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Subject Category: Health and Safety

UNION CARBIDE NUCLEAR COMPANY
Division of Union Carbide Corporation
Y-12 Plant
Contract No. W-7405-eng-26
with the U. S. Atomic Energy Commission

THE Y-12 HEALTH PHYSICS PROGRAM

Work done by:
Y-12 Health Physics Department

Report prepared by:
G. R. Patterson, Jr.
C. M. West
J. D. McLendon

Oak Ridge, Tennessee
November 1, 1957

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ABSTRACT

The program for protecting employees of the Union Carbide Nuclear Company at the Y-12 Plant from injury by exposure to radiation and/or radioactive materials is an integral part of the plant health and safety program. This report summarizes Health Physics activities, in Y-12, including organizations, responsibilities, limits, and methods, which have been established and are currently employed to accomplish the objective of personnel protection.

3. Waste Monitoring - In keeping with the policy of not subjecting the populace at large to undue hazards from plant operations, the Health Physics Department monitors the atmosphere of the general plant area and the streams which pass through the plant site, both of which might possibly carry contaminated wastes out of the plant area.

   a. Outdoor Air Sampling - The programs for continuous monitoring of the general plant atmosphere and the exhaust gas effluents already have been outlined in sections IV. C. 4. a., and IV. C. 4. b. of this report. They are mentioned again here only to point out that the data presented by these programs can be used to indicate the presence of air-borne contamination in quantities which might be an off-site hazard. It is extremely unlikely that operations at the Y-12 plant will ever generate a hazard for the general plant site, and certainly not for off the site.

   b. Stream and Pit Sampling - Samples are taken from all effluent streams and disposal areas in the Y-12 plant. From these samples the level of contamination, which is discharged into the streams from the operating processes, may be determined. Table IV. 6 gives a sampling schedule for all streams and disposal areas.

Table IV. 6

Water Sampling Schedule

Location	Frequency of Sampling
Bear Creek	Weekly (Monday)
Disposal Areas	
Burial Pit	Weekly (Monday)
Settling Pits	
Northwest Pit	Weekly (Monday)
Northeast Pit	Weekly (Monday)
Poplar Creek	Continuous

1) Since Poplar Creek carries off most of the liquid wastes which are discharged into area streams, the greater emphasis is placed on its sampling. A special sampling installation is located in the creek approximately seventy-five yards south of building 9720-8. A dam across the creek makes the stream deep enough to permit the use of automatic continuous water level recording and sampling equipment. Both the level of the stream and the rate of flow can be determined from the charts of the automatic level recorder and calibration curves.

   The automatic sampling equipment is a proportional sampler which removes from the creek and stores in a sample reservoir a sample of water proportional to the amount of water flowing in the creek. The actual amount of sample obtained can be varied by adjusting the automatic timing device. Each day two samples are taken from the sample reservoir, one fourteen ounce daily sample, and one 1/5 of a gallon sample which becomes part of a composite weekly sample. The daily samples are analyzed for pH and the presence of alkali metals. The one gallon weekly composite samples are analyzed for mercury and gross alpha and beta-gamma activities.

2) The Bear Creek sample is taken approximately one mile down stream from the Burial Pit and is analyzed for gross alpha and beta-gamma activities. This sample is dipped from the stream and poured into the sample bottle.

3) The burial pit sample is taken at the west end of the pit. The burial ground is located approximately two miles west of the Y-12 area. This also is a dip sample, dipped from any water standing in the pit, and poured into the sample bottle. This sample is analyzed for gross alpha and beta-gamma activities.

4) The settling pit samples are taken as near the dumping chutes as possible. These also are dip samples, but the technique of the sampling is unique. A long sampling pipe is used in an effort to obtain a sample which will be a composite of the activity at various depths of the pit liquid. The pipe is slowly stuck

down into the water so that water from each level of the pond enters the pipe, the top end of the pipe is closed off to hold the sample, and the pipe is lifted from the water and emptied into the sample bottle. This sample is analyzed for gross alpha and beta-gamma activities.

E. Special Surveys

1. Abnormal Result or Condition Investigations - When unsatisfactory conditions are found or when the results indicated by either personnel or environmental monitoring are abnormally high, special surveys to isolate the causes may be indicated. Personnel radiation exposures, either external or internal, in excess of maximum permissible levels are always investigated in an attempt to explain the indications. Some of the special surveys which may be performed are as follows:

   a. Special intensive film or instrument surveys or special film calibrations may be used to investigate abnormal external exposures.

   b. Increased frequency of sampling, twenty-four hour elimination samples, or even fecal samples may be used to investigate abnormal indications of internal exposure.

   c. Special breathing zone or operational samples or the installation of extra permanent sampling heads may be used to investigate abnormally high air sample results or unsatisfactory trends in air levels.

2. New Operation Investigations - New operations with radioactive materials are always the subject of intensive air sampling program. Extra permanent sampling heads, portable equipment general air samples, and many breathing zone or operational samples all may be used to evaluate the airborne contamination potentialities of a new operation. Special film programs or special urinalysis programs may be used to assist in the evaluations.

3. Special Operation Investigations - Special monitoring programs are set up to evaluate the hazards generated by special operations. These operations may be of short duration, or may be one of great hazard potential, emergency operations, or as outlined in section IV. C. 2., operations being carried

on temporarily in non-processing areas. Any of the methods of film monitoring, urinalysis, air sampling, or surface contamination monitoring may be used as required to protect personnel or evaluate environmental conditions.

4. Source and X-ray Surveys - At the request of supervision, the Health Physics Department will make any surveys necessary to evaluate the shielding requirements, the radiation intensities, or operating techniques used around source installations or X-ray generators. Special surveys are made during the changing of sources, start up operations of source or X-ray installations, or during special or unusual usages of such equipment.

F. Other Services

1. Consultation and Advisory Services - As was indicated in section II, outlining the responsibilities of various groups, one of the main functions of the Health Physics Department is consultation with line supervision or other staff groups on any phases of health physics; investigating and estimating the hazard potential of new or special operations, and advising supervision of health physics problems which are anticipated and means of combatting them. The Health Physics Department may be able to help circumvent some of the problems and operating difficulties by consultation and advice during the engineering or planning stage of the proposed operation or revision.

   Another of the consultation and advisory services performed by the Health Physics Department deals with the plant education and training program. The Health Physics Department may be called upon to assist in the training or education of employees in the various aspects of their jobs as they pertain to dealing with radiation or radioactivity. This may be in the form of short talks given to a group of employees during a regularly scheduled safety meeting; or it may be a specially called discussion meeting with a group of employees or supervisors to gain a better understanding of the problems of radioactivity, the entire Health Physics program, one particular phase of the program, or one particular operating problem.

2. Services for Other Departments - There are several programs more closely related to industrial health or industrial hygiene than to health physics which are administered by

other departments, but for which the Health Physics Department provides the manpower and supervisory services necessary to carry on the duties of the program.

a. Routine Industrial Toxicant Monitoring - An extensive program ~~is in operation~~ to determine the concentrations of non-radioactive toxic contaminants in the plant atmosphere. ~~This~~ program ~~is~~ administered by the Industrial Hygiene Department. The Health Physics Department provides the manpower to do the sample collection and reports the data ~~obtained~~ to the Industrial Hygienist for interpretation, ~~and further~~ action.

1) Mercury Vapor Sampling - A routine mercury vapor sampling program is maintained in buildings 9201-2, 9201-4, 9201-5, 81-10, and 9204-2; buildings in which a potentially serious mercury vapor problem may exist. Samples are collected at locations other than these at the request of the Industrial Hygienist or area supervision.

Two instruments are available for detecting and measuring the concentration of mercury vapor in the atmosphere; one AC powered instrument built by the General Electric Company, and one more portable, battery powered instrument designed and built by the Y-12 Development Department. Because of the greater portability (smaller size, lighter weight, and no need for a long, trailing power line) and other desirable features, the latter instrument has become the standard one in the Y-12 mercury vapor sampling program. Both instruments utilize the absorption by mercury vapor of ultra-violet light of 2537 A° wave length; the amount of absorption being proportional to the concentration of mercury vapor in the atmosphere.

Scheduling of the routine sampling programs is accomplished by agreement between the Industrial Hygienist, area supervision, and the Health Physics Department. "Survey Summary Sheets" which show the optimum and minimum sampling frequencies are provided for the guidance of the persons doing the sampling. These sheets serve also as a check sheet of work completed and work yet to be done.

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Figure IV.14

For all areas in which mercury vapor sampling is a routine program, "Solvent Air Analysis Report" forms are provided.

Dept. or Program ADP

Solvent Air Analysis Report

Bldg. 8110

Sludge Burner

Date

Test No.	Operation	Location	Scale Reading	Conc. mg/M^3	Remarks
1		Inside locker A			
2		Inside locker B			
3		Inside locker C			
4		Inside locker D			
5		Over scales			
6		BL between scales and lockers			
7		BL 10 ft. south of lockers			
8		BL 10 ft. west of lockers			
9		BL at storage bin			
10		BL over desk			
11		BL at control panel			
12		BL at center of office			
13		BL at center of rest room			
14		BL at center of lunch room			
15		At air intake duct in office			
16		At air intake duct in rest room			
17		At air intake duct in lunch room			

Observer

Figure IV.15

Mercury vapor samples are classified as either "Spot General Air" samples or "Source Samples". The spot general air (SGA) samples serve the same purpose and are collected for the same reason as uranium general air samples, to determine the average concentration of contaminant in the atmosphere of a given area. Unfortunately permanent, continuous sampling devices have not proved satisfactory for mercury sampling, so a series of samples at many locations or spots must be taken to determine the area average or general air level. SGA samples are taken with the instrument approximately at the height of the breathing zone and at predetermined, fixed locations. Source samples are an exploratory type of sample; taken while the instrument is moved from place to place near equipment, floors, drains, etc., in an effort to locate sources of a high mercury vapor concentration.

The "Solvent Air Analysis Report" form (figure IV.15 is used to record and report the information obtained by the survey. Indications of unusually high mercury

vapor concentration detected by either SGA or source samples are reported to area supervision immediately. Otherwise, the reports are sent to the Industrial Hygienist, the Alloy Division superintendant, area supervision, and the Health Physics Department files. For requested non-routine samples the reports are sent to the Industrial Hygienist, area supervision and the Health Physics Department files.

2) Beryllium Air Sampling - A program for the detection of beryllium in the atmosphere is maintained in building 9766. Since the beryllium contamination is in particulate rather than vapor form, continuous samplers using filtering collectors can be employed; thus, the program is similar to that for the detection of uranium in the atmosphere. A system of permanently installed sampling heads is used to collect samples for determining the level of general air contamination. Portable equipment is used to collect non-routine samples which may be considered either general air, breathing zone, or operational.

The permanent samplers for determining general air beryllium concentration are located in the machine shop, and the storage and changehouse facilities. In addition to those for general air sampling, two permanent sampling heads are installed in the filter house and exhaust stack of the shop ventilation system. These give a rough indication of the beryllium being exhausted to the outside atmosphere.

Since the beryllium group works two shifts a day, the permanent air samplers are operated for the whole sixteen hours each day. This is made simple by the fact that the central vacuum system to which all of the sampler heads are connected is controlled by the master electrical switch for the whole area.

Each morning the samples from the previous day are removed from the sampler heads, the new filters are put in place, and the rotometers are adjusted for the proper flow rate. Tweezers are used to handle the samples to help prevent cross-contamination, and prevent smearing of the sample or crumpling of the paper. Whatman No. 44 filter paper discs

1-1/8" in diameter are used to collect beryllium samples. This type of paper is the most suited to the spectrographic method of analysis which is used for beryllium. As they are removed from the sampler heads, the filter papers are placed in individual porcelain crucibles in which they will be transported to the laboratory and in which they will be ashed (the first step in laboratory sample preparation). The crucibles are numbered to identify the samples. The data necessary for the calculation of beryllium concentration in $\mu g/M^3$ of air is recorded on the "Air-Borne Beryllium Record" data card.

DATA CARD

Air-Borne Beryllium Record

Observe_____ Room Code_____ Date_____

Sample Number Location	Crucible Number	Req. No.	Average Air Flow M^3/min.	Total Time Min.	Volume of Air M^3	Total Be. μg	Air-borne Be. Conc. $\mu g/M^3$	Condition

Figure IV.16

Note: This card is used to record the data from the permanent samplers.

DATA CARD

Air-Borne Beryllium Record

Room Code _____ Date _____ Operation and Condition Code _____ Inspector Code _____

Machine Number _____ Material Type _____ Volume of Air M^3 _____

Start Time _____
Finish Time _____
Total Min. _____

Average Flow M^3 _____ Be. μg _____

$\mu g/M^3$ _____

Figure IV.17

Note: This card is used to record the data from portable samplers.

The form "Health Physics Request for Spectrographic Analysis" is used for a laboratory worksheet, and to report the results indicated by laboratory analysis.

HEALTH PHYSICS REQUEST FOR SPECTROGRAPHIC ANALYSIS

HF 1050

Date

Sample Type	Xble No	Y Be	Remarks

Original - To Spec. Lab.
First Copy - To Spec. Lab.
Second Copy - Retain.

Figure IV.18

This form is filled out by the Health Physics representative and sent to the laboratory with the samples. The actual request for analysis is made on the regular request form (C-1042, rev. 9-50). This form must accompany each ten samples; no more, no less.

When the completed spectrographic analysis forms are returned from the Laboratory Department, the

sample beryllium content data are transcribed to the "Air-Borne Beryllium Record" data card, the concentrations in $\mu g/M^3$ are calculated and recorded, and the cards are sent to the Industrial Hygienist.

A control program is carried on to evaluate the precision of laboratory determinations of beryllium content. With each day's samples two control samples are included, one a blank filter and one spiked with a known amount of beryllium. These controls are prepared by the Quality Control Department laboratory. When the completed spectrographic analysis forms are returned from the Laboratory Department, the laboratory determinations of beryllium content of the control samples are recorded on a "Health Physics Beryllium Controls" form and sent to the Quality Control Department for evaluation.

HEALTH PHYSICS

BERYLLIUM CONTROLS

Date_____

Requisition No._____

Crucible No._____ Crucible No._____

Control Value_____ μg. Blank Reported Value_____ μg.

Reported Value_____ μg.

_____

Health Physics Department

Figure IV.19

3) Beryllium Surface Contamination Monitoring - Beryllium is the only non-radioactive industrial toxicant for which the smear technique is used in the detection of surface contamination. The technique used in taking the smears is a slightly modified version of that used in the uranium smear program.

The quantity of beryllium collected on the smears is measured by spectrographic analysis as is the case with the beryllium air samples.

The machine shop, lunch room, and change-house areas in building 9776 are on the routine program to be smeared at least once each quarter. Smears may be taken more frequently or in areas other than these at the request of the Industrial Hygienist or area supervision.

Circular discs of Whatman No. 50 filter paper (10 cm. diameter) are used for smears. The smear paper is first wetted with alcohol, or some other good wetting agent, and rubbed over approximately 100 cm^2. area of the surface to be smeared. The smear is then placed in the crucible in which it will be transported to the laboratory and in which it will be ashed at the laboratory. The crucibles are prenumbered to identify the location of the spot smeared. The information necessary for later identification and reporting of smear results is recorded on a "Beryllium Smear Record" card and the card is retained by the Health Physicist.

BERYLLIUM SMEAR RECORD

Inspector _____ Date _____
Req. No. _____ Bldg. _____
Location _____

Sample #	Crucible #	Description of Smear	Be.
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

Figure IV.20

Smears are sent to the laboratory in groups of ten (no more, no less). Each group of ten is accompanied by a "Request for Analysis" form (C-1042, rev. 9-50), and a "Health Physics Request for Spectrographic Analysis" form. The latter form, the same one used for beryllium air samples, is used as a laboratory work sheet to report the results indicated by laboratory analysis.

When the completed spectrographic analysis work sheets are returned from the Laboratory Department, the smear beryllium content data are recorded on the "Beryllium Smear Record" card and the card is sent to the Industrial Hygienist.

4) Cadmium Air Sampling - Once each month air samples for the detection of cadmium contamination in the atmosphere are collected in the E-Wing of building 9212. Out of routine samples may be collected more frequently at the request of the Industrial Hygienist or area supervision.

Samples for the detection of cadmium are collected where and when the operator is sanding, deblistering, or numbering a cadmium coated part. Samples are collected using an electrostatic precipitator with a glass collector tube. The information necessary for the later identification and reporting of the sample results is recorded on a standard form for air analyses other than those already outlined.

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AIR ANALYSIS

To _____
Att.: _____
_____
_____

Sample No.	Date of Sample	Location of Sample	Time of Sample			Rate	Total Vol.	Contami-nant	Results	Remarks
			Start	Finish	Total Min.	----	-----	-------	-------	

Inspector _____

Analyzed by _____

Figure IV.21

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Determination of the cadmium content of the samples is made by spectrographic analysis. Samples are sent to the laboratory accompanied by the regular "Request for Analysis" form (C-1042, rev. 9-50). A portion of this form is returned to the requestor (the Health Physics Department) with the analysis determinations recorded on it.

The μg amounts of cadmium indicated by analysis and the $\mu g/M^3$ of air indicated for each air sample are recorded on the air analysis form, and the information is sent to the Industrial Hygienist for evaluation.

5) Cyanide Air Sampling - Once each month air samples for the detection of cyanide, or hydrogen cyanide, contamination in the atmosphere are collected in the electroplating shop in building 9212. The samples are collected at those locations in the area where cyanide fumes are most likely to be present. Out of routine samples at this or any other location may be collected at the request of the Industrial Hygienist.

A Mine Safety Appliances Company hydrocyanic acid gas detector kit is used to detect the presence of the contaminant. The color change of a chemical reaction in the presence of the gas is compared to a calibrated color standard to give concentration in parts cyanide per million parts of air. The concentrations indicated are recorded on the same air analysis form which was illustrated in the preceding section on cadmium sampling, and the information is sent to the Industrial Hygienist for evaluation.

6) Degreaser Air Sampling - Once each quarter-year the atmosphere around each of four degreaser units is sampled for the presence of fumes from the trichloroethylene or perchlorethylene solvents used in degreasing. Samples are taken at the locations in each area where the fumes are most likely to be present. The locations and frequencies of sampling were recommended by the Industrial Hygienist.

A Davis Halide Meter is used to detect the solvent fumes and determine the concentrations. Concentrations are determined from a calibration curve which accompanies the instrument. All pertinent survey

information and the concentrations determined by sampling are recorded on the form for degreaser air analysis reporting and sent to the Industrial Hygienist for evaluation.

Degreaser Air Analysis

1 Bldg No _____ 2 Date _____ 3. Type of ventilation _____ 4 Approximate size of part _____

5 Type of Degreaser _____ 6. Sampling time: from _____ to _____ Total time in minutes _____

7 Instrument Employed < a. Davis Halide Meter ☐ b. Davis Micro Gas ☐

Samples taken at 3-5 minute intervals at the following locations ------p.p.m. of ----------

	SAMPLE NUMBER															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
General Air Samples																
1 BL at radius of 1'-2' of Degreaser																
2 BL at radius of 10' of Degreaser																
3 BL at radius of 20' of Degreaser																
4 BZ loading Degreaser																
5 BZ while spraying parts																
6 BZ unloading Degreaser																
Source Samples																
1 1" above North edge																
2 12" above North edge																
3 1" above East edge																
4 12" above East edge																
5 1" above South edge																
6 12" above South edge																
7 1" above West edge																
8 12" above West edge																

Observer _____

Figure IV.22

Changes in the above list of sampling points may be made or out of routine samples may be collected at the request of the Sanitary Engineer.

