Construction of a Standard Curve for Isopropyl Ether

Known concentrations containing 10, 20, 40, 60, 80, 100, and 120 parts per million isopropyl ether were prepared. After mixing, and adding the mixture to the 10-meter cell, an infrared scan was made from 1250 to 1050 wavenumbers. The optical density of the ether band at 1128 wavenumbers was recorded. Figure 7 shows a plot of ppm isopropyl ether vs optical density.

Dilution of Bottles With Air

A series of eight individual test runs were made. In the first six cases, the original concentration of isopropyl ether in the bottles was 150 ppm. In the latter two cases, the concentrations of ether in the bottles were 60 and 190 ppm, respectively.

A series of runs were made using dilution air flow rates from 0.93 to 9.6 liters/min. The decrease in the concentration of the ether over a period of time was automatically recorded by the infrared spectrophotometer. The results of a representative run are shown in Fig. 8. The dashed line of Fig. 8 is the theoretical curve obtained from the data given in Table I. Table II is a comparison of the experimental and theoretical results. Figure 9 is a plot of experimental data of isopropyl ether remaining in the bottles against the number of liters of air entering the bottles for three flow rates, but with the same initial ether concentration.

Fig. 6. Block diagram of system.

Fig. 7. Isopropyl ether in air at one atmosphere using 10-meter infrared cell at 1128 wavenumbers.

Fig. 8. Measurement of the concentration of isopropyl ether during dilution process.

Table II. Dilution of ether with air.

Total liters of air pulled into bottles	Percent ether remaining in bottles	Ether (ppm) remaining in bottles (actual)	Ether (ppm) remaining in bottles (theory)	Percent difference from theory
0	100	144	144	0
16.0	100	144	144	0
26.3	98	142	142	0
36.7	94	136	136	0
47.0	91	131	131	0
57.4	84	121	126	4
67.7	77	111	118	6
78.1	71	102	109	6
88.4	63	91	102	11
98.8	56	81	92	12
109.1	50	72	83	13
119.5	44	64	74	13
129.8	38	55	64	14
140.2	33	47	57	17
150.5	28	40	51	21
160.9	24	34	46	26
171.2	19	27	41	34
181.6	15	21	35	40
191.9	11	16	31	48
202.3	8	12	27	55
212.6	5.5	8	22	64
223.0	3.5	5	20	75
233.3	2.1	3	17	83
243.6	1.4	2	15	87

Fig. 9. Dilution of isopropyl ether with air flow rate.

Conclusions

An examination of Fig. 8 and Table II indicates that no measurable error will occur until approximately 47 liters have been removed from the system. (This is approximately equivalent to the volume of one bottle.) Up to 78 liters of air can be withdrawn from the system without the error exceeding 6%. It should be noted that the average error is substantially less than 6%. Figure 9 and Table II show that regardless of the rate of air flow into the bottles, the percent of vapor (ether) remaining in the bottles will be the same for any given amount of air volume taken from the bottles.

This data can be applied to an actual calibration of a field recording instrument. Noting the required air flow pertaining to the instrument, the allowable operation time can be taken from the cited equation and theoretical table. For Threshold Limit Value concentrations, the adsorption of material on the glass walls of the bottles and stirring apparatus is negligible within the suggested operating limits.

Safety Precautions

Due to their chemical inertness, Pyrex glass bottles were selected as the mixing chambers. Possible breakage of glass under stress made it necessary to shield the operator from the bottles. An aluminum container (shown in Fig. 10) was designed for this purpose. Casters were installed to make the apparatus mobile. Connections were made with stainless steel tubing.

A stirrer is necessary to prepare homogeneous concentrations in the bottles. Since the majority of compounds are combustible, an explosion-proof stirrer, operated by a brushless motor is used.

Fig. 10. Safety housing of calibration bottle.

MODIFICATION OF A DAVIS HALIDE METER FOR METHYL CHLOROFORM MEASUREMENT. THE RESPONSE OF A DAVIS HALIDE METER CORRELATED TO AN INFRARED SPECTROPHOTOMETER

Introduction

The Davis Halide Meter is a portable field instrument designed specifically to analyze the majority of chlorinated hydrocarbons in air. Its principle of operation is as follows: The intensity of the blue lines of the copper spectrum, produced in an electric arc between two copper electrodes, is continuously measured with a photoelectric photometer after passing through a slit system with a blue sensitive phototube and a blue glass color filter. Halide vapor coming in contact with the hot tip of the copper electrode reacts to form a copper halide, which vaporizes at the temperature of the electrode and is carried into the arc. The intensity of the electrode blue spectrum is increased by formation of the copper halide in proportion to the concentration of halide vapor present.

It was found that Threshold Limit Value concentration of methyl chloroform (500 ppm) gave an off-scale reading with the Davis Halide Meter. To increase the operating range, a modified slit system was incorporated into the instrument so that 500 ppm methyl chloroform would give approximately one half scale deflection in a manner similar to Schaffer and Hoyle.⁷ The instrument was to be used as a continuous monitor for methyl chloroform in air. A recorder was attached to the meter so that the readout could be compared simultaneously with an infrared spectrophotometer.

Procedure

A set of variable width slits for the Davis Halide Meter were constructed by our machine shop. By preparing different concentrations of methyl chloroform in calibration bottles, we found that a slit width of 0.021 inch gave an approximate midpoint reading on the Davis Halide Meter scale for Threshold Limit Values concentrations (Fig. 11).

⁷ A. W. Schaffer and H. R. Hoyle, Nine Years Experience with the Davis Halide Meter, Am. Ind. Hyg. Assoc. J. 22, 93 (1961).

Fig. 11. Calibration of Davis Halide Meter with methyl chloroform using 0.021 in. slit and Drierite drying tube.

To determine the response of the Davis Meter to comparatively high concentrations over long periods of time the following procedure was used.

(a) Three calibration bottles containing 3200 ppm methyl chloroform were attached in series to an infrared spectrophotometer 10-meter cell, and the Davis Meter with recorder (Figs. 12 and 13). This gave about a full scale deflection.

(b) Test procedure:

The infrared spectrophotometer was locked on 1403 wavenumbers for constant recording. The Davis Meter was operated at the standard air flow of 1.1 liters/min. After passing through the 10-meter cell, the mixture of methyl chloroform in air passed into the Davis Meter and its concentration was recorded.

Results

The concentration of methyl chloroform indicated by the Davis Meter began to decrease while that of the infrared spectrophotometer showed a constant concentration. After a 30-minute run the concentration recorded by the Davis Meter was down to approximately 100 ppm whereas the actual concentration of methyl chloroform as recorded by the infrared spectrophotometer remained at a constant 3200 ppm (Fig. 14).

The Davis Meter was shut down and the cell compartment opened. Heavy deposits of residue from combustion of the methyl chloroform were present on the window of the instrument. This decreased the amount of light entering the photocell, and explains the apparent decrease in concentration of methyl chloroform recorded by the instrument. It should be pointed out that the instrument was not designed for this type of service, and that the manufacturer recommends regular cleaning of the filter window.

These tests indicate that a Davis Halide Meter should not be used to record long period chlorinated hydrocarbon exposures in a workroom atmosphere.

Fig. 12. Block diagram of Davis meter with recorder under test.

Fig. 13. Davis Meter with recorder under test.

Fig. 14. Recordings of a constant concentration of methyl chloroform in air by the Davis Halide Meter and infrared spectrophotometer.

ARC SENSITIVITY OF A 3.4-METER SPECTROGRAPH FOR SOME COMMON ELEMENTS IN WATER RESIDUES

A conversion factor, applicable to our 3.4 meter, Ebert Mount, Jarrel-Ash emission spectrograph, for the determination of the concentration of some 33 common elements (Table III) has been experimentally resolved. Arc sensitivity tables for the 33 elements listed in Table III have been previously published.⁸

As no two spectrographs are exactly alike and operate sometimes under different principles, a conversion factor must be found before tabulated information compiled by one spectrograph can be applied to another. More simply, a great deal of time can be saved by utilizing the information already compiled, with respect to arc sensitivities of various elements, by checking the reported sensitivity of one of the elements on the spectrograph to be calibrated. The thirty-three elements listed in Table III are particularly important in the field of industrial hygiene and sanitary engineering.

Analysis of Sample

Sample preparation - To determine the arc sensitivity of each element a matrix is prepared according to the following procedure: 10.8-g calcium sulfate dehydrate, 13.4-g sodium bicarbonate, 4.8-g sodium chloride, and 12.6-g magnesium sulfate heptahydrate are mixed and heated in a platinum dish at 500°C (muffle furnace) for 1 hour.

Ten milligrams of matrix and 10 milligrams of graphite are weighed and mixed into each of six paraffined, United No. 100-L electrodes. The electrodes are paraffined by filling the crater with a 20% solution of paraffin in benzene, shaking out the excess benzene, and drying under a heat lamp.