The sampling program has two phases; determination of the concentration of chlorine, and determination of the concentration of foreign bodies or organisms in the water. The chlorine concentration determination is made in the field by the Health Physics representative. The determination of bacterial or foreign organism content is made by the Public Health Laboratory of the Department of Public Health in Oak Ridge.

The samples for laboratory analysis are collected in sterilized four ounce glass bottles supplied by the Public Health Laboratory. Precautions must be taken to see that the water touches nothing which might contaminate the sample giving a high but untrue bacterial count. The outlet from which the sample is obtained is sterilized with a small gas torch, the top of the stoppered bottle is covered with paper on which the sample identification is written, and the stopper must not be allowed to become contaminated while the bottle is being filled. Each sample submitted to the laboratory is accompanied by a form (Mun-PH-11) which is supplied by the Public Health Laboratory for recording sample designation and laboratory determinations.

DEPARTMENT OF PUBLIC HEALTH
PUBLIC HEALTH LABORATORY
OAK RIDGE, TENNESSEE

Lab. No._____

Source of Sample_____ Chlorine_____ p. p. m. _____ pH_____

Date Collected_____ Time Collected_____ A. M. _____ P. M.

Point of Sampling_____ Sampled by_____

Date Received_____ Date Reported_____

37° C. STANDARD AGAR PLATE COUNT	GAS IN LACTOSE BROTH							COLIFORM GROUP	M. P. N.*
	10 ml.	1 ml.	.1 ml.	.01 ml.	.001 ml.	.0001 .001	.00001 ml.		

*"Most Probable Number" of coliform organism per 100 mL of sample.

Form Mun-PH-11-2-56 For interpretation consult Division of Public Health Engineering.

Figure IV.23

Samples must be submitted to the Public Health Laboratory within three hours after the time of collection or the growth of bacteria in the sample after collection may give rise to a high, but untrue, laboratory determination.

Samples for the determination of chlorine content are collected at the same time as the samples for the laboratory. However, they are collected in small vials or viewing cells rather than sample bottles. The Ortho-Tolidine Arsenite test is used for on the spot determination of chlorine concentration. The determination is made using a Hellige Comparator and calibrated color disc to evaluate a chemical reaction color change which is proportional to the amount of chlorine present. The results indicated by these tests are entered in the proper blank on the Mun-PH-11 form before the samples go to the laboratory.

Once each month the Health Physics Department reports the results of all water sample analyses to the Y-12 Medical Director and the Sanitary Engineer. In the case of abnormal sample results which have been reported from the Public Health Office by telephone, the Health Physics Department notifies the Medical Director and the Sanitary Engineer immediately. The outlet from which such a sample was obtained will be resampled the following Monday rather than a month later as scheduled. Analysis of follow-up samples more frequently than once a week can be arranged if necessary.

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Rad. Support
Air Monitoring

UNION CARBIDE NUCLEAR COMPANY

A DIVISION OF UNION CARBIDE AND CARBON CORPORATION

UCC

POST OFFICE BOX P
OAK RIDGE, TENNESSEE

January 21, 1958

U. S. Atomic Energy Commission
Post Office Box E
Oak Ridge, Tennessee

Attention: Mr. S. R. Sapirie

Gentlemen:

Subject: ENVIRONMENTAL MONITORING PROCEDURES

The attached information supplements our letter of November 25, 1957, which was inadvertently omitted at that time.

Yours very truly,

UNION CARBIDE NUCLEAR COMPANY

Clark E. Center

Clark E. Center
Vice President

CEC:JAS:esMc

Attachments 3:
Environmental Monitoring
Procedures for:
Oak Ridge Gaseous Diffusion Plant
Y-12 Plant
Paducah Plant

cc: L. B. Emlet
A. P. Huber
R. G. Jordan
J. P. Murray
K. Z. Morgan
A. H. Snell
J. A. Swartout

H. P. –
Rad. Exposure
Air Monitoring

INTER-COMPANY CORRESPONDENCE

UNION CARBIDE NUCLEAR COMPANY

A Division of Union Carbide and Carbon Corporation

To: Mr. M. E. Ramsey
Building 4500
ORNL

Plant: Y-12

Date: December 23, 1957

Subject: Y-12 Environmental Monitoring Procedures

Copies To: Mr. C. E. Center
Mr. L. B. Emlet
Mr. A. P. Huber
Mr. G. A. Strasser
Mr. W. C. Moore
Mr. W. K. Whitson, Jr.
Mr. J. D. McLendon
Mr. W. A. Pfeiler
Mr. J. F. Morehead

As requested by Mr. Emlet, we are forwarding the following data for inclusion in the four-plant reply to Mr. Sapirie's letter of November 12, 1957, "Environmental Monitoring Procedures".

Effluent Water Sampling

East Fork of Poplar Creek - There is a water sampling station due south of Building 9720-8. An automatic sampling device takes water samples from the creek at approximately 15-minute intervals. This sampler is so designed that it takes a sample proportional in volume to the amount of water flowing in the creek. A portion of this sample is analyzed daily for pH and the alkali metals Na, K, and Li. Another portion is composited into a weekly sample which is analyzed for alpha, beta, and mercury.

Bear Creek - Once a week a spot sample is dipped from Bear Creek, at a spot one mile west of the Y-12 burial pit, at a location where the Bear Creek road crosses the creek. This sample is analyzed for alpha and beta.

Air Sampling

Outside Air Sampling - There are three air samplers which are considered to be representative of the general outside air levels at their respective locations as listed below:

1. Approximately 15 feet east of Building 9723-12.
2. Approximately 10 feet south of Building 9983.
3. In the intake air on the west side of Building 9995.

These samplers are operated on a 24-hour per day, seven days a week basis. The samples from Building 9723-12 and Building 9983 locations are analyzed for alpha and beta. Those taken at Building 9995 are analyzed for alpha only.

Beryllium samples are taken each work day in the filter house and exhaust of Building 9766 (Y-12 Beryllium Shop) for spectrographic analysis. Air samples are taken in the vicinity of the building if the results of the air exhaust approaches the established limits for an eight-hour day.

Two of Health Physics outside uranium air samplers, located east of Building 9723-12 and west of Building 9711-1, have recently been utilized for all cations not radioactive. These samples are collected daily, composited weekly, and analyzed spectrographically.

All process building exhausts are sampled during the initial start-up of operations containing potential hazardous materials and continued until the contaminant is below the established limit. Surveys are made at random, depending on conditions, to determine whether air-borne contaminants are remaining below the established threshold limits.

Building Effluent Monitoring - A routine air monitoring program is maintained in the following locations in the Area 5 exhaust systems:

1. Exhaust from Sunflower, east of Building 9980.
2. Exhaust from Daffodil Machining and Foundry area, northeast corner of Building 9212.
3. Exhaust from Daffodil Salvage areas, east end of roof of C-Wing of Building 9212.
4. Exhaust from Daffodil Salvage, Special Processing, and Dry Chemistry areas, east end of roof of D-Wing of Building 9212.
5. Exhaust from Daffodil Salvage area, west end of 9212.
6. Exhaust from Daffodil Salvage area, center of roof of C-Wing of Building 9212.

7 & 8. Two exhausts from Daffodil Special Processing area, northwest corner of Building 9212 roof.

Samplers 1 through 4 are run continuously from ~8:00 p.m. Monday to ~3:30 p.m. Friday of each week. Samplers 5 through 8 are run once per month for a period of from 3 to 7 hours. Both types of samples are analyzed for uranium by alpha counting.

These samples are taken for the dual purpose of estimating inventory loss and air contamination potential.

Planned Building Effluent Monitoring - The following additional sampler locations for building effluent monitoring are planned.

Eight samplers in the exhaust from [redacted] located as follows:

1. West canopy of Building 9206.
2. North low roof of Building 9206.
3. Building 9768.
4. South canopy of Building 9206.
5-8. South low roof of Building 9206.

Three samplers in the exhaust from Building 9215 Daffodil areas located at the west end of the building.

Types of Analyses Normally Made on Effluent Water Samples

Alpha Activity - A portion of the liquid sample is evaporated on a steel planchet and counted with a proportional alpha counter.

Beta Activity - The same planchet from the above measurement is counted with a beta Geiger-Muller counter.

Lithium-Potassium-Sodium - The liquid sample is filtered and the individual elements are determined directly with a Perkin-Elmer flame photometer.

pH - The measurement is made directly on the sample with an electrometric pH meter.

Mercury - Mercury in the water sample is separated as the insoluble sulfide, on a cadmium sulfide impregnated asbestos filter pad. The pad is inserted into a tube furnace where the mercury is volatilized and the quantity of vapor is measured with the mercurometer.

Types of Analyses Normally Made on Air Samples

Beryllium - The samples are collected on a pre-tested ashless filter paper. The paper containing the sample is treated with a calcium solution, ashed, and analyzed spectrographically. A Jarrell-Ash, 21-foot, grating spectrograph is used for the analysis.

Alpha Activity - The air samples are collected on Hollingsworth and Voss Type 70 filter paper. The sample paper is mounted on a cardboard disc which has been designed for use in an automatic alpha counter. A Berkely Model 620-1 scintillation counter is employed to measure the alpha activity from the sample.

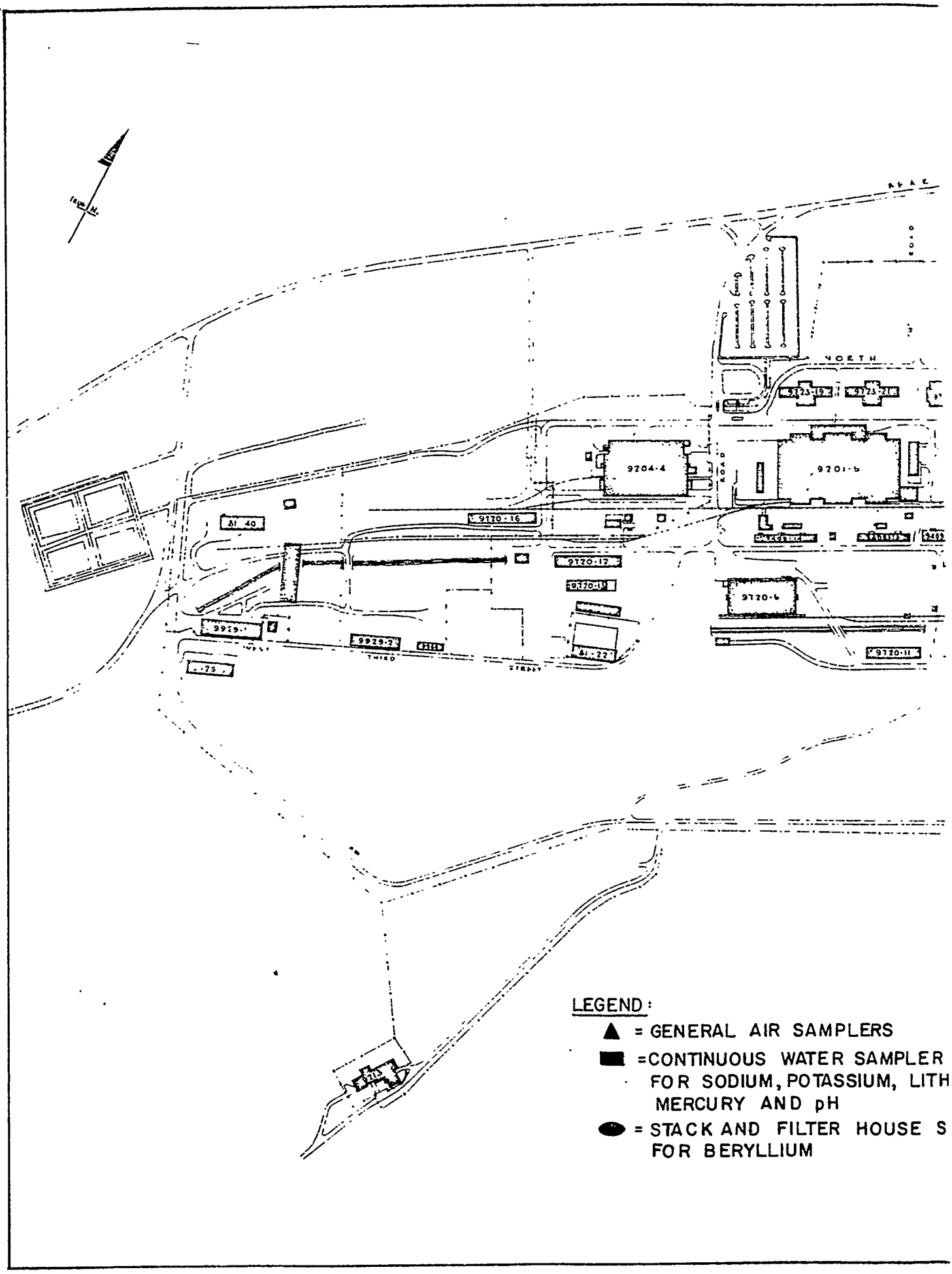
Beta Activity - The same filter paper sample from the above measurement is counted with a beta Geiger-Muller counter.

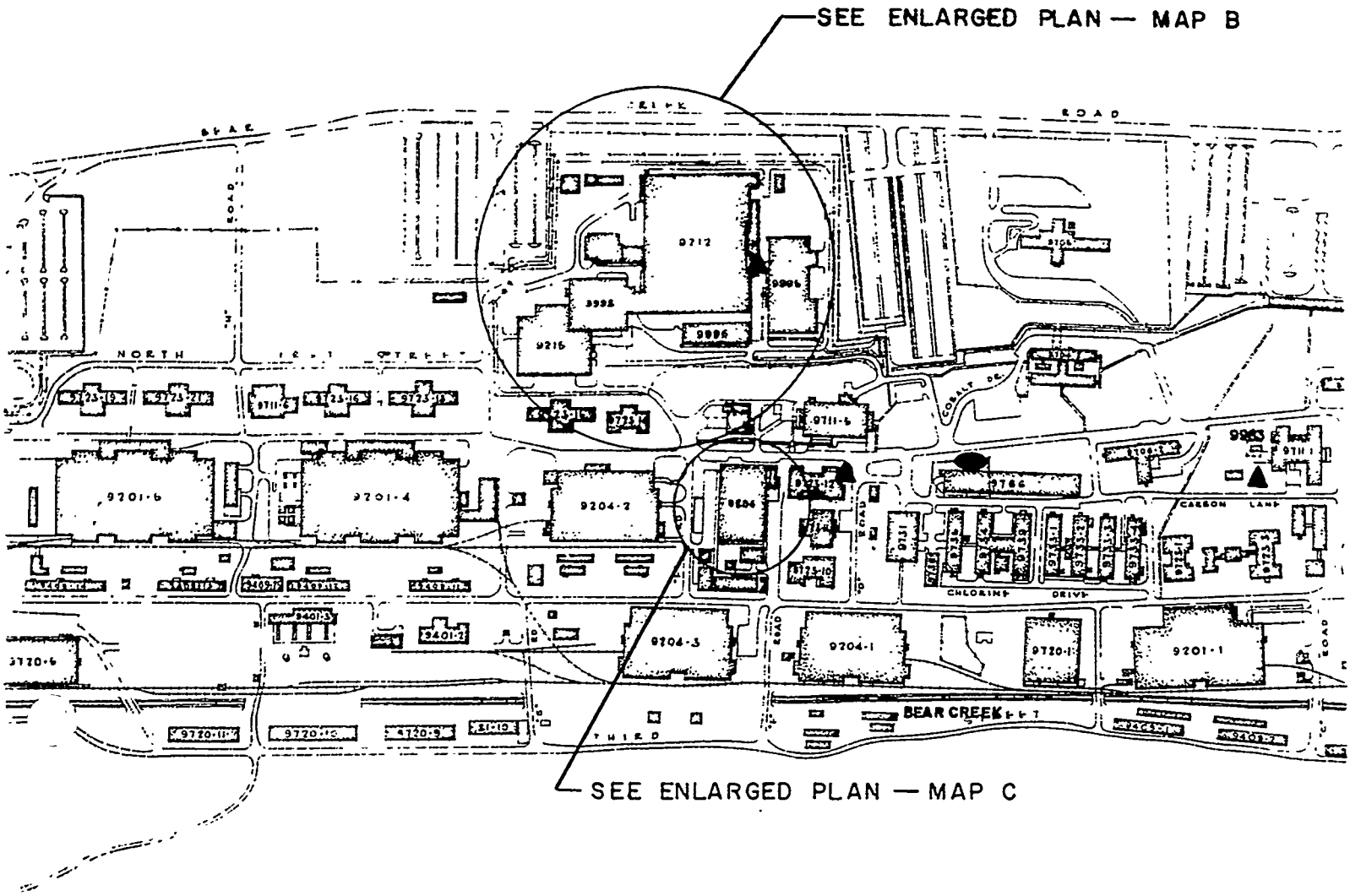
Non-Radioactive Cations - The filter paper upon which the air sample has been collected is acid treated and ashed. The residue is analyzed spectrographically for approximately 35 individual elements. A Jarrell-Ash 21-foot grating spectrograph is used for this analysis.

Maps are included giving locations of all monitoring stations.

J. P. Murray

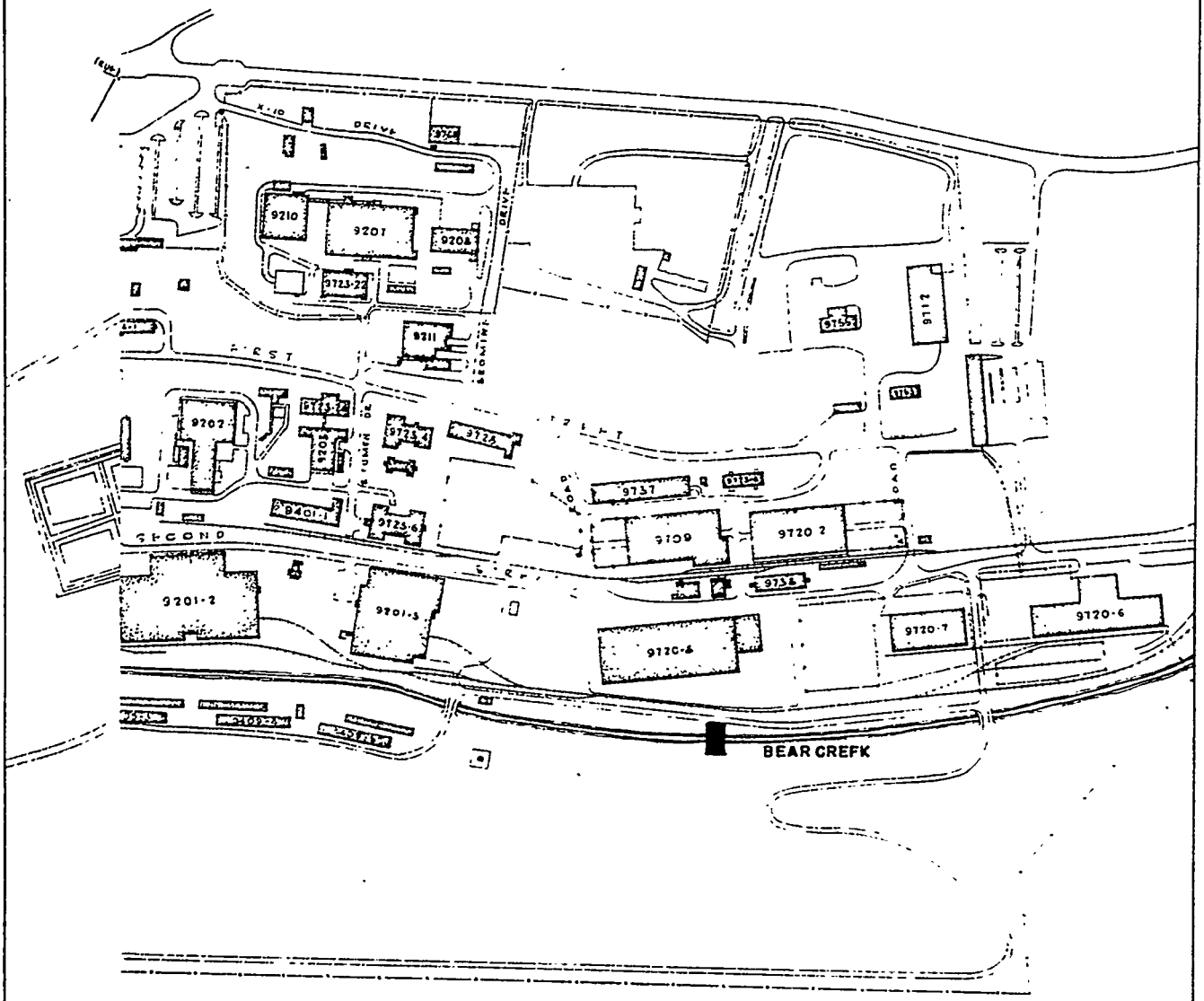
J. P. Murray


NORTH
9204-4
9201-5
9720-16
9720-12
9720-13
9720-6
9720-11
9929-2
81-40
81-22
LEGEND:
= GENERAL AIR SAMPLERS
=CONTINUOUS WATER SAMPLER
FOR SODIUM, POTASSIUM, LITH
MERCURY AND pH
= STACK AND FILTER HOUSE S
FOR BERYLLIUM



UNION CARBIDE NUCLEAR COMPANY
Y-12 PLANT

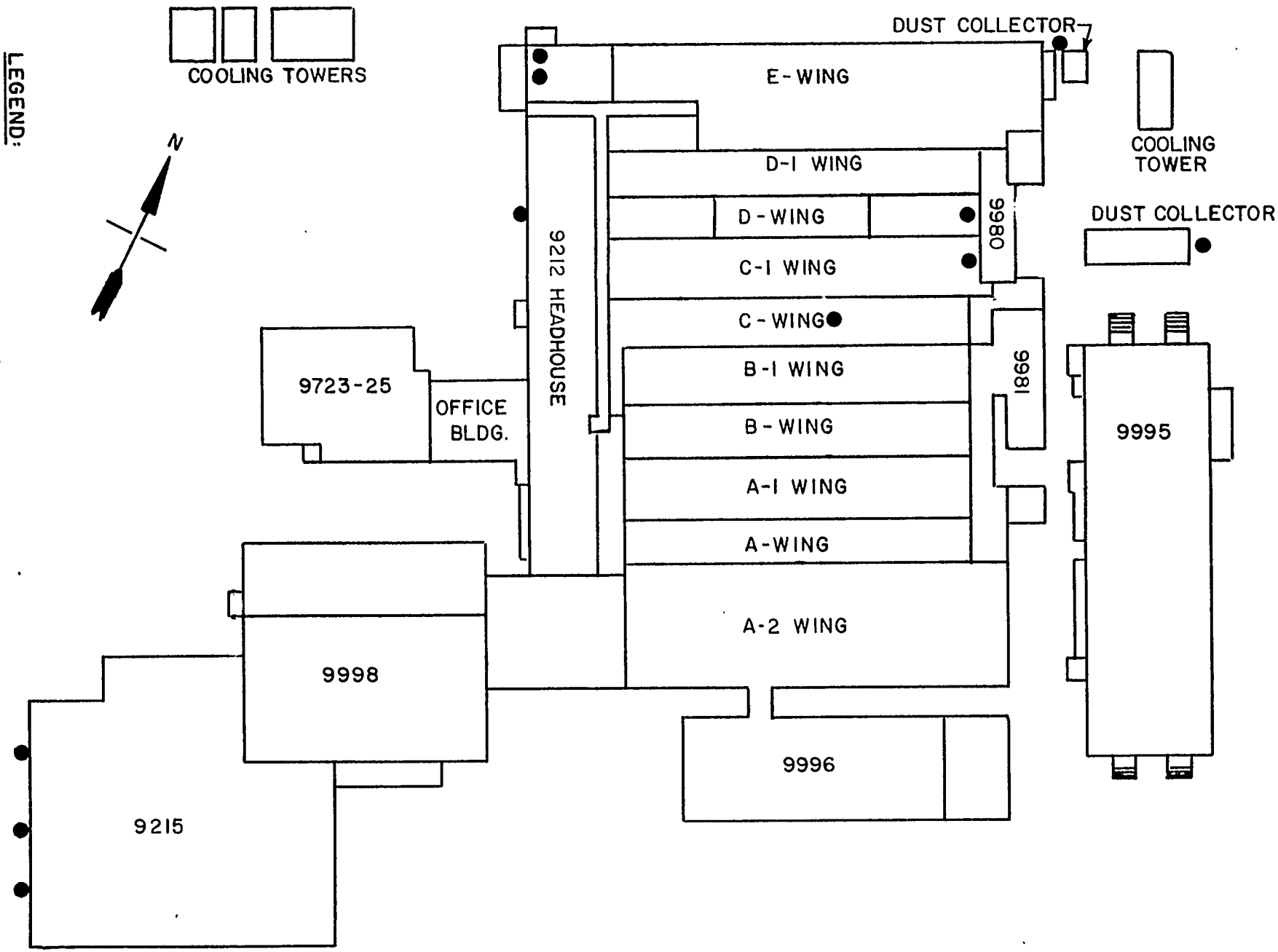
AIR SAMPLERS
JS WATER SAMPLER
UM, POTASSIUM, LITHIUM,
AND pH
D FILTER HOUSE SAMPLERS
YLLIUM



MAP A

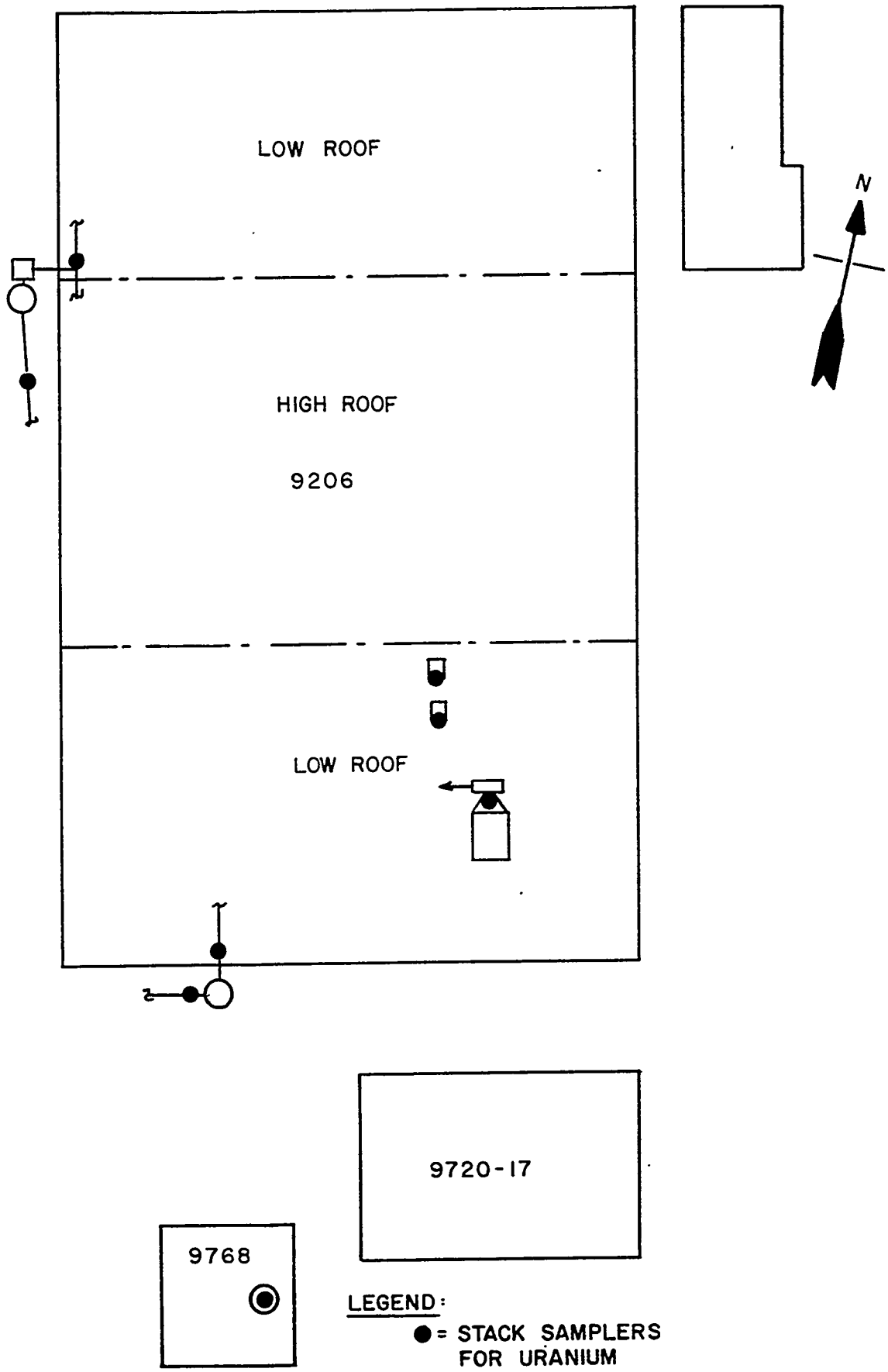
AIR AND WATER MONITORING STATIONS

REVISED TO 11-1-57
r e. kennedy 3-1-57



LEGEND:
● = STACK SAMPLERS FOR URANIUM

AREA-5 — MAP B



9206 AREA — MAP C

H. T.
Rad. Exp. —
Air Monitoring,
etc

INTER-COMPANY CORRESPONDENCE

UNION CARBIDE NUCLEAR COMPANY

A Division of Union Carbide and Carbon Corporation

To: Mr. M. E. Ramsey
Oak Ridge National Laboratory

Plant: Oak Ridge Gaseous Diffusion

Date: December 9, 1957

Copies To: Mr. K. W. Bahler
Mr. L. B. Emlet
Mr. R. G. Jordan
Mr. J. P. Murray

Subject: Environmental Monitoring Procedures

Copy Fwd. by MER, 12-16-57
WKWhitson

As requested by Mr. Emlet, we are forwarding the following data for inclusion in the four-plant reply to Mr. Sapirie's letter of November 12, "Environmental Monitoring Procedures":

1. Environmental Monitoring Procedures, ORGDP, giving air monitoring stations for radioactive materials and other air contaminants.

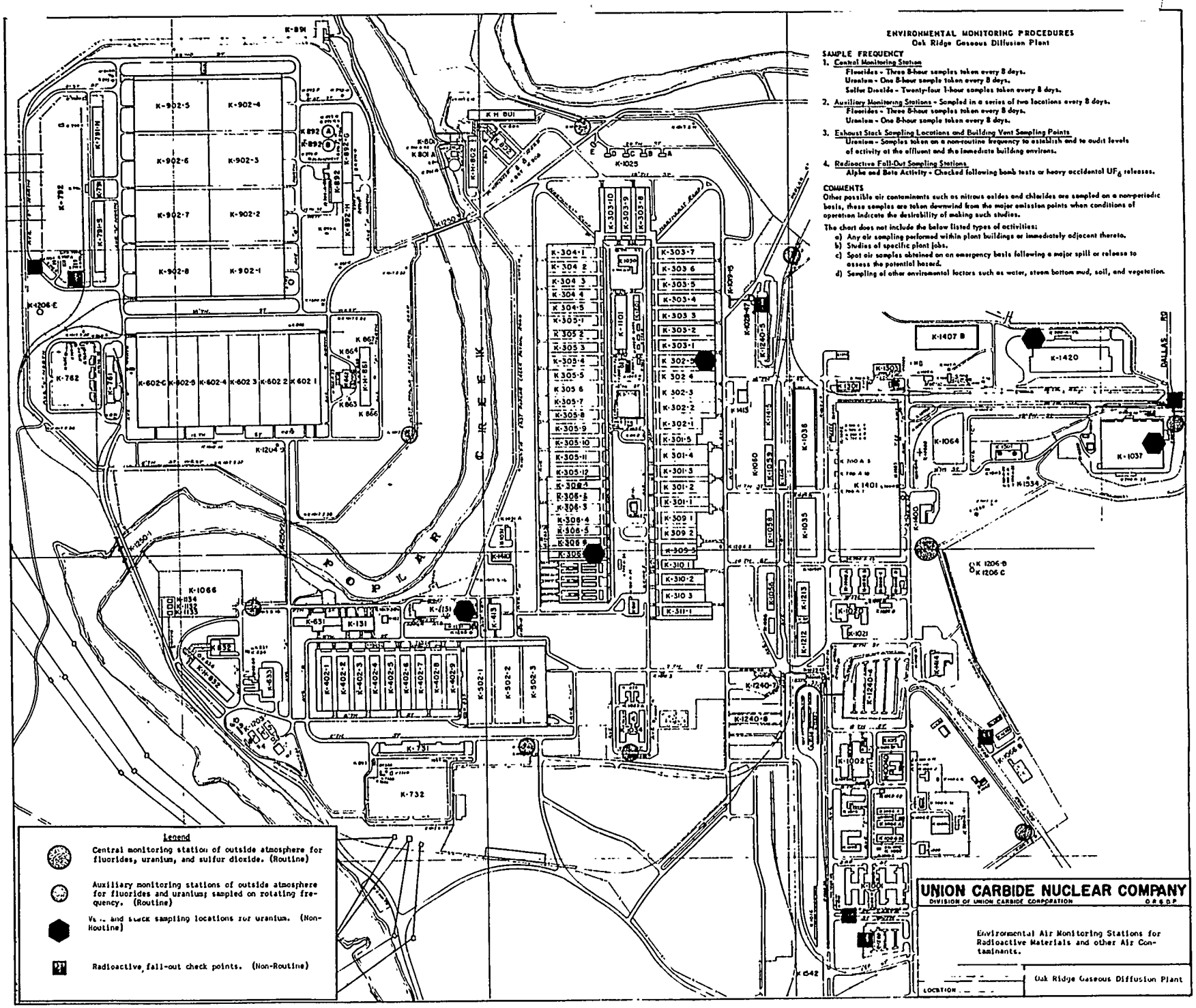
2. ORGDP Drainage Area Map Showing Continuous Water Sampler Locations, with Table I, Water Survey Sampling, and Table II, Water Survey Analyses.

A P Huber
A. P. Huber

AFB:mhb

Attachments
Described abv (In Trip.)

No RC



ENVIRONMENTAL MONITORING PROCEDURES
Oak Ridge Gaseous Diffusion Plant

SAMPLE FREQUENCY

1. Central Monitoring Station
   Fluorides - Three 8-hour samples taken every 8 days.
   Uranium - One 8-hour sample taken every 8 days.
   Sulfur Dioxide - Twenty-four 1-hour samples taken every 8 days.
2. Auxiliary Monitoring Stations - Sampled in a series of two locations every 8 days.
   Fluorides - Three 8-hour samples taken every 8 days.
   Uranium - One 8-hour sample taken every 8 days.
3. Exhaust Stack Sampling Locations and Building Vent Sampling Points
   Uranium - Samples taken on a non-routine frequency to establish and to audit levels of activity of the effluent and the immediate building environs.
4. Radioactive Fall-Out Sampling Stations
   Alpha and Beta Activity - Checked following bomb tests or heavy accidental UF_6 releases.

COMMENTS

Other possible air contaminants such as nitrous oxides and chlorides are sampled on a non-periodic basis, these samples are taken downwind from the major emission points when conditions of operation indicate the desirability of making such studies.

The chart does not include the below listed types of activities:

a) Any air sampling performed within plant buildings or immediately adjacent thereto.
b) Studies of specific plant jobs.
c) Spot air samples obtained on an emergency basis following a major spill or release to assess the potential hazard.
d) Sampling of other environmental factors such as water, stream bottom mud, soil, and vegetation.

Legend

- Central monitoring station of outside atmosphere for fluorides, uranium, and sulfur dioxide. (Routine)
- Auxiliary monitoring stations of outside atmosphere for fluorides and uranium; sampled on rotating frequency. (Routine)
- Vent and stack sampling locations for uranium. (Non-Routine)
- Radioactive fall-out check points. (Non-Routine)

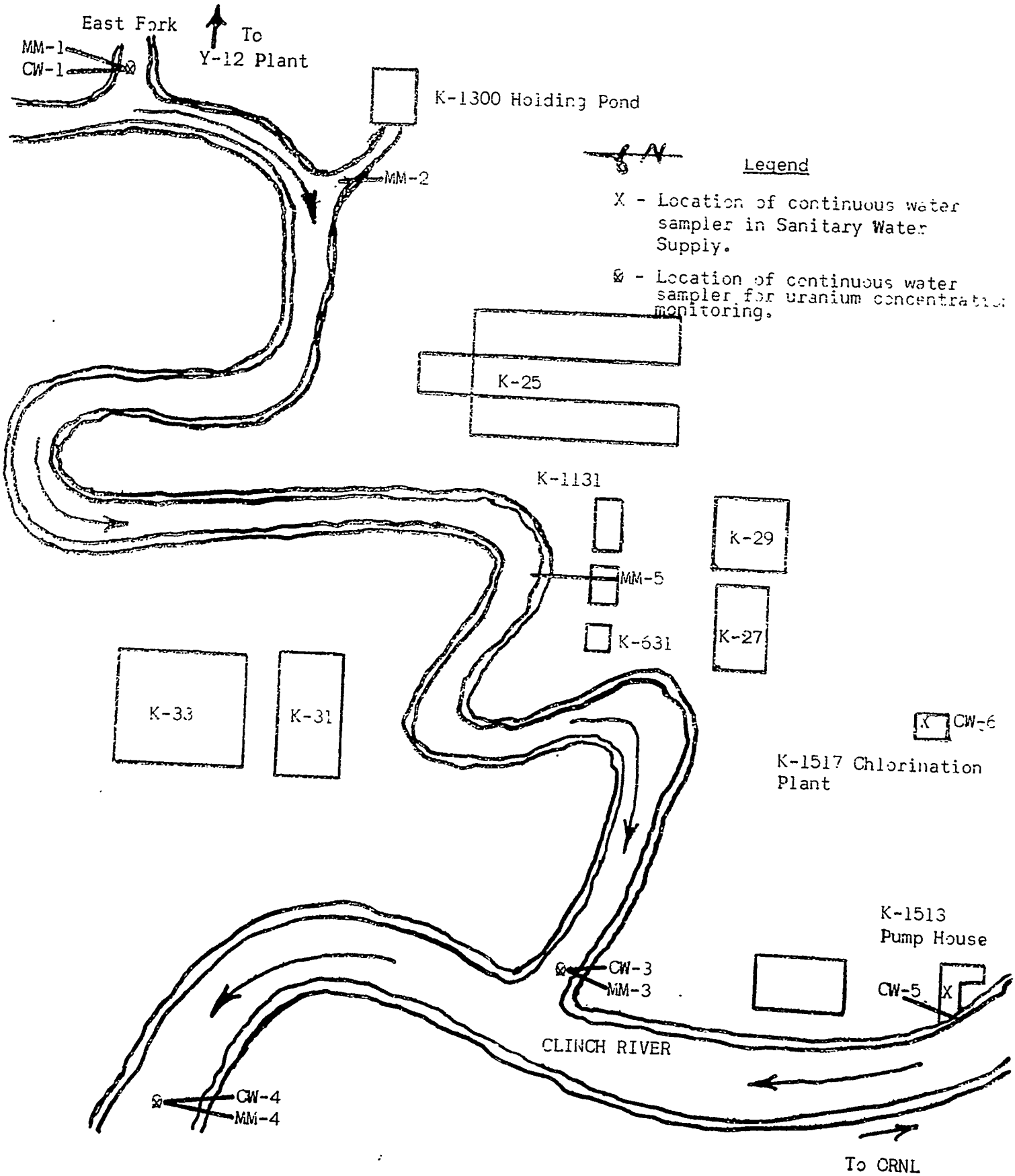
UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORPORATION
O R G D P

Environmental Air Monitoring Stations for Radioactive Materials and other Air Contaminants.