Method of Analysis

The material in each electrode is moistened with 30 microliters of 95% ethyl alcohol. Thirty microliters of solution is pipetted into the first electrode. This represents 0.01 microgram or 0.0001% of the element based on a 10-milligram sample. Into each of the remaining five electrodes, solution is added as follows: 0.1 microgram (0.001%), 1.0 microgram (0.01%), 10 micrograms (0.1%), 100 micrograms (1%), and 500 micrograms (5.0%).

⁸ W. A. Van Sandt and G. H. Marshall, Arc Sensitivity Tables for Thirty-Three Common Elements in Water Residues, Calif. Dept. Health, Berkeley (1959).

Table III. Arc sensitivity table.

Element	Arc sensitivity		Wavelengths, Å
	%	μg	
Aluminum	0.00001	0.001	3961.5, 3944.0
Antimony	.01	1.0	2311.5, 2598.1, 2877.9
Arsenic	.01	1.0	2349.8, 2860.5
Barium	.01	1.0	2335.3, 3071.6, 3501.1, 3891.8
Beryllium	.00001	0.001	3130.4
Bismuth	.0001	.01	3067.7
Boron	.001	.1	2497.7, 2496.8
Cadmium	.0001	.01	3466.2
Calcium	.00001	.001	3933.7, 3968.5
Chromium	.00001	.001	4254.3, 4274.8, 3593.5
Cobalt	.00001	.001	3453.5, 3405.1, 3529.8
Copper	.00001	.001	3247.5, 3274.0
Iron	.00001	.001	3737.1
Lead	.00001	.001	2833.1
Lithium	.001	.1	3232.6
Magnesium	.00001	.001	2795.5, 2852.1
Manganese	.0001	.01	4030.7, 4033.0, 4034.4, 2798.3, 2801.1
Mercury (capped electrode)	.0005	0.1	2536.5, 3650.1
Mercury (open electrode)	.1	10	3650.1, 2967.3
Molybdenum	.00001	0.001	3132.6, 3170.3, 3194.0, 3902.9
Nickel	.00001	0.001	3414.7, 3524.5
Phosphorous	.1	10	2535.6, 2553.3
Potassium	.01	1.0	4044.1, 4047.2, 3446.4, 3447.4
Silicon	.0001	0.01	2516.1, 2881.5
Silver	.00001	.001	3280.7, 3382.9
Sodium	.001	.1	3303.0, 3302.3
Strontium	.00001	.001	4215.5
Thallium	.0001	.01	3775.7, 3519.2
Tin	.0001	.01	3175.02, 3262.3, 2840.0
Titanium	.00001	.001	3361.2
Tungsten	.001	.1	4008.8
Uranium	.001	.1	3670.1
Vanadium	.00001	.001	3184.0, 3185.4
Zinc	0.001	0.1	3345.0, 3282.3

After setting at room temperature ($\sim 21^{\circ}\text{C}$) for one and one-half hours, the electrodes are dried again under a heat lamp.

As the spectral region in which the 33 elements lie also contains cyanogen bands that interfere with spectra of certain elements, it is necessary to inhibit nitrogen from the arc to prevent formation of cyanogen. This is accomplished by mounting a Vycor glass cell (Fig. 15) with an optically flat quartz window in the excitation stand. Pure oxygen flowing at the rate of five liters per minute is passed through the cell during the arcing period. To maintain a relative background reading of 80-95% transmission (T) of the spectrum from 2200-4500 Å, it is necessary to use a seven-step filter. Without a step filter, exposure providing a background reading of 80-95% T at 2200 Å would show a background of 5-15% T at 4500 Å.

The spectrograph settings and conditions must simulate as much as possible those in Reference 8, with respect to the following: sample atmosphere, excitation conditions (amperage, voltage, etc.), polarity, analytical gap, exposure, film, and film processing.

Completion of the analysis requires a comparator-densitometer to sort the lines of the elements with respect to their wavelengths and optical densities. Tables of this type are useful for analysis of all samples where the common matrix is plain dirt or water residue. Table III has been converted and is presently ready for use with our spectrograph.

NOTES: The percent (%) and microgram (μg) columns of the arc sensitivities refer to a ten-milligram sample. For example, it takes at least 0.1-microgram zinc in a 10-mg sample or (0.001% Zn) to detect a zinc line at 3345.0 and 3282.3 Å.

Cyanogen bands interfere in the region between 3500 and 4300 Å.

If the wavelengths of any of the above elements lie in this region, steps must be taken to eliminate cyanogen bands.

Fig. 15. Vycor cell used for the suppression of cyanogen bands.