LOCATION: Oak Ridge Gaseous Diffusion Plant

FIGURE I

ORGDP DRAINAGE AREA MAP SHOWING CONTINUOUS WATER SAMPLER LOCATIONS



November 26, 1957

TABLE I

WATER SURVEY SAMPLING

Plot No.	Frequency of Sampling	Sampling Location
CW-1	Biweekly	East fork junction with Poplar Creek
CW-2	Monthly	Poplar Creek opposite K-27 drain
CW-3	Biweekly	Poplar Creek at junction with Clinch River
CW-4	Biweekly	Clinch River one mile below junction with Poplar Creek
CW-5	Biweekly	Sanitary water pumphouse influent
CW-6	Biweekly	Effluent from ORGDP Water Purification Plant
CW-7	Biweekly	Clinch River intake of make-up cooling water at K-901
DW-1	Weekly - Include cafeteria cooking water at least once monthly	Plant drinking water
DW-3	Monthly composite of weekly samples	Drainage from Labs. A, B, C, and D
MM-1	Monthly	Bottom mud, east fork at junction with Poplar Creek
MM-2	Monthly	Bottom mud of K-1300 drain at junction with Poplar Creek
MM-3	Monthly	Bottom mud of Poplar Creek at junction with Clinch River
MM-4	Monthly	Bottom mud of Clinch River one mile below junction with Poplar Creek

Plot No.	Frequency of Sampling	Sampling Location
MM-5	Monthly	Bottom mud of Poplar Creek opposite the K-27 drain
MM-7	Sample each batch as dumped	Sludge, Sewage Disposal Plant

GSH:msp
November 26, 1957
UCNC - ORGDP

TAB. II

WATER SURVEY ANALYSES

Plot No.	Type of Sample	Type Analyses
CW-1	3-4 day composite	Beta activity, uranium, fluorides, and pH
CW-2	Spot sample	Beta activity, uranium, and pH
CW-3	3-4 day composite	Beta activity, uranium, fluorides, and pH
CW-4	3-4 day composite	Beta activity, uranium, fluorides, and pH
CW-5	3-4 day composite	Beta activity, uranium, and pH
CW-6	3-4 day composite	Beta activity and fluorides
CW-7	3-4 day composite	Beta activity and uranium
DW-1	Spot sample	Beta and alpha activity, and uranium
DW-3	Spot sample	Beta and alpha activity
MM-1	Spot sample	Beta and alpha activity, and uranium
MM-2	Spot sample	Beta and alpha activity, and uranium
MM-3	Spot sample	Beta and alpha activity, and uranium
MM-4	Spot sample	Beta and alpha activity, and uranium
MM-5	Spot sample	Beta and alpha activity, and uranium
MM-7	Spot sample	Beta and alpha activity, and uranium

GSH:msp
November 26, 1957
UCNC - ORGDP

H. P.
Rad. Exposure
Air Monitoring
etc

INTER-COMPANY CORRESPONDENCE

UNION CARBIDE NUCLEAR COMPANY

A Divison of Union Carbide and Carbon Corporation

To: Mr. M. E. Ramsey

Plant: Paducah, Kentucky

Date: November 22, 1957

Copies To: Mr. L. B. Emlet
Mr. E. C. Cain
File

Subject: Environmental Monitoring Procedures.

Copy Fwd. by MER, 12-16-57
WKWhitson

Information on our outdoor environmental monitoring program is attached. Drainage and water monitoring information has been omitted as suggested in the letter requesting this material.

R. G. Jordan

RCB/bjp
KYnoRC

Enclosures (2)

WCP-163 (8/55)

This form for Inter-Company Correspondence only

ENVIRONMENTAL MONITORING PROCEDURES

Building Exhausts and Vents

Sources of possible air pollution at the Paducah Plant are enumerated below. The only radioactive material vented in measurable quantities is normal uranium amounting to approximately 6 to 8 millicuries per day. The most significant materials of pollution are the gaseous fluorides, HF and F_2.

POSSIBLE SOURCES OF AIR POLLUTION

Source	Contaminant
C-400	
Day filter exhaust (from micropulverizer and screener)	U
Small parts decontamination hood	U, NH_3
Ash receiver evacuation exhaust	U, HF
Spray booth exhaust	U, HNO_3, NH_3
Dissolver tank exhaust (3)	U, HNO_3
Drum dryer exhaust	HNO_3
Calciner Exhaust	U, HNO_3
Converter conditioning exhaust	F_2, HF
Cleaning tanks exhaust stack	Trichlor, NH_3 troxide, alkali
C-410	
Main stack	U, F_2, HF
Day filter exhaust (local exhaust system)	U
Vacuum Collector exhausts	U, HF, F_2
Refrigerant Pressure Relief System	NH_3
Fluorine Plant Vents	F_2, HF, H_2
C-420	
HF System Vent	HF
H_2 Burner vents	U, H_2S
Dust collector exhausts	U, H_2S, HF
C-310	
Purge Gas Vent	HF, F_2, U
C-340	
Neutralizer Vent	HNO_3
Vacuum Collector exhausts	U, HF
C-600 (Steam Plant)	
urnace stack	SO_2, smoke

Exhaust system vents have been checked for emissions by observation, instruments, and chemical analyses to determine normal and maximal pollution potential. Non-routine samples for HF, F_2, uranium, SO_2 and alpha activity have been taken downwind of the probable sources of emission. A routine sampling program was begun this month to sample the air at points on the attached map. Gaseous fluorides are being given the greatest emphasis, but a few analyses of uranium and SO_2 are being scheduled. Three samplers are being operated every eighth day at 3 of the positions marked to collect 3 consecutive 8-hour samples.

RCB

November 22, 1957

Air Monitor. etc

UNION CARBIDE NUCLEAR COMPANY
A DIVISION OF UNION CARBIDE AND CARBON CORPORATION
UCC
POST OFFICE BOX P
OAK RIDGE, TENNESSEE

November 25, 1957

Copy Fwd. by MER, 12-16-57
WKWhitson

U. S. Atomic Energy Commission
Post Office Box E
Oak Ridge, Tennessee

Attention: Mr. S. R. Sapirie

Gentlemen:

Subject: ENVIRONMENTAL MONITORING PROCEDURES

Reference is made to your letter of November 12, 1957 concerning environmental monitoring procedures.

The attached maps show the locations of the stations on the local area (Map 2) and our perimeter stations (Map 1).

Air samples are collected at all stations, both local and perimeter, by passing air continuously through a filter paper. The filter papers are changed normally once each week. Filter papers are autoradiographed to determine the number and activity range of the radioactive particles collected. They are counted for gross beta activity to determine the average concentration of radioactivity in the air sampled. Local air monitoring chart recordings are read daily to determine the hourly increase or decrease in activity collected on the filter paper. The counting rates of the ten local air monitors are telemetered via telephone line to Area Monitoring headquarters, Building 2012.

Gummed paper trays are located at each station to measure the fallout occurring in that area. Gummed paper trays are changed normally once each week. Gummed papers are autoradiographed to determine the number and activity range of the radioactive particles collected. After autoradiographing, each gummed paper is ashed in muffle furnace and the ash counted for gross beta activity collected as fallout.

Rainwater is collected at the seven perimeter stations and at one of the Laboratory area stations to measure the rainout occurring in these areas. Samples of the rainwater are filtered to separate the soluble and insoluble fractions and each fraction is analyzed for gross beta activity.

Collection of samples from air monitoring stations may be more frequent than once per week where air contamination levels are significantly high to warrant more frequent changes. Samples containing significant quantities of activity are given a more detailed analysis than described above by gamma spectrometry, radiochemical, decay and absorption techniques.

Liquid wastes leaving the Laboratory are sampled at three locations: (1) at the settling basin where the effluent enters White Oak Creek; (2) at White Oak Dam; and (3) at Centers Ferry on the Clinch River at Kingston, Tennessee.

Samples from the Settling Basin and White Oak Dam are analyzed daily for gross beta activity and gamma submersion exposure. Aliquots of each of these daily samples are composited into weekly samples which are analyzed radiochemically for plutonium content. Further aliquotes of each of these daily samples are composited into monthly samples which are concentrated and analyzed radiochemically for the presence of long lived fission products. The daily analyses are used to calculate the probable concentration of radioactivity in the Clinch River. The weekly composite analysis is used to determine the concentration and total quantity of plutonium released. The monthly composite analysis is used to calculate a weighted MPCw value for the radioactivity released to the Clinch River.

A sample is collected daily at Centers Ferry and composited for a three month period. The composite is filtered and the filtrate concentrated. The residue, or suspended solids, and the concentrate are analyzed for fission products to determine the level and composition of the activity existing in the Clinch River.

Yours very truly,

UNION CARBIDE NUCLEAR COMPANY

Clark E. Center

Clark E. Center
Vice President

CEC:DMD:mfm

cc: Alvin M. Weinberg
J. A. Swartout
L. B. Emlet
K. Z. Morgan
A. H. Snell
J. C. Hart
A. P. Huber, 1-21-58
R. B. Jordan "
J. P. Murray "

MER

L.B.Emlet (4)
J.A.Swartout (2) 11/15

UNITED STATES
ATOMIC ENERGY COMMISSION

Copies forwarded 11-15-57
K. Z. Morgan
A. H. Snell
J. C. Hart - Please prepare reply for CEC's signature.
JAS

IN REPLY REFER TO:
ORB:JAL

Oak Ridge, Tennessee
November 12, 1957

Copy Fwd. by MER, 12-16-57
WKShitson

COPY
FORWARDED BY
C. E. CENTER

Union Carbide Nuclear Company
Post Office Box P
Oak Ridge, Tennessee

Attention: Mr. C. E. Center, Vice President

Subject: ENVIRONMENTAL MONITORING PROCEDURES

Gentlemen:

We are interested in obtaining for our files information concerning the general environmental monitoring procedures followed by our major contractors.

The following information is requested concerning the monitoring programs in effect at UCNC installations:

a. Location of any building exhaust and environmental air monitoring stations, (a small marked map would be helpful).

b. Frequency of sampling at each station.

c. Types of analyses normally made on samples.

Your Paducah plant submitted sewer effluent and surface water monitoring procedures recently and only the additional information is requested from Paducah.

Your cooperation in this matter is appreciated.

Very truly yours,

for S. R. Sapirie
Manager
Oak Ridge Operations

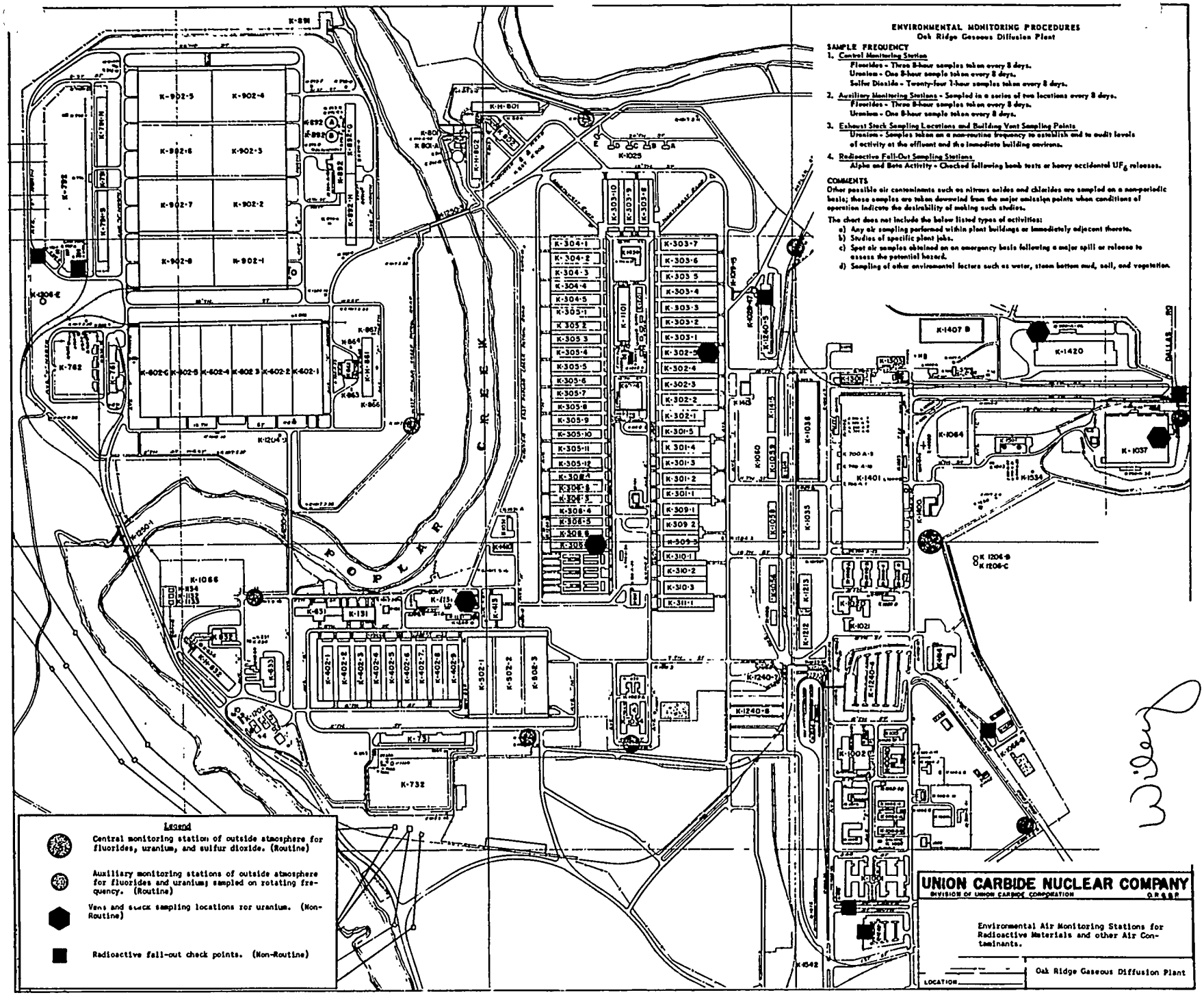
CC: R. C. Armstrong
H. M. Roth

Enclosure I

Oak Ridge Gaseous Diffusion Plant

Attachments: Environmental Monitoring Procedures, ORGDP, giving air monitoring stations for radioactive materials and other air contaminants.

ORGDP Drainage Area Map Showing Continuous Water Sampler Locations, with Table I, Water Survey Sampling, and Table II, Water Survey Analyses.



ENVIRONMENTAL MONITORING PROCEDURES

Oak Ridge Gaseous Diffusion Plant

SAMPLE FREQUENCY

1. Central Monitoring Station
   Fluorides - Three 8-hour samples taken every 8 days.
   Uranium - One 8-hour sample taken every 8 days.
   Sulfur Dioxide - Twenty-four 1-hour samples taken every 8 days.
2. Auxiliary Monitoring Stations - Sampled in a series of two locations every 8 days.
   Fluorides - Three 8-hour samples taken every 8 days.
   Uranium - One 8-hour sample taken every 8 days.
3. Exhaust Stack Sampling Locations and Building Vent Sampling Points
   Uranium - Samples taken on a non-routine frequency to establish and to audit levels of activity at the effluent and the immediate building environs.
4. Radioactive Fall-Out Sampling Stations
   Alpha and Beta Activity - Checked following bomb tests or heavy accidental UF_6 releases.

COMMENTS

Other possible air contaminants such as nitrous oxides and chlorides are sampled on a non-periodic basis; these samples are taken downwind from the major emission points when conditions of operation indicate the desirability of making such studies.

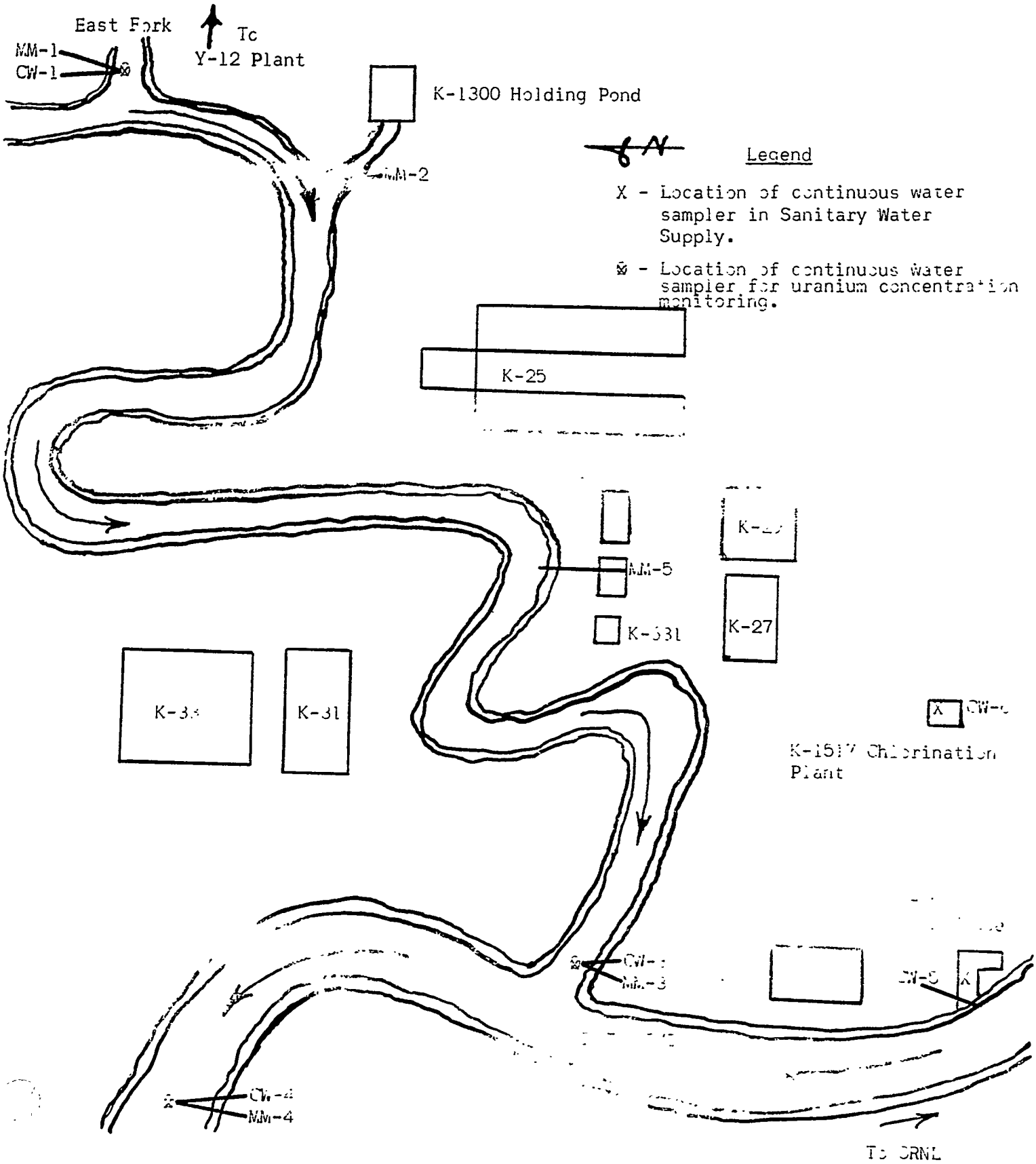
The chart does not include the below listed types of activities:

a) Any air sampling performed within plant buildings or immediately adjacent thereto.
b) Studies of specific plant jobs.
c) Spot air samples obtained on an emergency basis following a major spill or release to assess the potential hazard.
d) Sampling of other environmental factors such as water, stream bottom mud, soil, and vegetation.

3

FIGURE I

ORGDP DRAINAGE AREA MAP SHOWING CONTINUOUS WATER SAMPLER LOCATIONS



November

TABLE I

WATER SURVEY SAMPLING

Plot No.	Frequency of Sampling	Sampling Location
CW-1	Biweekly	East fork junction with Poplar Creek
CW-2	Monthly	Poplar Creek opposite K-27 drain
CW-3	Biweekly	Poplar Creek at junction with Clinch River
CW-4	Biweekly	Clinch River one mile below junction with Poplar Creek
CW-5	Biweekly	Sanitary water pumphouse influent
CW-6	Biweekly	Effluent from ORGDP Water Purification Plant
CW-7	Biweekly	Clinch River intake of make-up cooling water at K-901
DW-1	Weekly - Include cafeteria cooking water at least once monthly	Plant drinking water
DW-3	Monthly composite of weekly samples	Drainage from Labs. A, B, C, and D.
MM-1	Monthly	Bottom mud, east fork at junction with Poplar Creek
MM-2	Monthly	Bottom mud of K-1300 drain at junction with Poplar Creek
MM-3	Monthly	Bottom mud of Poplar Creek at junction with Clinch River
MM-4	Monthly	Bottom mud of Clinch River one mile below junction with Poplar Creek

Water Survey Sampling (Continued)
Page 2

Plot No.	Frequency of Sampling	Sampling Location
HM-5	Monthly	Bottom mud of Poplar Creek opposite the K-27 drain
HM-7	Sample each batch as dumped	Sludge, Sewage Disposal Plant

TABLE II

Water Survey Analyses

Plot No.	Type of Sample	Type Analyses
CW-1	3-4 day composite	Beta activity, uranium fluorides, and pH
CW-2	Spot sample	Beta activity, uranium, and pH
CW-3	3-4 day composite	Beta activity, uranium, fluorides, and pH
CW-4	3-4 day composite	Beta activity, uranium, fluorides, and pH
CW-5	3-4 day composite	Beta activity, uranium, and pH
CW-6	3-4 day composite	Beta activity and fluorides
CW-7	3-4 day composite	Beta activity and uranium
DW-1	Spot sample	Beta and alpha activity, and uranium
DW-3	Spot sample	Beta and alpha activity
MM-1	Spot Sample	Beta and alpha activity, and uranium
MM-2	Spot Sample	Beta and alpha activity, and uranium
MM-3	Spot Sample	Beta and alpha activity, and uranium
MM-4	Spot Sample	Beta and alpha activity, and uranium
MM-5	Spot Sample	Beta and alpha activity, and uranium
MM-7	Spot Sample	Beta and alpha activity, and uranium

Enclosure II

Y-12 Plant

The following information relating to environmental monitoring procedures as employed by the Y-12 Plant is discussed as outlined in the letter to UCNC dated November 12, 1957.

a. and b.

Effluent Water Sampling

East Fork of Poplar Creek - There is a water sampling station due south of Building 9720-8. An automatic sampling device takes water samples from the creek at approximately 15-minute intervals. This sampler is so designed that it takes a sample proportional in volume to the amount of water flowing in the creek. A portion of this sample is analyzed daily for pH and the alkali metals Na, K, and Li. Another portion is composited into a weekly sample which is analyzed for alpha, beta, and mercury.

Bear Creek - Once a week a spot sample is dipped from Bear Creek, at a spot one mile west of the Y-12 burial pit, at a location where the Bear Creek road crosses the creek. This sample is analyzed for alpha and beta.

Air Sampling

Outside Air Sampling - There are three air samplers which are considered to be representative of the general outside air levels at their respective locations as listed below:

1. Approximately 15 feet east of Building 9723-12.
2. Approximately 10 feet south of Building 9983.
3. In the intake air on the west side of Building 9995.

These samplers are operated on a 24-hour per day, seven days a week basis. The samples from Building 9723-12 and Building 9983 locations are analyzed for alpha and beta. Those taken at Building 9995 are analyzed for alpha only.

Beryllium samples are taken each work day in the filter house and exhaust of Building 9766 (Y-12 Beryllium Shop) for spectrographic analysis. Air samples are taken in the vicinity of the building if the results of the air exhaust approaches the established limits for an eight-hour day.

Two of Health Physics outside uranium air samplers, located east of Building 9723-12 and west of Building 9711-1, have recently been utilized for all cations not radioactive. These samples are collected daily, composited weekly, and analyzed spectrographically.

All process building exhausts are sampled during the initial start-up of operations containing potential hazardous materials and continued until the contaminant is below the established limit. Surveys are made at random, depending on conditions, to determine whether airborne contaminants are remaining below the established threshold limits.

Building Effluent Monitoring - A routine air monitoring program is maintained in the following locations in the area 5 exhaust systems:

1. Exhaust from Sunflower, east of Building 9980.
2. Exhaust from Daffodil Machining and Foundry area, northeast corner of Building 9212.
3. Exhaust from Daffodil Salvage areas, east end of roof of C-Wing of Building 9212.
4. Exhaust from Daffodil Salvage, Special Processing, and Dry Chemistry areas, east end of roof of D-wing of Building 9212.
5. Exhaust from Daffodil Salvage area, west end of 9212.
6. Exhaust from Daffodil Salvage area, center of roof of C-wing of Building 9212.
7. and 8. Two exhausts from Daffodil Special Processing area, northwest corner of Building 9212 roof.

Samplers 1 through 4 are run continuously from ~8:00 p.m. Monday to ~3:30 p.m. Friday of each week. Samplers 5 through 8 are run once per month for a period of from 5 to 7 hours. Both types of samples are analyzed for uranium by alpha counting.

These samples are taken for the dual purpose of estimating inventory loss and air contamination potential.

Planned Building Effluent Monitoring - The following additional sampler locations for building effluent monitoring are planned.

Eight samplers in the exhaust from [ ] located as follows:

1. West canopy of Building 9206.
2. North low roof of Building 9206.
3. Building 9768.
4. South canopy of Building 9206.
5-8. South low roof of Building 9206.

Three samplers in the exhaust from Building 9215 Daffodil areas located at the west end of the building.

c. Types of Analyses Normally Made on Effluent Water Samples

Alpha Activity - A portion of the liquid sample is evaporated on a steel planchet and counted with a proportional alpha counter.

Beta Activity - The same planchet from the above measurement is counted with a beta Geiger-Muller counter.

Lithium-Potassium-Sodium - The liquid sample is filtered and the individual elements are determined directly with a Perkin-Elmer Flame photometer.

pH - The measurement is made directly on the sample with an electrometric pH meter.

Mercury - Mercury in the water sample is separated as the insoluble sulfide, on a cadmium sulfide impregnated asbestos filter pad. The pad is inserted into a tube furnace where the mercury is volatilized and the quantity of vapor is measured with the mercurometer.

Types of Analyses Normally Made on Air Samples

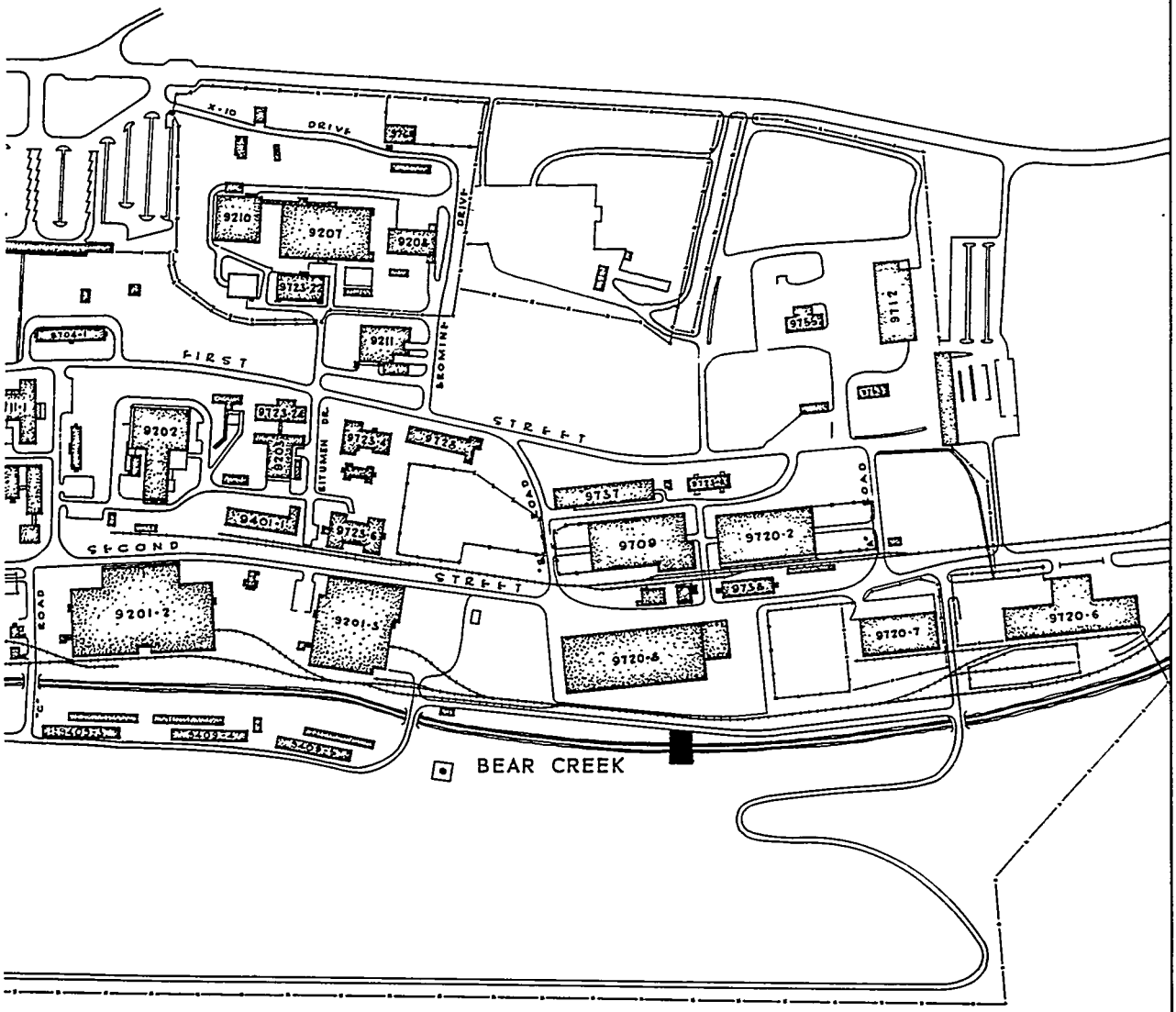
Beryllium - The samples are collected on a pre-tested ashless filter paper. The paper containing the sample is treated with a calcium solution, ashed, and analyzed spectrographically. A Jarrell-Ash, 21-foot, grating spectrograph is used for the analysis.

Alpha Activity - The air samples are collected on Hollingsworth and Vose Type 70 filter paper. The sample paper is mounted on a cardboard disc which has been designed for use in an automatic alpha counter. A Berkely Model 520-1 scintillation counter is employed to measure the alpha activity from the sample.

Beta Activity - The same filter paper sample from the above measurement is counted with a beta Geiger-Muller counter.

Non-Radioactive Cations - The filter paper upon which the air sample has been collected is acid treated and ashed. The residue is analyzed spectrographically for approximately 35 individual elements. A Jarrell-Ash 21-foot grating spectrograph is used for this analysis.

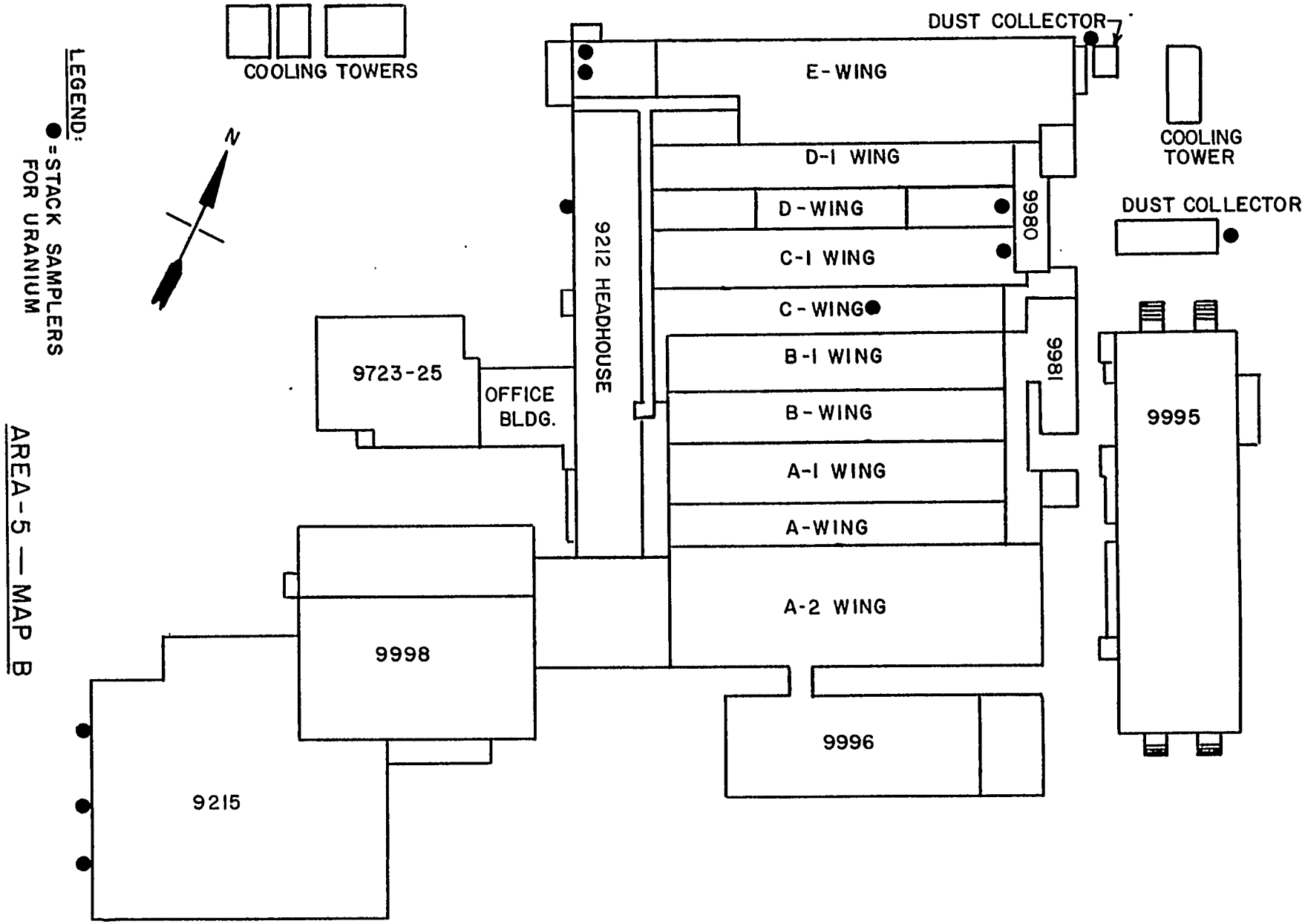
Attachments: Maps giving locations of Monitoring Stations



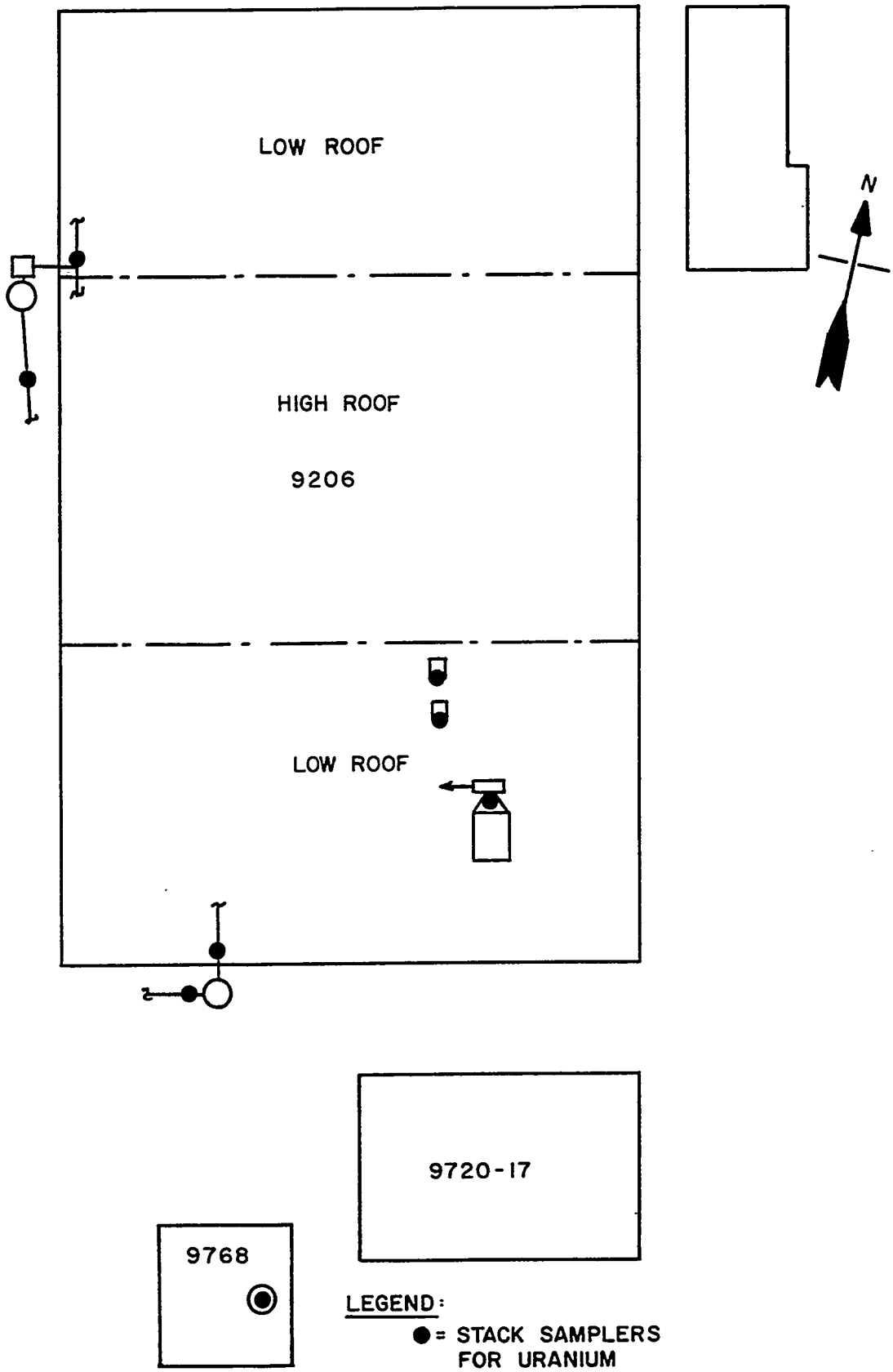
MAP A

AIR AND WATER MONITORING STATIONS

REVISED TO 11-1-57
r. e. kennedy 5-1-57


LEGEND:
● = STACK SAMPLERS FOR URANIUM
N
COOLING TOWERS
DUST COLLECTOR
E-WING
COOLING TOWER
D-I WING
D-WING
9980
DUST COLLECTOR
C-I WING
C-WING
9212 HEADHOUSE
9723-25
OFFICE BLDG.
B-I WING
1866
9995
B-WING
A-I WING
A-WING
A-2 WING
9998
9996
9215

AREA-5 — MAP B



9206 AREA — MAP C

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ABSTRACT:

Compilation of memos describing the environmental monitoring program at K-25 and Y-12 during 1957 and 1958. Information provided includes maps showing water and air sampler locations, and tables describing the frequency of sampling, ~~and~~ type of sample and analyses and the location of sampling. ~~The~~ Detailed figures showing the locations of stack samplers for uranium at Y-12 are included, as are fairly detailed descriptions of the sampling and analytical methods.