FLOORING FOR HIGH-EXPLOSIVE HANDLING AREAS

Introduction

For the past three years, we have been seeking a flooring for use in high-explosive handling areas with the following properties:

1. Shock absorbance to minimize the detonation hazard of an accidentally dropped mass of high explosive.
2. Good service characteristics: i. e., resistance to abrasion and age hardening.
3. A moderate price, e. g., less than the \$4.00/SF indicated to be the price of installing large polyurethane tiles.

The histories of the evolution of the criteria, examinations of various flooring materials, and the results of testing, are given in UCRL reports 6115, 6818, 7035, 7143, and 7355.

In the latest report, UCRL-7355, results were given on the laboratory tests of a sprayable polyurethane material, the composition of which had been modified to meet our service needs. We noted that the final formulation and surface pattern were satisfactory, and that samples were being sent to Pantex Ordnance Plant for proof testing.

Proof Tests

Samples of the material U-823AH with the approved spatter finish were prepared in nominal 1/16- and 1/8-inch thickness on steel plates and subjected to the Mason and Hanger Drop Skid test as follows:

Explosive	50 lb PBX-9010
Release heights	10, 14, 20 ft
Skid angle	45°
Results	Good hits, no reaction, pieces intact, no tearing of floor material

NOTE: The same explosive dropped at 45° onto a steel-backed sand epoxy mixture yields a high-order detonation when released from a height of 3.5 feet.

Further Work

Following these successful results, cost estimates were obtained from the application for installation of the material in various job sizes, in both thicknesses, and on old and new floors. The results are plotted on Fig. 16.

Since the prices were satisfactory, the floor system was approved for use at LRL Site 300. Installations 1/8 inch thick were made in three test buildings and in two magazines. Operating personnel are reported to be satisfied with these new floors.

Conclusions

The flooring material U-823AH is likely to provide adequate safety against the detonation-by-dropping hazard in high-explosive handling areas. Previously reported test results (UCRL-7135) show that the material is stable, will wear well, and will require little maintenance. Use of the fine spatter finish provides a reasonably good antislip surface. The costs of this flooring, although higher than normal resilient materials, is considerably less than that of urethane tiles. Furthermore, the spray application results in a monolithic installation including a cove base.

RADIOLOGICAL HAZARDS SURVEY OF THE COCKCROFT-WALTON ION ACCELERATOR

Introduction

Proposed design changes in the Cockcroft-Walton ion accelerator call for an increase in beam power level. The planned maximum power level would increase the target neutron yield 25 times and indicates the need to re-evaluate existing shielding. In this respect, stray fast neutron and gamma dose rates were measured outside the C-W pit shield during fixed operating conditions, extending the study previously described by Hughes.⁹

The C-W ion beam is directed into a 40-ft-cubed, shielded target room. The walls are 20 ft above ground level and are made of 5-ft-thick concrete with normal density (2.35 g/cm³). The room also extends 20 ft below ground level and is sometimes known as the "Pit." No overhead shielding is provided. The ion beam is usually deflected so that it makes an acute angle (usually

⁹L. Hughes, UCRL-6172 (October 1960).

Fig. 16. Estimated costs of application of Urapol.

26 or 52°) with respect to the ground. However, "straight-through shots," (where the beam is parallel to the ground) are not uncommon.

Neutrons can be produced by several different reactions. The most frequently generated source of neutrons is the $T(d, n)He^4$ reaction. The 14-MeV neutrons produced this way are essentially monoenergetic. The present maximum yield is 4×10^{10} n/sec at the target. For this study a horizontal beam was used in order to obtain maximum scattering.

Methods

Fast neutron doses were measured with a modified double moderator dosimeter developed by DePangher.¹⁰ This instrument is sensitive to neutrons above the cadmium cutoff (0.076 eV), but its useful range is from 0.025 to 10.0 MeV. Thus, the thermal neutron dose is not measured by this technique and is not included in the tabular data presented below. The axis of the detector was oriented normal to a radius vector from the target to the point of measurement. Integrated counts were such that the standard deviation was two percent of the total count, except in a few instances when it approached six percent. The factor limiting accuracy was the C-W beam itself which was constant to within $\pm 10\%$. The total error for any single measurement was $\pm 15\%$ at the 95 percent confidence level.

Gamma dose rates were determined with a commercially available side window G-M survey meter.

Results

The response of the DePangher neutron detector was plotted as a function of the neutron yield produced at the target. A direct proportionality was found, as shown in Fig. 17. The data was taken with the counter located 20 feet east of the pit shielding in line with the C-W beam. The neutron flux produced at the target is determined by measuring the number of recoil alpha particles produced in the $T(d, n)He^4$ reaction.