REVIEWER: GM Bruce DATE REVIEWED: 4/1/96

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Y-1401 – Revised
Health & Safety

Y-12 RADIATION SAFETY MANUAL

Editors:

P. C. McRee
C. M. West
J. D. McLendon

Y-12 PLANT
Oak Ridge, Tennessee

UNION CARBIDE

UNION CARBIDE CORPORATION
NUCLEAR DIVISION

Operating the

OAK RIDGE GASEOUS DIFFUSION PLANT • OAK RIDGE NATIONAL LABORATORY
OAK RIDGE Y-12 PLANT • PADUCAH GASEOUS DIFFUSION PLANT

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UNION CARBIDE CORPORATION
Nuclear Division

Y-12 PLANT

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Y-12 RADIATION SAFETY MANUAL

P. C. McRee
C. M. West
J. D. McLendon

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INTRODUCTION

POLICY

It is the policy of the Y-12 Plant to protect personnel from exposure to ionizing radiation and/or radioactive materials, industrial toxicants, or other environmental factors which may cause sickness, impair health and well-being, or cause inefficiency among plant workers; to carry on effective monitoring programs; and to encourage the cooperation of all employees involved in effecting ample control programs.

PLANT ORGANIZATION AND RESPONSIBILITIES

Line organization is responsible for the protection of plant employees to the same extent that it is responsible for plant operations, production, or research. While the prime responsibility for implementing the policy rests with line supervision, staff and service groups have been established to provide technical assistance, to render any service that will help in the investigation and evaluation of radiation and industrial hygiene problems, to maintain exposure records, and to give proper training to employees.

The following specific responsibilities are assigned to fulfill the objectives of the policy:

Line Supervision

It is the responsibility of line supervision to:

1. Inform the Radiation Safety Department of potentially hazardous processes or materials being contemplated or used, and to initiate requests for protective devices or services.

2. Formulate, administer, and enforce safety rules and regulations necessary to the health physics and industrial hygiene programs in all areas within the scope of their authority.

3. Plan, incorporate, and utilize adequate health safeguards and practices in new equipment and/or procedures.

4. Inform all concerned employees of potential health hazards and the necessary safeguards which are established to guard against them.

5. Arrange for participation of employees in the established personnel monitoring programs.

6. Maintain material control by the proper routing, shipping, and disposal of contaminated materials in accordance with established procedures.

7. Determine whether Company clothing will be made available and whether it is mandatory that clothing be worn for contamination or exposure control.

8. Issue Safety Work Permits to Maintenance supervision.

Radiation Safety Department

It is the responsibility of the Health Physics and Industrial Hygiene Sections of the Radiation Safety Department to:

1. Provide line supervision with technical assistance in the establishment of suitable environmental controls, carry out an effective environmental monitoring program for substances of concern, and recommend appropriate equipment, systems, and analytical procedures.

2. Continually evaluate potential personnel exposures by means of external monitoring, body fluid or excreta analyses, in vivo counting, and X-ray and clinical examinations (Medical Department). Maintain suitable records and issue reports to apprise management of existing conditions and/or immediate action requirements.

3. Provide technical information, assistance, and guidance to insure conformance to AEC regulations and other federal and state laws pertaining to these functions; namely, employee exposure records, transportation of hazardous materials, waste disposal, release of effluents to the public domain, and exposure of the general population.

4. Audit operations for compliance with prescribed procedures such as: (1) advise appropriate supervision of violations and, if necessary, take immediate action through line supervision to have the operation shut down, and (2) seek improved methods of reliability as well as recommend equally safe methods of improved operating efficiency.

5. Represent Y-12 in all interplant health physics and industrial hygiene meetings with consultants and other AEC contractors. Recommend beneficial research projects, participate in the formulation of regulations and policy, and remain abreast of new developments for possible application to Y-12 operations.

6. Conduct plant-wide meetings, prepare and issue useful reference and training materials, assist in emergency preparedness planning, and offer consultation on immediate problems.

7. Maintain an organization of well-trained inspectors and engineers for routine, independent field monitoring and evaluation, maintain pertinent emergency equipment in operable condition, and provide immediate control and guidance in event of an emergency.

8. Review proposed alterations, modifications, or additions to plant facilities and equipment for compliance with pertinent plant health and safety standards.

9. Upon the request of the Medical Department, assist in investigating conditions in work areas that may be suspected of contributing to the health problems of employees.

10. Provide special services to other departments within the plant such as: (1) sample and analyze potable water and sewer effluents to evaluate the control of waste discharge and to determine the possibility of potable water contamination; (2) sample stack gases for operations supervision in order to determine what material is released to the atmosphere, and (3) recommend shielding requirements for the safe use of radioactive sources and X-ray units.

Laboratory Division

It is the responsibility of the Laboratory Division to provide and maintain special and routine health physics and industrial hygiene analytical services pertinent to an effective health monitoring program.

Safety Department

It is the responsibility of the Safety Department to assist in the evaluation of protective clothing and equipment and in the disposal of hazardous chemicals, gases, and radioactive wastes.

Engineering Division

It is the responsibility of the Engineering Division to incorporate radiation and industrial hygiene safety requirements in the design of new equipment and plant layouts and in plans for alterations or the rearrangement of existing facilities.

Plant Shift Superintendents

It is the responsibility of the Plant Shift Superintendents to be familiar with radiological and industrial health hazards associated with plant operations and the controls established for personnel and plant protection. Appropriate health and safety considerations shall be incorporated in emergency plans.

Medical Department

It is the responsibility of the Medical Department to conduct periodic physical examinations of employees to detect possible incipient injury which may result from exposure to radioactive or toxic materials and to make recommendations for work reassignment as may be necessary.

Additional Responsibilities

Additional details and responsibilities are incorporated in appropriate Standard Practice Procedures.

PLANT OPERATIONAL GUIDES

Protection guides used in administering the radiation safety and industrial hygiene programs are in keeping with those established by the Federal Radiation Council, the National Committee on Radiation Protection, the American Industrial Hygiene Association, and others. These guides are as prescribed by the Atomic Energy Commission in the AEC Manual, Chapter 0550, "Codes and Standards for Health, Safety, and Fire Protection"; the UCNC Standard Practice Procedures and Committee on Radiation Standards and Practices; the AEC Manual, Chapter OR OX12, "Recommendations for the Control of Beryllium Hazards"; and the Chapter titled, "Beryllium Compounds" of the AIHA's Hygienic Guide.

Radiation Protection Guides (RPG) for Exposure to External Radiation

The guides accepted for external exposure at Y-12 are those established by the Federal Radiation Council as listed in Table 1.

Table 1

RADIATION PROTECTION GUIDE FOR EXTERNAL EXPOSURE

Part of Body	Quarter (rems)	Year (rems)	Remarks
Penetrating (whole body, blood forming organs, gonads, lens of eye)	3	12	Cumulative yearly average(1) must not exceed 5 rems.
Skin (whole body)	10	30	
Extremities (hands, forearms, feet, and ankles)	25	75	

(1) The average during the total employment history of the employee.

In order to assure compliance with this guide, the control and action points listed in Table 2 are followed.

Table 2

CONTROL AND ACTION POINTS

Penetrating (mrems/qtr)	Skin (mrems/qtr)	Extremities (mrems/qtr)	Action Taken
1. 300	1,000	2,500	Examine film; investigate work area to determine if exposure is authentic.
2. 1250	7,500	18,750	Written notice to supervisor that employee exceeded RPG. Advise: (1) amount of indicated dose; (2) cumulative dose for year; (3) recommendation that exposure be limited.
3. 3000	10,000	25,000	Written notice as in Step 2 with recommendation that the person be removed from the areas of potential exposure until his cumulative for the year, or his average exposure for period of Y-12 employment, is below the rate specified in the previous table.

Radiation Protection Guides for Internal Exposure

The body burden values in Y-12 are those established by the National Committee on Radiation Protection(1) and/or the International Commission on Radiological Protection.(2) These values will limit exposure to the levels established by the Federal Radiation Council.(3) Table 3 shows the maximum permissible body burden for some of the more common isotopes monitored in Y-12.

Table 3

RADIATION PROTECTION GUIDES FOR INTERNAL EXPOSURE[a]
(Maximum Permissible Body Burdens)

	Critical Organ							
	Lung		Bone		Kidney		Whole Body	
	(μc)	(μg)	(μc)	(μg)	(μc)	(μg)	(μc)	(μg)
Uranium								
Normal(1)	0.009	2.69×10^4	0.03	8.99×10^4	0.005	1.50×10^3	0.2	5.99×10^5
Oralloy (20)	0.017	2.03×10^3	0.05	5.98×10^3	0.08	9.56×10^3	0.4	4.78×10^4
Oralloy (30)	0.017	1.04×10^3	0.05	3.05×10^3	0.08	4.88×10^3	0.4	2.44×10^4
Oralloy (50)	0.017	7.64×10^2	0.05	2.25×10^3	0.08	3.60×10^3	0.4	1.80×10^4
Oralloy (70)	0.017	5.32×10^2	0.05	1.56×10^3	0.08	2.50×10^3	0.4	1.25×10^4
Oralloy (90)	0.017	2.68×10^2	0.05	7.90×10^2	0.08	1.26×10^3	0.4	6.32×10^3
Neptunium-237	0.017	24.60	0.06	86.95	0.10	1.45×10^2	0.5	7.25×10^2
Plutonium-239	0.016	0.26	0.04	0.65	0.50	8.10	0.4	6.48
Thorium(1) (natural)	0.003	2.66×10^4	0.01	8.88×10^4	0.07	6.22×10^5	0.07	6.22×10^5
Tritium							2×10^3	0.2

(1) Special curies used as defined by NBS Handbook 69.

(a) International Commission on Radiological Protection, "Report of Committee II on Permissible Dose for Internal Radiation (1959)," Health Physics, 3, pp 1-380 (1960).

National Committee on Radiation Protection, "Maximum Permissible Body Burdens and Maximum Permissible Concentration in Air and Water for Occupational Exposure," NBS Handbook 69, US Department of Commerce, June 5, 1959.

Urinalyses samples are used as an indication of the dose to the critical organ. In order to control the body burden below the levels established, the following guide criteria (Table 4) as established by the UCC-ND Committee on Radiation Standards and Practices is used in Y-12.

Table 4

PLANT GUIDE FOR INTERNAL EXPOSURE CRITERIA THROUGH URINALYSIS

Element	Investigation of Situation		Immediate Removal of Employee	
	Single Sample	Quarterly Average	Single Sample	Quarterly Average
		d/m/24 Hour Specimen		
Uranium	140	70	2000	140
Plutonium	2	1	20	2
Neptunium	6	1.3	60	6
		μc/24 Hour Specimen		
Tritium	17	9	350	35

Since uranium is the chief internal hazard in Y-12 and since the in vivo facility is used to assist in the Y-12 uranium body burden evaluation, the exposure control and action points, summarized in the sections that follow, are used for uranium.

Action Before Removal - In cases showing elevated levels, additional samples or measurements are requested and/or supervision is notified when:

1. A participant scheduled quarterly has a urine result > 70 d/m/24-hour voiding.

2. A participant scheduled monthly has a urine result > 140 d/m/24-hour voiding.

3. A participant scheduled weekly has a urine result > 140 d/m/24-hour voiding.

4. Quarterly average urinalyses results are > 70 d/m/24-hour voiding.

5. An in vivo measurement is > 100% of the Plant Acceptable Lung Burden (PALB).

Removal Criteria - Personnel are restricted from working in uranium areas when:

1. Quarterly urine average is statistically > 70 d/m/24-hour voiding and in vivo measurements are > 50% of the PALB.

2. Quarterly urine average is > 70 d/m/24-hour voiding and the in vivo measurements are > 100% of the PALB.

3. Quarterly urine average is > 140 d/m/24-hour voiding or the in vivo average is > 150% of the PALB.

4. Single urine sample is > 2000 d/m/24-hour voiding or a single in vivo measurement is > 500% of the PALB.

Release of Restriction - Restrictions from working in uranium areas will be removed when the following conditions are met:

1. The average of all urine samples becomes < 70 d/m/24-hour voiding.

2. The average of urine samples submitted during the current quarter is < 35 d/m/24-hour voiding.

3. The average in vivo results obtained during the current quarter is < 50% of the PALB.

Concentration Guides for Material in Air

Concentration guides for the control of contamination in the air are those established by the UCC-ND Committee on Radiation Standards and Practices, those listed in Handbook 69,[1] and those published by the American Congress of Government Industrial Hygienists.[4] Table 5 lists the radioactivity concentration guides for selected radioisotopes. In the case of the radioisotopes handled more routinely in Y-12, a Plant Action Limit (PAL) below the Radioactivity Concentration Guide (RCG) has been established as an administrative technique to assist in controlling air contamination levels.

Table 5

RADIOACTIVITY CONCENTRATION GUIDE FOR SELECTED RADIOACTIVE CONTAMINANTS IN AIR

Element	Plant Action Limit ($d/m/M^3$)	Critical Organ	Radiation Concentration Guides ($\mu c/cc$)	($d/m/M^3$)	($\mu g/M^3$)(1)
Uranium					
Normal	70.0	Lung	9×10^{-11}	200.0	132.4
Oralloy (20)	70.0	Lung	9×10^{-11}	200.0	8.3
Oralloy (30)	70.0	Lung	9×10^{-11}	200.0	5.8
Oralloy (50)	70.0	Lung	9×10^{-11}	200.0	3.3
Oralloy (70)	70.0	Lung	9×10^{-11}	200.0	2.0
Oralloy (90)	70.0	Lung	9×10^{-11}	200.0	1.4
Neptunium-237	8.8	Bone	4×10^{-12}	10.0	5.8×10^{-3}
Plutonium-239	4.4	Bone	2×10^{-12}	4.4	3.3×10^{-5}
Thorium (natural)	4.4	Lung	4×10^{-12}	8.8	17.6
Radium-228	88.8	Lung	4×10^{-11}	88.8	1.7×10^{-7}
Tritium	20.0 $\mu c/M^3$	Total Body	2×10^{-5}	4.4×10^{7}	2.0×10^{-3}

(1) Weights for uranium will vary as the isostopic distribution. The values determined above are typical for a range of distributions. Specific activities are assumed as follows: Normal, 1.51; Oralloy (20), 24.2; Oralloy (30), 34.5; Oralloy (50), 60.8; Oralloy (70), 99.5; Oralloy (90), 143 $d/m/\mu g$.

Table 6 contains a selected list of Threshold Limit Values (TLV) for nonradioactive contaminants used in Y-12.

Table 6

THRESHOLD LIMIT VALUES FOR SELECTED NONRADIOACTIVE CONTAMINANTS IN AIR

Contaminant	Threshold Limit Value (ppm)	Threshold Limit Value ($\mu g/M^3$)	Form
Ammonia	50.0		Gases and Vapors
Bromine	0.1		Gases and Vapors
Beryllium		2.0	Dusts
Cadmium Oxide		100.0	Fumes
Carbon Monoxide	100.0		Gases
Carbon Tetrachloride	10.0		Vapor
Chlorine	1.0		Gases
Diborane	0.1		Gases and Vapors
Fluorides		2.5	Fumes
Hydrogen Cyanide	10.0		Gases and Vapors
Hydrogen Fluoride	3.0		Gases and Vapors
Lead		0.2	Dust and Fumes
Mercury		0.1	Vapors
Methyl Chloroform	350.0		Vapors
Nitric Acid	2.0		Vapors
Ozone	0.1		Gases
Perchloroethylene	100.0		Vapors
Phosgene	1.0		Gases and Vapors
Selenium		0.1	Fumes
Thallium		0.1	Dusts
Toluene	200.0		Fumes
Trichloroethylene	100.0		Vapors

Concentration Guides for Toxic Materials in Water

Concentration guides used for the degree of radioactive contamination in water being discharged from the Y-12 Plant are those established in Handbook 69[1] for locations in the neighborhood of a controlled area. Table 7 lists the concentration guides.

Table 7

RADIOACTIVITY CONCENTRATION GUIDE FOR CONTAMINATION LEVELS IN WATER DISCHARGED FROM THE PLANT

Element	Acceptable Limit ($\mu c/cc$)
Uranium	3×10^{-5}
Thorium (natural)	2×10^{-6}
Thorium-234	2×10^{-5}
Plutonium	5×10^{-6}
Tritium	3×10^{-3}
Neptunium	5×10^{-6}

The values used for chemicals in the discharge water are those recommended by consultants for the US Public Health Service and Industrial Hygiene Association and are presented in Table 8.

Table 8

CHEMICAL CONCENTRATION GUIDE FOR CONTAMINANTS IN WATER DISCHARGED FROM THE PLANT

Contaminant	Acceptable Limit (ppm)
Nitrate	45
Sulfate	200
Chloride	100
Hypochlorite	1
Copper	1
Cyanide	0
Chromium	0.05
pH	6.8 to 8.6

Control Criteria for Surface Contamination

Control criteria for removable surface contamination in various Y-12 areas is presented in Table 9.

In order to limit the spread of contamination to nonprocess areas and to minimize the contamination or radiation hazards that might be associated with such transfers, materials and equipment being transferred from control areas are surveyed and tagged according to the limits listed in Table 10 in the manner prescribed in an appropriate Y-12 Standard Practice Procedure.

Table 9

CONTROL CRITERIA FOR REMOVABLE SURFACE CONTAMINATION

Element and Area	Alpha Smear Control Criteria
d/m/100 cm^2	
Uranium	
Control Areas	500
Nonprocess Areas	20
Neptunium, Plutonium, or Thorium	
Control Areas	50
Nonprocess Areas	20
μg/12 in^2	
Beryllium	
Control Areas	25
Nonprocess Areas	4

Control Criteria for Shipments Leaving Y-12

In order to minimize the degree of exposure to offsite personnel and to assure compliance with the provisions of state and federal regulations applying to the shipment of radioactive materials,(5) the limits listed in Table 11 are applied according to the appropriate standard practice procedure.

Table 10

RADIOACTIVITY LIMITS FOR TRANSFERS

Contaminant	Smear (d/m/100 cm^2)	Direct (d/m)	Tag Used	Comments
		Uncontaminated Materials		
Uranium Thorium or Plutonium	< 500 < 50	< 2000 < 500	Material Green Transfer Approval (Form UCN-14)	Classified as uncontaminated.
		Alpha Contaminated Materials		
Uranium Thorium or Plutonium	> 500 > 50	> 2000 > 500	Contamination Tag (Form UCN-15)	Handle according to precautions listed on tag.
		Beta, Gamma, or Neutron Contaminated Materials		
Beta, Gamma, or Neutron Radiation		> 7.5 (mr/hr)	Radiation Hazard Tag (Form UCN-11)	Observe precautions listed on tag.