Fast neutron dose rates are shown by the isodose lines in Fig. 18. They represent levels obtained with the available maximum beam current. Peak dose rates were obtained about 20 feet from the shield, indicating that most of the contribution was from sky shine. Gamma dose rates were, in all instances, less than 0.1 mr/hr.

¹⁰J. DePangher, Nucl. Instr. Methods 5, 61 (1959).

Fig. 17. DePangher response.

GLL-639-2251

Fig. 18. Fast neutron dose rate contours in vicinity of Cockcroft-Walton generator. Doses are in mrem/hr normalized to maximum beam currently available.

Discussion and Conclusions

Under present operating conditions, the existing shielding surrounding the C-W pit is adequate, if marginal. With ordinary operating conditions, the dose rates are generally lower than those given in Fig. 18 by a factor of two or more. Hence 2 mrem/hr or less is the average dose rate at any point outside the shield during a work week.

If the beam power level is increased as planned, the fast neutron dose rates would be increased proportionately and will create a potentially hazardous stray radiation field outside the shield. Moreover, the fast neutron levels in and adjacent to the control room might greatly exceed permissible levels when the beam sweeper is used or during beam collecting with a Faraday cup. Roof shielding and possibly additional shielding around the beam generating rooms (Fig. 18) would be required to reduce these expected dose rates to permissible levels.

INVESTIGATION OF FLOOR FINISHES

Purpose

A number of people at LRL slip on office floors each year and blame the incident on the slipperiness of the floor polish used. Although it is known¹¹ that the slip resistance of floor finishes is only one of several floor factors affecting floor safety, it was decided to obtain several commercial finishes and subject them to laboratory and field evaluations.

Floor Finishes

Preliminary investigation indicated that many industrial floor polishes are water emulsions of organic polymers rather than of waxes. What waxes are used are usually synthetic rather than natural. The proposed field testing was discussed with representatives of 5 reputable floor finish formulators, and 10 suitable products were selected, as follows:

¹¹ Causes and Measurement of Walkway Slipperiness, Report No. 43 for the Federal Construction Council by Task Force T-41. Publication 899, National Academy of Sciences, National Research Council, (1961).

<u>Material</u>	<u>Indicated % Solids</u>	<u>Indicated Composition</u>	<u>Current Price - 55-gal drums (\$/gallon)</u>
1S	14	latex, polyethylene, leveling agents	1.56
1F	14	acrylic-latex, polystyrene, levelers	1.56
2D	15	acrylic, phenolic, polystyrene	1.76
2K	15	styrene-acrylic, polyethylene, synthetic waxes	1.55
2S	14	polyethylene, polystyrene	1.86
3C	15	polyvinyl-polyethylene	1.54
3K	15	acrylic	1.82
4S	15	polystyrene	2.25
4T	12	synthetic waxes	2.00
5L	22	fluoro-acrylate	5.35

Test Program

Two evaluation programs were carried out: field tests and laboratory examinations. For the field tests a long hall in an office building was chosen where foot traffic is heavy. The asphalt tile floor was carefully stripped of old finish and rinsed twice with clean water. Two coats of each finish were applied to 200-sq ft patches following the manufacturers' procedures, including the use of new mops and clean pails. Those finishes which were indicated to be buffable were polished with power-driven floor polishers. After the final coats were dry, dynamic antislip coefficients were measured using a Sigler Slipperiness Tester fitted with a rubber heel piece.

Thereafter, the floors were examined at 17, 28, and 46 days after the original application, for gloss, dirt impregnation, scuffing and wet- and dry-antislip coefficients (Sigler, rubber heel). Maintenance during the test period consisted of daily dry mopping, weekly wet mopping, and spot waxing 32 days after original application.

At the same time laboratory examinations were made on the products, according to procedures in Federal Specification P-W-155a, on the following properties: pH, total solids, film characteristics, storage stability, water spotting, and removability.

Results and Evaluation

The data obtained are summarized in Table IV, the laboratory test results are shown in Table V, and the field test results are shown on Figs. 19 and 20. Employing the following scoring and rating systems:

<u>Item</u>	<u>Scoring</u>	<u>Quality</u>	<u>Rating</u>
	Total points		Percentage of points
Laboratory tests	10	Excellent	90-100
Application ease	15	Good	75-89
Gloss retention	10	Fair	60-74
Resistance to dirt	10	Poor	40-59
Resistance to scuffing	10		
Antislip coeff. - dry	20		
Antislip coeff. (dry-wet)	25		
Totals		100	

the test finishes were evaluated independently by the authors with the following average results:

<u>Code</u>	<u>Overall score</u> (100 = max)	<u>Relative position</u> (1-10)	<u>Antislip score</u> (45 = max)	<u>Relative safety position</u> (1-10)
1S	73.9	4	34.2	4
1F	75.4	2	29.0	7
2D	74.0	3	38.0	1
2S	67.2	7	31.3	5
2K	78.1	1	37.7	2
3K	65.9	8	26.0	8
3C	67.5	6	29.0	7
4S	70.8	5	31.1	6
4T	63.5	9	22.2	9
5L	73.9	4	35.8	3
Spread				
Overall	63-78		22-38	
Top 4	74-78		34-38	

Table IV. Evaluation summary of test floor finishes.

Material	Results of Lab Tests Fed Spec P-W-155a 10*	Field test evaluations – use and appearance				Field tests safety		Totals lab & use/ appearance 55 max	Totals antislip properties 45 max	Totals overall 100 max	Relative position general 1-10	Relative position safety 1-10
		Appli-cation ease 15	Gloss reten-tion 10	Resist-ance to dirt impreg-nation 10	Scuff resist-ance 10	Antislip coeff.						
						Dry 20	Dry-wet 25					
1S	Failed aging test OK other-wise	OK	Good-fair	Good	Excellent-fair	Good	Good-fair					
Average score	4.0	12.7	6.7	9.0	7.3	16.7	17.5	39.7	34.2	73.9	4	4
1F	OK	OK	Good+	Good	Excellent-fair	Good	Poor-fair					
Average score	9.4	12.0	9.0	8.7	7.3	15.7	13.3	46.4	29.0	75.4	2	7
2D	Failed aging test OK other-wise	Good-	Fair-good	Good-fair	Excellent-fair	Good	Good+					
Average score	4.0	11.0	6.7	7.0	7.3	16.0	22.0	36.0	38.0	74.0	3	1
2S	Good – hard to remove	Good	Fair-poor	Fair-poor	Excellent-fair	Good	Fair					
Average score	8.0	12.3	3.3	5.0	7.3	16.3	15.0	35.9	31.3	67.2	7	5
2K	OK	Good-	Fair	Good-fair	Excellent-fair	Good	Good+					
Average score	9.4	11.0	6.0	7.0	7.0	15.7	22.0	40.4	37.7	78.1	1	2
3K	Good – slightly hard to remove	Good	Good	Fair-good	Excellent-fair	Good	Fair-poor					
Average score	8.0	12.3	7.0	6.3	6.3	16.0	10.0	39.9	26.0	65.9	8	8
3C	OK	Good	Fair	Good-poor	Excellent-fair	Good	Fair-poor					
Average score	9.4	11.7	5.7	5.0	6.7	15.7	13.3	38.5	29.0	67.5	6	7
4S	OK	Good	Fair	Fair-good	Good-poor	Good	Fair					
Average score	10.0	14.0	5.0	5.7	5.0	16.3	14.8	39.7	31.1	70.8	5	6
4T	Good – slightly hard to remove	Good-	Good+	Good-fair	Excellent-fair	Good	Poor					
Average score	7.6	11.3	9.0	6.7	6.7	15.7	6.5	41.3	22.2	63.5	9	9
5L	Very difficult to remove – other-wise OK	Poor-fair	Good+	Good	Excellent-good	Good	Fair-good					
Average score	5.4	5.7	9.3	8.7	9.0	16.3	19.5	38.1	35.8	73.9	4	3

* Maximum possible score

Table V. Federal Specification (P-W-155a) Test results on test floor finishes.

Code	pH	Total solids %	Film characteristics	Removability		Storage stability	Water spotting	Manufacturer's claims	
				Linoleum	Asphalt tile			% T. S.	Type
1 F	8.8 OK	15.1	OK	95% uniform residue	92% uniform residue	OK	OK	14	Latex, polyethylene, and leveling agents
1 S	8.9 OK	15.3	OK	90% uniform residue	80% uniform residue	Failed - gelled	OK	14	Acrylic-latex, polystyrene, and levelers
2 D	9.5 OK	15.8	OK	90% uniform residue	90% uniform residue	Failed - gelled	OK	15	Acrylic, polystyrene, and phenolic
2 K	8.7 OK	14.8	OK	100% clear	95% uniform residue	OK	OK	15	Synthetic waxes, styrene-acrylic, and polyethylene
3 S	9.3 OK	15.0	OK	80% slight streaks	40% noticeable streaks	OK	OK	14	Polyethylene and polystyrene
3 C	9.4 OK	14.3	OK	90% uniform residue	90% uniform residue	OK	OK	15	Polyvinyl-polyethylene
3 K	9.5 OK	14.3	OK	70% noticeable streaks	90% one spot remaining	OK	OK	15	Acrylic
4 S	8.5 OK	14.9	OK	90% slight uniform residue	90% uniform residue	OK	OK	15	Polystyrene
4 T	9.7 OK	11.8	OK	90% slight uniform residue	80% uniform residue	OK	OK	12	Synthetic waxes
5 L	10.3 too high	18.3	OK	0% not affected	0% not affected	OK	OK	22	Fluoro-acrylate

Fig. 19. Appearance factors of test floor finishes.