Table 11

RADIOACTIVITY LIMITS ON MATERIAL OR EQUIPMENT LEAVING Y-12

Material or Equipment	Limit	Form Used	Comment
Commercial Vehicles	< 500 d/m/100 cm^2 for α (average) < 0.4 mr/hour	Radiation Survey	ICC specified limits.(1)
Shipping Boxes	< 500 d/m for a smear of total outside area < 2000 d/m/100 cm^2 uranium	Shipment Inspection Report	Applies to all shipments by Materials and SS Accountability Departments.(1)
Radioactive Material(1)	< 2700 mc/container < 40 radiation units per container(2)	Shipment Inspection Report	ICC specified limits for commercial carrier shipments.(1)
Radioactive Material	> 2700 mc/container 0.3 mr/hour	Shipment Inspection Report	Requires Bureau of Explosive exemption.

(1) Labeling and placarding must meet requirements of the ICC for the shipment of radioactive materials.
(2) One radiation unit = 1 mr/hour at one meter from surface.

HEALTH PHYSICS

INTRODUCTION

This portion of the report is a comprehensive outline of the programs or methods by which the Health Physics Department discharges its responsibilities with regard to fulfilling the policies of the Y-12 Plant.

PERSONNEL MONITORING

The personnel monitoring program at Y-12 is designed to measure and record the amount of ionizing radiation dose (both external and internal) received by employees during their normal routine job assignments and during any accidental radiation incident. The use of a radiation accident monitoring meter is discussed in the section titled RADIATION SAFETY EMERGENCY MONITORING PROGRAM (Pages 83-95).

External Radiation Monitoring

Radiation-sensitive film is used in all plant security dosimeter badges to measure the doses of beta, gamma, X-ray, or neutron radiation received by plant personnel. Films used for beta, gamma, or X-ray dosimetry are processed quarterly. Special emulsion films used for routine neutron dosimetry are changed semiannually but are processed only when possible neutron exposure is suspected. However, neutron films are changed and processed quarterly for those persons who work with neutron sources. Any individual film is processed immediately if there is reason to suspect that an accidental overexposure may have occurred.

The film badge presently in use at Y-12 has been approved by the AEC and serves both as a security pass and personnel routine and emergency monitoring dosimeter. An "exploded" view of the badge is shown in Figure 1. It consists of a plastic case with the photoidentification on the front and an insert that holds the film in position. Two types of films are used: DuPont, Type 544, for beta-gamma monitoring and Eastman NTA for neutron measuring. On the front side of the slide there is a strip of indium on which the employee's payroll number is indented. The indium serves as one of the emergency monitoring features of the meter. The badge is designed for energy determination of a radiation exposure and has four areas for this purpose: the open window, plastic, aluminum, and cadmium. In addition to the indium for emergency monitoring, there are two gold discs, bare and cadmium-shielded, and a sulfur pellet.

Badge Distribution - All badges are assembled and loaded with film by the Plant Security Department. Payroll numbers and the quarter identification code are X rayed

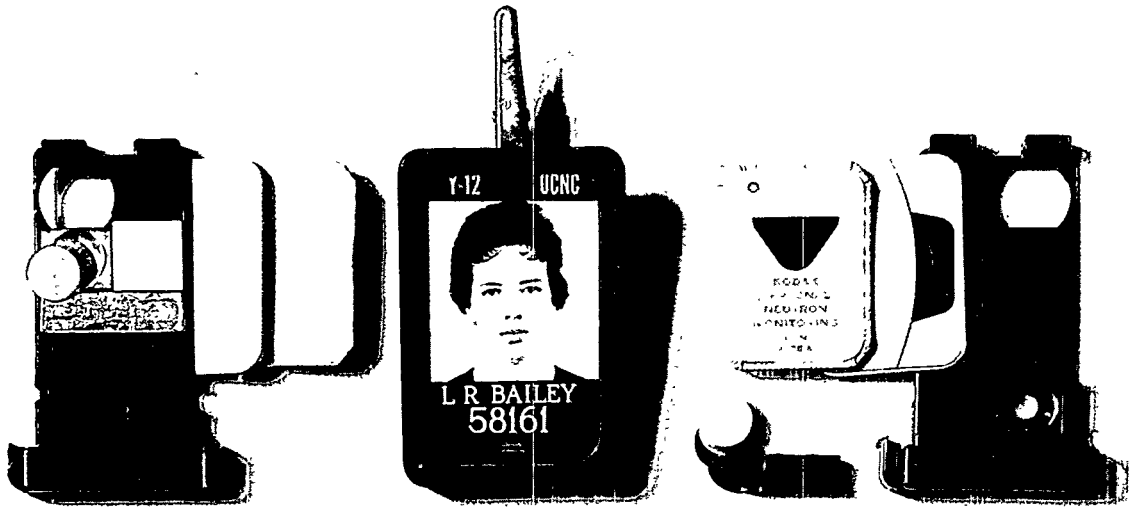

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Figure 1. SECURITY BADGE AND PERSONNEL MONITORING DOSIMETER.

onto the film badge before the badges are distributed. On the last day of the calendar quarter, during the evening shift, the badges are placed in numerical order by badge payroll number in badge exchange racks at stations located inside each plant entrance. The employee picks up his badge at the station of his choice which he has indicated previously in writing, and leaves the badge for the quarter just ended in the rack from which the new badge was selected. Two weeks are allowed to complete the exchange after which all badges are picked up by plant guards and taken to the Badge and Pass Laboratory where the film is removed from last quarter's badge and sent to the Bioanalysis Laboratory for processing. Persons failing to exchange badges at the portals within the period of two weeks must go to the Badge and Pass office to make their exchange.

Processing - Beta-gamma films are developed by standard film developing techniques using a DuPont developer and replenishing solution. After a three-minute developing time, the films are put through the fixer, rinse, and drying cycles before reading. Densities are read for the four areas: open window, plastic, aluminum, and cadmium, on a semiautomatic reader and recorder. Results are translated into volt units (1.800 volts) and punched automatically by the reader into IBM tabulation cards along with the employee's badge number which an analyst reads from the film and punches into the card. The cards are sent to Tabulating Services for dose calculations and recording. A penetrating dose and total skin dose are calculated from the film response values for the cadmium and open window areas by comparison of the volt units obtained with those determined from a set of precalibrated films. These volt units are also converted to optical density units for ease of comparison with other systems.

The Eastman NTA neutron films are developed by the same processing method as that used for the beta-gamma films but using a five-minute developing time. Films are

read under a microscope by counting the number of tracks in 50 fields and the dose is computed by calibration against an approved neutron source of known strength.

Recording - A quarterly radiation dose is calculated from the information punched on IBM cards, and is compiled and recorded by machine on IBM sheets for each individual in numerical payroll number order by departments. Recorded on the sheet is the beta, gamma, and neutron doses in mrads with total skin dose and total penetrating dose in mrems. At the end of each calendar year a tabulation of all exposures that have been reported for each individual is made and filed by badge number. The annual exposure records, the quarterly IBM cards, and the developed films are retained as permanent personnel exposure records.

Reporting - A summary of all exposures is made for each division and is included in the Y-12 Plant Quarterly Report. In addition, a breakdown of the results is included in a personnel exposure report made annually to the AEC. Significant exposures are handled as outlined in Table 2.

Film Calibration - All routine films are read against sets of quarterly calibrated films. (See the section titled, CALIBRATION PROGRAMS, Page 74.)

Control Program - Three sets of calibrated film are processed each quarter for both beta and gamma. These films are picked at random from the same boxes from which the films loaded into the personnel badge were taken, and are exposed to known doses in the range of 30 - 5000 mrems. They are then processed through the laboratory in a random manner along with the film from the badges worn by plant personnel during the quarter. The film results at several levels are composited and the precision of the measurement spanned by these levels is calculated by the Statistical Services Department and reported quarterly in the Quality Control Report. If the precision shows an unusually high limit of error, attempts are made to locate and correct the influencing factor or factors.

In addition to the films just described, approximately 50 films are exposed to 960-mrem gamma and sent to the laboratory. These films are used by the laboratory to check on the consistency of the interpretation between and within processing batches.

Internal Radiation Monitoring

Two primary internal dosimetry programs are employed in Y-12: urinalysis and in vivo radioactivity measurement (IVRM). Urinalysis is used at Y-12 to estimate the body burden of three radionuclides: uranium, plutonium, and tritium. The in vivo facility is used for the estimation of uranium and thorium lung burdens. Routine monitoring programs are maintained on all personnel who are assigned to work regularly with these isotopes and exposure data are recorded.

Plant acceptable limits of body burden, concentration in urine, and control points for action to be taken are discussed in the Introduction to this report under the topic, "Radiation Protection Guides for Internal Exposure", Page 13.

Uranium Urinalysis -

Scheduling - Scheduling personnel for participation in the urinalysis programs is accomplished by agreement between the supervision of the participating departments and Health Physics. Supervision is responsible for keeping up to date the list of employees scheduled to participate and uses the form shown in Figure 2 for this purpose. The changes are compiled weekly by Computing Services to keep a current list of participants.

CHANGES IN URINARY URANIUM PARTICIPATION

DATE

NAME	BADGE	FROM:			TO:		
		DEPARTMENT	SHIFT	PROGRAM	DEPARTMENT	SHIFT	PROGRAM

SIGNATURE

Figure 2. FORM FOR REPORTING PERSONNEL CHANGES IN THE URINALYSIS PROGRAMS.

From this information and a schedule of participation frequency for each department, Computing Services prepares a urinalysis participation list and processes the mark-sense cards for those persons scheduled for the next week. The participation list and the mark-sense cards are forwarded to the analytical laboratory where measurements on the sample are entered.

For ease of administration, frequency of participation is determined on a departmental or subdepartmental basis. Recent past experience with urinalyses results for a department is considered the best index to determine what the future experience will be and the best guide for determining what frequency of participation is appropriate; accordingly, frequency-of-participation schedules are reviewed monthly and adjusted semiannually to meet the following criterion: "Sample at the frequency necessary to assure, with at least 95 percent confidence, that 95 percent of the individuals in a department have a

quarterly average below the plant action limit." This criterion is used within the limitations of a maximum frequency of once per week, which is imposed by the Monday-morning-type sample required, and a minimum of once per quarter. The frequency of sampling is dependent on the following qualifications: (1) the departmental mean exposure level, (2) the variation among exposures for individuals within the department, and (3) the variation among measurements within an individual.

Sample Collection - Since urinalysis is intended to estimate the amount of uranium stored in the body, samples are voided upon return to work following an absence from work of 48 hours or more. This time interval is applied to minimize bias in the exposure estimate because of the possible excretion of recently inhaled soluble uranium.

Since it is important that the activity which is in the sample be only that which is excreted, all incidental contamination of the sample or the sample bottle must be avoided. Therefore, sample collection stations, as shown in Figure 3, are maintained apart from the work areas in conjunction with change facilities. To encourage the participants to follow the proper voiding procedures, signs (as shown in Figure 4) are posted in conspicious places at each of the collection stations.

Employees are sometimes asked to submit "overnight samples" at home in order to improve the quality of the sample and the validity of the results. In cases of high uranium excretion rates, more frequent samples over longer periods of time may be needed. Take-home kits are provided for collecting this type of sample.

The collection stations are checked periodically to see that housekeeping is adequate. Removable surface contamination checks are made at these times.

Sample container labels (of different colors to indicate the type of exposure or analysis) are used to facilitate processing. For example, a label such as shown in Figure 5, is used for samples to be analyzed for depleted uranium.

The Laboratory Division is responsible for making the properly labeled bottles available at the various collection stations and collecting the voided urine samples.

Laboratory Processing - At the Analytical Laboratory, each of the incoming urine samples is matched with the proper IBM mark-sense card which has been sent to the laboratory by the Computing Services Department.

A sample, for which no prepunched IBM card is provided, is checked against the participation lists to see if the person submitting the sample is on the pro-

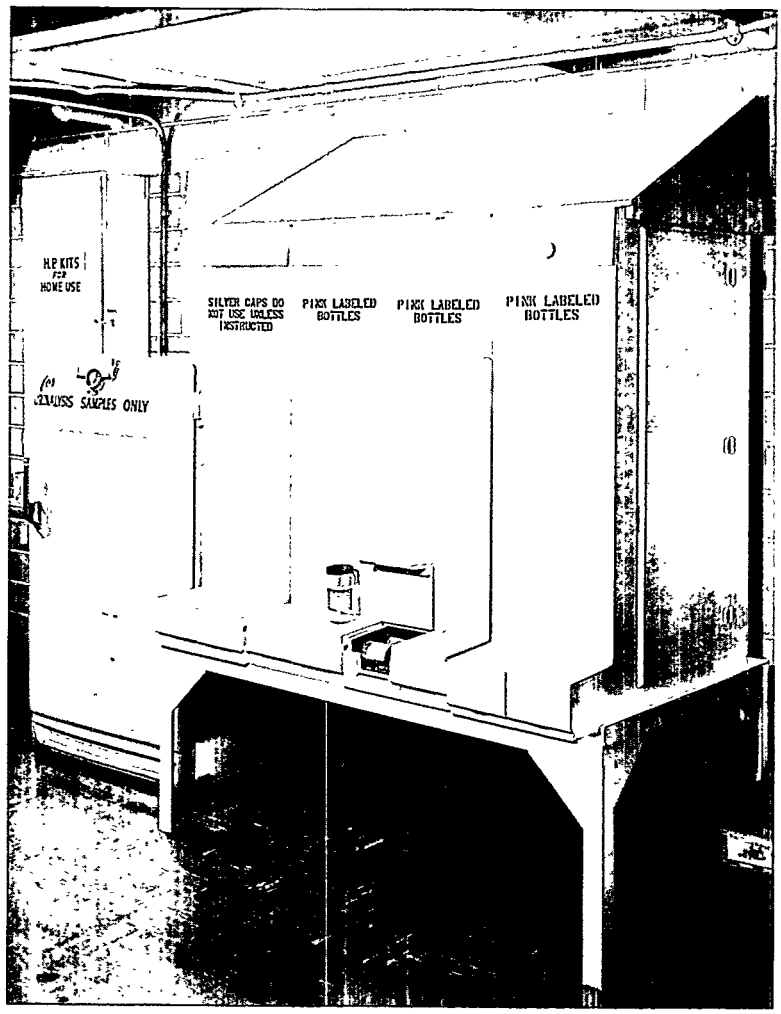

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Figure 3. TYPICAL URINE SAMPLE COLLECTION STATION.

gram. If a person is on the program and submitting a sample out of routine, a handwritten card is filled out for the sample. If a person not assigned to the program submits a voiding, the sample is analyzed by the most appropriate method. The employee's supervisor is contacted and a decision is made concerning what should be done with the result and whether the employee is to be assigned to the routine program.

Samples from areas in which normal or depleted uranium is processed are analyzed by fluorometric measurement. Samples from areas in which either enriched uranium or both enriched and normal uranium are handled are analyzed by electrodeposition of the uranium followed by alpha counting. The sections that follow offer a brief description of each analysis method.

Electrodeposition Method: Urine samples are analyzed for alpha activity using the equipment shown in Figure 6 for the electrodeposition of en-

NOTICE

IT IS IMPORTANT THAT THE PROCEDURE BELOW BE FOLLOWED FOR SUBMITTING URINE SAMPLES FOR URANIUM ANALYSIS. FAILURE TO DO SO MAY AFFECT EXPOSURE ESTIMATES.

1. Wash Hands.

2. Submit sample prior to changing into work clothes or going into work area.

3. Submit all of the voiding.

4. Fill in clearly the information called for on the uranium urinalysis bottle. It is extremely important that the times called for be given as accurately as possible.
   Previous void time means the time of last urination before this present one.
   Present void time means right now, when you submit this sample.

5. Place sample into refrigerator or cabinet provided.

QUESTIONS RELATING TO ANY OF THE ABOVE PROCEDURES SHOULD BE REFERRED TO YOUR SUPERVISOR.

THE HEALTH PHYSICS DEPARTMENT.

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Figure 4. POSTED PROCEDURE FOR SUBMITTING URINE SAMPLE.

riched uranium from raw urine. Figure 7 shows, schematically, the steps in these analyses. Two aliquants from each urine sample are plated for 30 minutes. Each uranium-bearing silver disc is then counted in two different alpha proportional counters (as shown in Figure 8) for 30 minutes.

The d/m/day is calculated as follows for the samples analyzed by the plating method:

$$\frac{AP \times Vol}{Eff \times TI} \times 8 = d/m/day$$

where:

NORMAL URANIUM URINALYSIS

NAME

BADGE NO. | DATE

PREVIOUS VOID TIME

PRESENT VOID TIME

DEPARTMENT NO.

Figure 5. TYPE OF LABEL PLACED ON URINE SAMPLE BOTTLE. (Blue Color for Depleted Uranium)

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Figure 6. ELECTRODEPOSITION CELLS.

AP is the average plate count per 30 minutes,

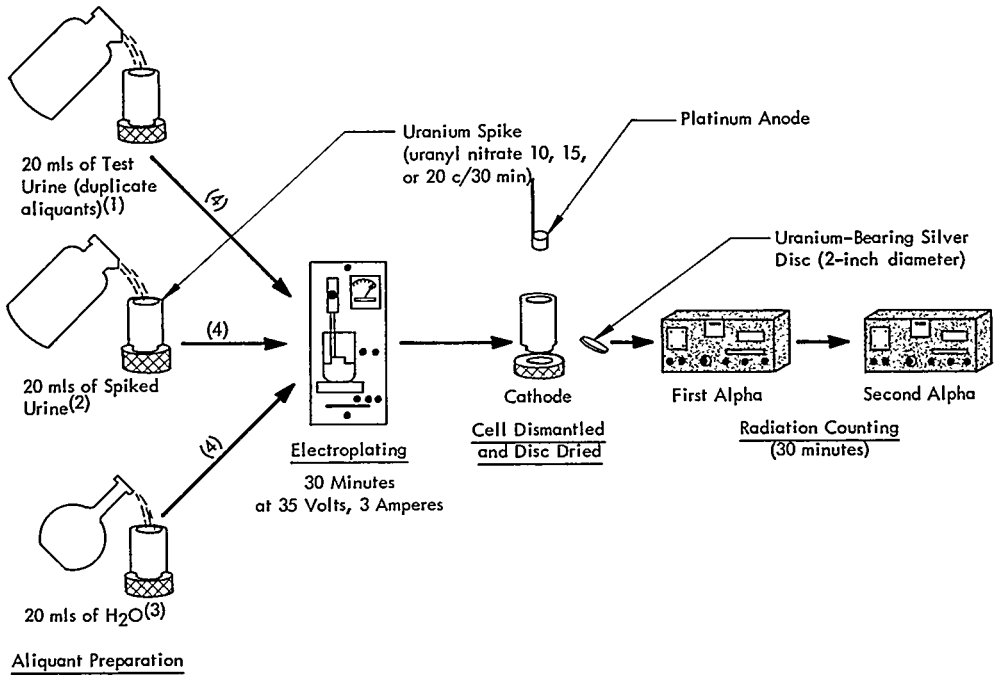
Vol is the volume of the urine sample in milliliters,

Eff is the plating recovery in percent,

TI is the time interval in hours between the time the sample was voided and the time of the last previous urine voiding,

and

8 is a constant that combines all volume, count, and time constants.



(1) The samples are submitted by the participant.
(2) These spiked samples comprise about 20% of the samples and determine the percent of recovery.
(3) These blanks are used to control cell contamination.
(4) To each aliquant is added 60 mls of 1.5 M ferric ammonium oxalate.

Figure 7. STEPS IN THE Y-12 PROCESS FOR ANALYZING URINE FOR URANIUM BY THE ELECTRO-DEPOSITION PROCESS.

Fluorometric Method: Figure 9 shows, schematically, the steps in this analytical method. The method consists of analyzing two 0.2-milliliter aliquants from each specimen. After the elimination of all volatile material from the dishes, any organic residue is burned off. Approximately 0.3 gram of sodium fluoride is added to each dish and the fluorescence is measured by the fluorophotometer which is illustrated in Figure 10. From the fluorescence of the blank, original sample, and using a constant quenching factor, the uranium content is calculated.