Fig. 20. Antislip characteristics of test floor finishes.

Discussion

Each one of the products tested is listed by the Underwriters Laboratories. This means that the products meet minimum standards as to flash point and static dry antislip coefficient.

The data obtained in this investigation tend to support the Underwriters' approvals in that

1. they all show good dry antislip coefficients with small differences among the products, and

2. the overall ratings show a moderate spread in values, i.e., 63-78. However, the dry-minus-wet coefficients show greater difference (scores of 6-22 out of 25 maximum) among the products. This difference is an important factor in floor safety, since a person suddenly encountering a wet spot may slip or not depending upon the spread between dry and wet coefficients.

The five highest rated products, 2K, 1F, 2D, 1S, and 5L, show a very narrow spread - 74-78 - in overall rating; four of these, 2D, 2K, 5L, and 1S, are the best in antislip scoring, showing a 4-point spread in this regard. Material 1F ranked seventh in antislip rating.

The pertinent data on the five top-scoring products are summarized as follows:

Product	2K	1F	2D	1S	5L
Type	Styrene acrylic polyethylene synthetic waxes	Acrylic, latex poly-styrene	Acrylic, phenolic styrene	Latex polyethylene	Fluoro-acrylate
Current cost \$/gal	1.55	1.56	1.76	1.56	5.35
Fed. spec. tests	OK	OK	OK except for aging test	OK except for aging test	OK, but very difficult to remove
Application ease	Good	Good +	Good -	Good	Poor-fair
Appearance	Fair-good	Excellent-fair	Excellent-fair	Excellent-fair	Excellent-good
Antislip characteristics (dry-wet)	Good +	Poor-fair	Good +	Good-fair	Fair-Good

(Continued)

Product	2K	1F	2D	1S	5L
General rating %	78.1	75.4	74.0	73.9	73.9
relative position	1	2	3	4	4
Safety rating % *	83.8	64.3	84.5	76.0	79.5
relative position	2	7	1	4	3

$$* \text{ Safety rating (\%)} = 100 \times \frac{\text{safety score}}{45}$$

The four top-scoring products were also evaluated for the effect of strong chemicals. The results are given in Table VI.

Table VI. Effect of strong chemicals on top-rated floor finishes.*

Finish	2K	2D	1S	5L
98% sulfuric acid	Moderate attack	Moderate attack	Considerable attack	Considerable attack
70% nitric acid	Considerable attack	Considerable attack	Considerable attack	Moderate attack
48% hydrofluoric acid	Slight attack	Slight attack	Very slight attack	Slight attack
50% sodium hydroxide	Instant surface attack	Instant surface attack	Instant surface attack	No effect
Mixed solvent†	Moderate attack	Moderate attack	Considerable attack	Moderate attack

* Fifteen-minute test on samples of linoleum double coated with finish and buffed after each coating.

† Equal parts by volume of paint thinner, toluene, methyl ethyl ketone, butyl alcohol, and butyl acetate.

Considering safety, quality, and price, materials 2K and 2D are approximately equal first choices; material 1S is a third choice. Although it ranked second overall, material 1F should not be used because of its relatively poor antislip rating.

Material 5L has two disadvantages: it is very difficult to remove the base coat, which soaks into the "pores" of the resilient floor, and it costs ~3-1/2 times as much as the other waxes. However, because of its superior chemical resistance to caustic and nitric acid, it may have some application in chemical laboratory floors.

To protect the Laboratory against unknown formula changes, samples of the five top scoring waxes are being analyzed by infrared spectrophotometry. Copies of the results will be submitted and it is suggested that:

1. vendors whose products are to be used be asked to submit affidavits that products bought from them under the brand name will conform to the analysis shown by the spectrogram,
2. no changes be allowed in the formula or solids content of the particular items without approval of LRL Custodial Service and Hazards Control Department, and
3. vendors be advised that their products will be subject to spot check analyses.

FIRE DETECTION CIRCUITS

Fail Safe Circuit

The so-called "fail safe" circuit (Fig. 21) consists of thermostats or heat detectors connected in series. Under normal conditions, the circuit is energized. When a fire occurs the thermostat contacts open, interrupting the current. This causes a relay to close which shorts out a resistor in leased telephone lines leading to the alarm headquarters. The alarm relay in the emergency alarm headquarters is then opened by the increase in current over the telephone lines.

With this type of circuit, a ground or open circuit in the building portion of the circuit will drop out both alarm relays thus giving a false indication of fire. A ground or open circuit in the leased telephone lines will activate a trouble relay in the emergency alarm headquarters thus giving a trouble signal.

Supervised Circuit

The disadvantage of a "fail safe" circuit is that a signal for a ground or open fault in the building circuit cannot be distinguished from an alarm signal. To provide for a distinct trouble signal for ground and open faults the "fully supervised" circuit is used. This circuit (see Fig. 22) utilizes thermostats connected in parallel. Under nonfire conditions, the circuit carries the weak supervisory current. Thermostat contacts closed by a fire short out an end of the line resistor, thereby increasing the current.

T = Trouble relay — held closed by weak supervisory current. An open or ground in the Telephone line causes this relay to open.

Δ = Alarm relay — picks when thermostats open or when there is an open or ground in the building circuit. GLL-639-2254

Fig. 21. "Fail safe" fire alarm circuit.

Fig. 22. Supervised alarm circuit using parallel normally open thermostats.

Relay and resistor values are approximate and tentative
 GLL-639-2256

Fig. 23. Supervised alarm circuit using series loop normally closed thermostats.

Increased currents pick up the alarm relay which shorts out the end of the line resistor in the telephone lines. From here on the alarm is transmitted the same as in the "fail safe" system.

An open or ground fault in either the building circuit or the leased telephone pairs will cause the trouble relay in the emergency alarm headquarters to open. Thus the systems distinguishes between trouble and fire conditions.

Supervised Circuit Using Series Loop Normally Closed Thermostats

To convert a series loop alarm circuit (fail safe) to a fully supervised circuit, the following scheme was devised (Fig. 23). A resistor is connected in parallel with each thermostat. This supervisory current holds the alarm relay open. When the thermostat contacts are opened by a fire, the current decreases, dropping out the alarm relay. The alarm relay shorts the end of the line resistor and the signal is transmitted to the emergency alarm headquarters as before. When a ground or open fault occurs the supervisory current is disrupted and the supervisory relays opens, transmitting a trouble signal.

By adding a resistor to each thermostat and installing the appropriate alarm and trouble relay a series "fail safe" system can be converted to a "fully supervised" system.

NOMOGRAPHS FOR AIRBORNE RADIOACTIVITY SAMPLING

Air Sampling Data

In airborne radioactivity sampling programs at LRL a variety of sampling rates and sampling periods are used. A nomograph has been prepared to rapidly determine if the airborne radioactivity of these samples exceeds MPC levels.

In construction, the initial scales were drawn with as large a modulus as was practical. The modulus and spacing of the secondary scales were computed using the data of Davis.¹² Two nomographs were prepared to retain sensitivity (see Figs. 24 and 25).

¹² D. S. Davis, Nomographs and Empirical Equations, 2nd Ed. (Reinhold, New York, 1962), pp.137-169.

Fig. 24. Nomograph to convert counting rate (c/m) to disintegration rate (d/m).

FLCW RATE IN
CFM

VOLUME IN
 m^3

SAMPLING TIME
(min)

ACTIVITY PER UNIT
VOLUME IN DPM/ m^3
 $\mu C/cc$

ACTIVITY IN
DPM

ILL-639-2258

Fig. 25. Nomograph relating sample volume and disintegration rate to radioactivity per unit volume ($\mu C/m^3$) ($\mu C/cc$).

The following example will illustrate the use of the nomographs. Assume the following data: Flow rate - 25 cfm; sampling time - one day (1440 minutes); net counts on sample filter - 800 cpm; counter efficiency - 40%.

1. Using a ruler connect 25 cfm and 1440 minutes.
2. The volume is read then as $1.0 \times 10^3 \text{ m}^3$.
3. Connect 800 cpm and 40% efficiency.
4. The dpm is read as 2000.
5. Connect $1.0 \times 10^3 \text{ m}^3$ and 2×10^3 dpm.
6. The activity unit volume is 2.0 dpm/m^3 or $8.9 \times 10^{-3} \mu\text{C/cc}$.

Parameters outside the range of the nomographs will yield answers differing only in orders of magnitude with proper substitutions. For example: given a flow rate of 4 cfm, use 40 cfm on nomogram and multiply the answer by 10 to get true values.

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