The d/m/day is calculated as follows for samples analyzed by the fluorometric method:

$$FR \times \frac{Vol}{Tl} \times 0.0773 = d/m/day$$

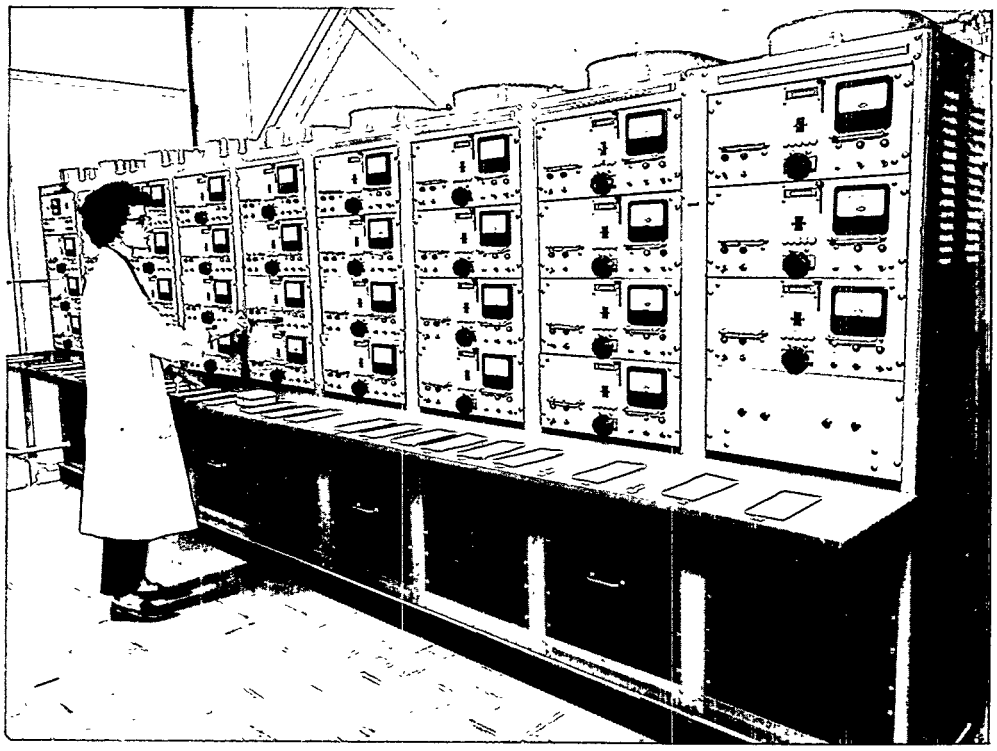


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Figure 8. ALPHA PROPORTIONAL COUNTERS.

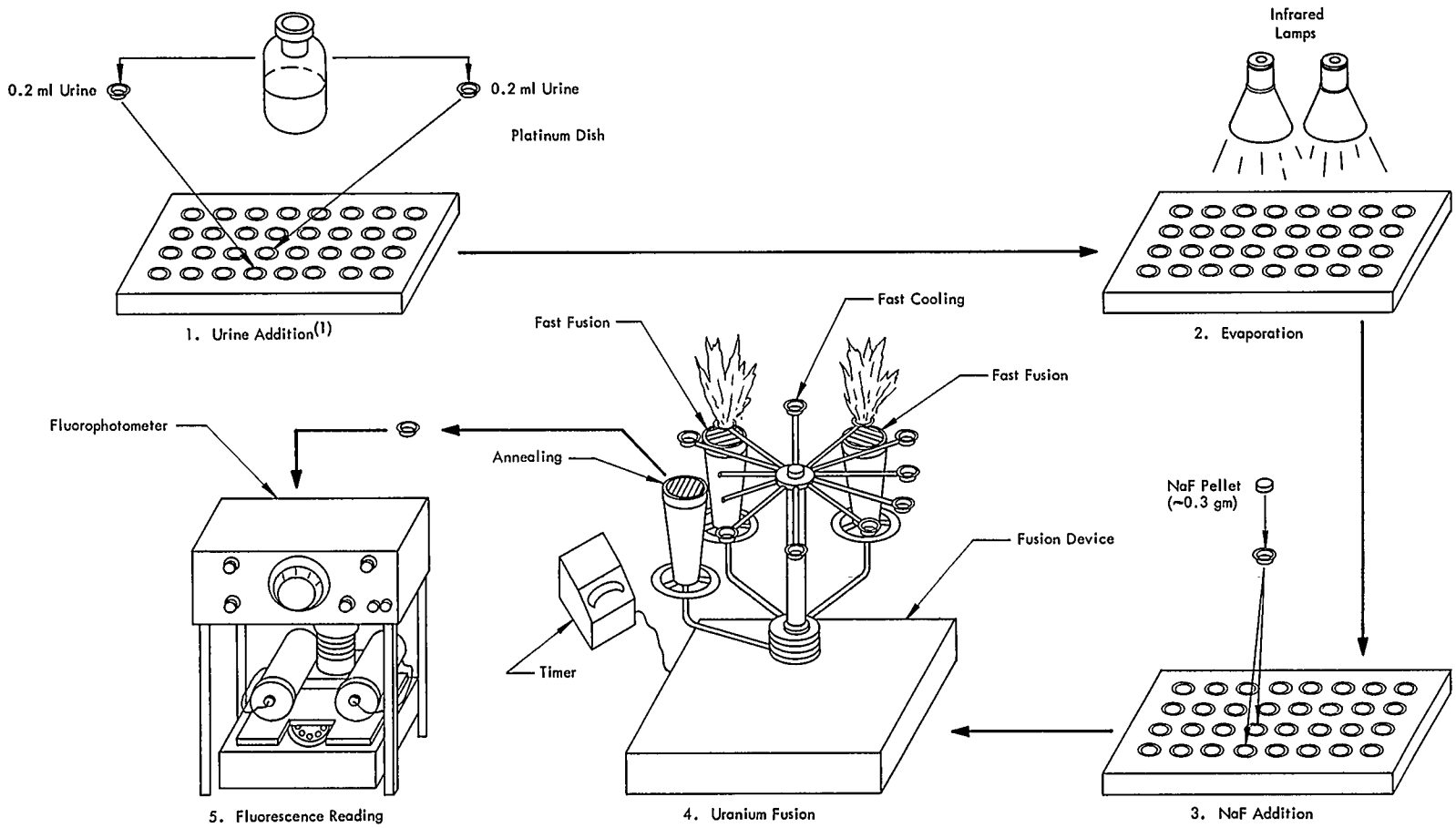
where:

FR is the fluorophotometer reading in microamperes.

Laboratory personnel note the uranium excretion level and notify Health Physics in advance of IBM tabulation of the results for any sample which indicate an arbitrarily established count or fluorometric reading.

Data Reporting and Records - Health Physics notifies the appropriate supervisor immediately upon the receipt of any results which are too high. Any other action taken is dependent upon the level shown by the sample. Investigation and some recommendations may be made on the basis of single-sample evaluations if the results seem to merit such action, but the 13-week excretion rate is the principal value that is used for recommending any action to be taken. A summary of the action points is given on Pages 14 and 15.

After the samples comprising a week's run have been analyzed and the data recorded on the cards, the cards along with those cards for which no samples were submitted are sent to the Computing Services Department. From the IBM cards for which no samples were submitted, the Computing Services Department prepares lists, grouped according to department, of all persons who failed to participate as scheduled.



(1) Urine is added to spikes to obtain an average quenching factor. All other samples are run with two aliquants of 0.2 ml of urine each without a spike.

Figure 9. STEPS IN THE Y-12 PROCESS FOR ANALYZING URINE FOR URANIUM BY THE FLUOROMETRIC METHOD.

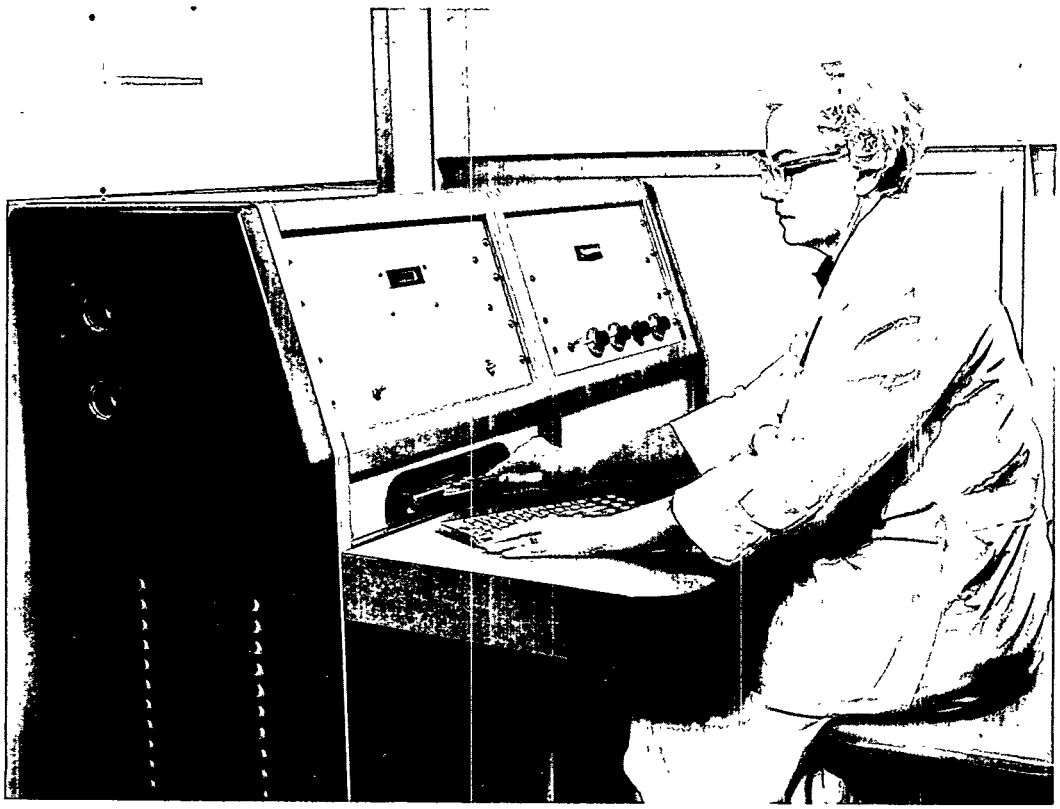


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Figure 10. A FLUOROPHOTOMETER.

These lists, in turn, are forwarded with a form letter to the appropriate supervisors giving them further instructions relative to obtaining a sample from the employee who failed to participate.

The Computer Services Department computes the results and compiles the weekly uranium data and summary report which gives for each scheduled participant the internal uranium excretion rate indicated by each sample submitted during the most recent 13 weeks. Individual histories and departmental summaries are also included. This report is available to departmental supervision on request.

Each week Health Physics prepares a list containing the names of all employees that submitted a minimum of four urine samples within a 13-week period and had at least two samples over the PAL (an average over 13 weeks $\geq$ 70 d/m/24 hours). This list gives the total number of samples analyzed and the number of samples which indicated uranium activity $\geq$ 70 d/m/24 hours. Distribution is made to departmental supervision having personnel on the list. Employees are listed in categories according to the indicated significance of their exposure estimates.

Once each quarter uranium excretion rates are summarized and included in the Health Physics Quarterly Report. The urinalysis section of this report gives the uranium excretion averages for each division.

Annually, the Computing Services Department prepares summary listings for each person who participated in the program during the year. This list is made a part of the person's exposure history record.

A uranium urinalysis record flow chart, Figure 11, shows, schematically, the steps that are necessary in the operation of the Y-12 urinalysis program.

High results for individuals are reported periodically. If subsequent samples are low (an indication that the high sample may have been contaminated or something else happened that prevented a true indication of exposure) the high result is subjected to a statistical test[6] to determine if the result should be disregarded. If this test indicates that the sample should be disregarded, it is deleted from use in compiling the individual's average.

When an employee's 13-week excretion average, as indicated by four or more samples, reaches 75 d/m/24 hours, the limit of error and 68% confidence band for his average quarterly excretion are calculated from the results shown by his individual samples. The following formula is used:

$$LE_q = \sqrt{\frac{\sum_{i=1}^{N} (R_i \times LE_i)^2}{N}}$$

where:

LE_q is the limit of error for the quarter,

R_i is the result in d/m/day for the ith result,

LE_i is the limit of error for the ith result of the 68% confidence level,

and

N is the number of samples.

If the limits of this 68% confidence band lie entirely above 70, one is 84% confident that the employee has statistically exceeded the plant acceptable limit of 70 d/m/24 hours (average) for 13 weeks.

The action taken at this point depends on the level of the in vivo measurement on the involved employee. This and other action criteria relative to the uranium dose program are shown in Table 4 and outlined on Pages 14 and 15. As noted, employees meeting certain criteria are removed from uranium processing areas on the basis of their indicated internal exposure, but they continue to submit samples for urinalysis. A form titled, "Individual Exposure Record - Case History", is initiated and a case history file for such information as internal dosimetry data and correspondence is maintained on the employee until his

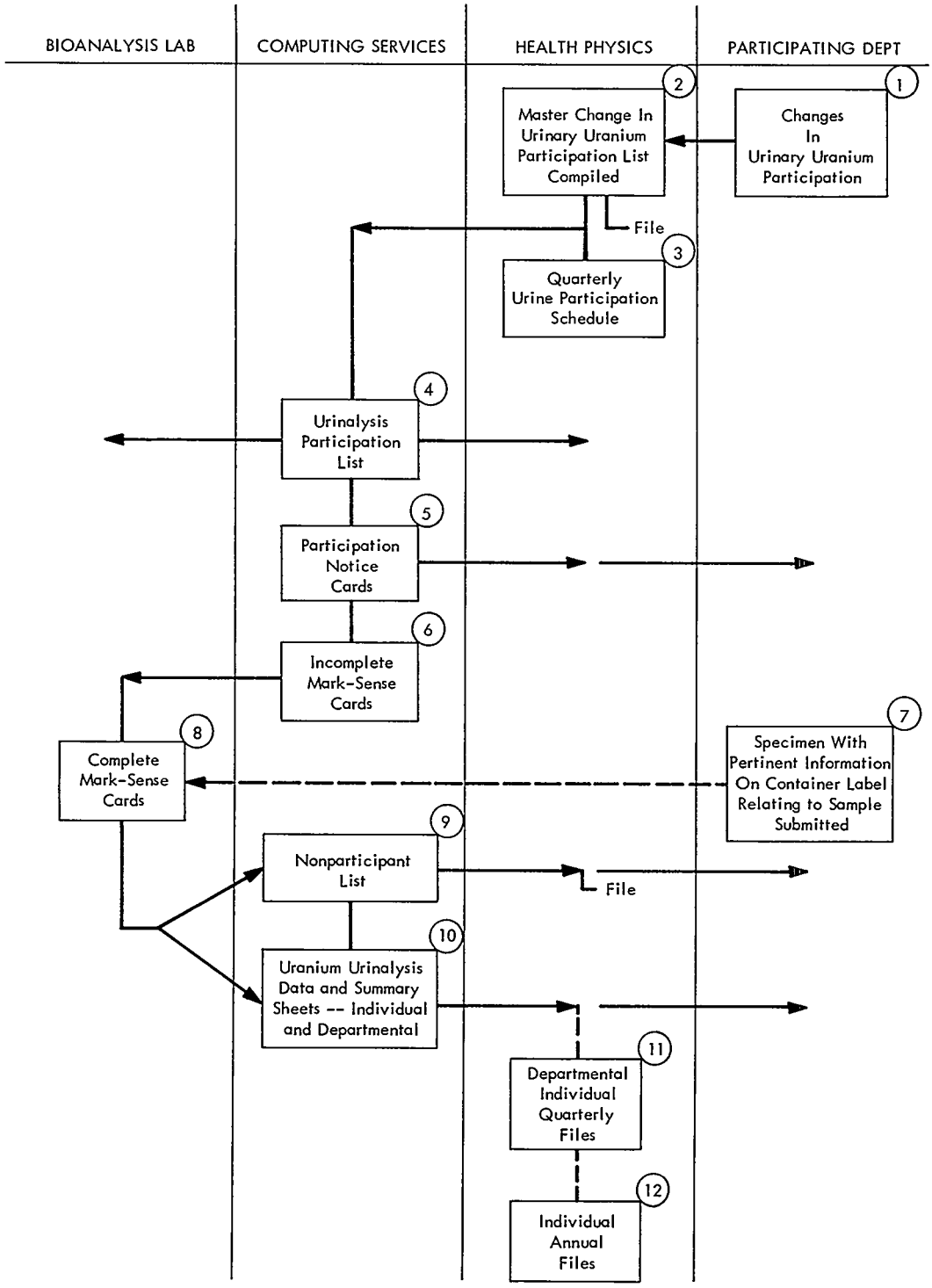

Figure 11. STEPS IN THE HANDLING OF URANIUM URINALYSIS RECORDS.

removal-from-exposure restriction is removed. Restrictions are removed from employees when their urine and in vivo results meet the standards outlined on Pages 14 and 15.

Control Programs - Several programs are carried on to determine the accuracy of calculations, the average recovery factor, and the precision of laboratory determinations. These control programs are discussed in the sections that follow.

Computer Tabulation Sheets: Each month, spot checks are made of IBM calculations. Data and summaries to be checked are chosen at random and are checked against the Computer Tabulation Sheets for comparison. Any disagreement of calculations is investigated.

Electrodeposition Control Program: The control program for enriched uranium urinalysis is carried on by the monitoring laboratory itself. The results of these programs are tabulated weekly and the Health Physics Department receives copies of this tabulation. There are four routine controls maintained within this program:

1. Recovery: Recovery is controlled by spiking a third aliquant for approximately 20% of the samples. The spiked aliquant is then compared with the corresponding unspiked aliquants to determine the percent of recovery.

   The average recovery of the plating cells is about 73 percent. If the recovery of the plating run exceeds a prescribed variation, the samples contained in this run are reanalyzed. If the recovery continues to be out of control, routine analyses will be stopped if necessary to find and eliminate the cause. Variation of recovery among cells is also maintained within prescribed limits.

2. Cell Contamination: Contamination of the cells is controlled by plating blank solutions and counting them to determine the background level. The urinalysis blank, including counter background, is maintained at about 0.15 count/minute. It is necessary to run a relatively large number of blanks because the laboratory is located adjacent to a uranium processing building and, consequently, contamination is a possibility. Three blanks are analyzed for each plating run of 19 sample aliquants. If the level exceeds established limits, routine analyses are stopped and the equipment cleaned until the level is acceptable.

3. Counter Background: The background of the counters is maintained at an average of approximately 0.12 count/minute. Thirty-minute backgrounds are taken at the beginning of each shift during which sample counting is done. A four-hour background is obtained overnight. The thirty-minute backgrounds are used to maintain control

during the work shifts, and the four-hour background is used to assure, with a high probability, that all counters are below the specified maximum background level. The counters are controlled for level by the use of alpha standards along with the routine sample counts. Counts must fall within established limits. Maintenance is required on counters not meeting this standard.

4. Plate Variation Control: The counts on the two plates are compared to determine that the counting errors and the variations between plates are within specified limits. If the agreement between the two counts on a plate exceeds the usual counting variation, an additional count is obtained on a third counter, and the deviant result is omitted. Also, if the agreement between the two plates exceeds the usual variation, an additional plate is analyzed and the deviant plate result omitted. The agreement between plates is routinely evaluated to determine the precision of laboratory measurements.

   Precent bias of the laboratory determination is calculated by the Statistical Services Department from the mean of analyses as compared to a predetermined expected recovery. Percent limit of error is calculated from the variation shown by the analyses of two aliquants from each sample. These determinations of precision of the laboratory electrodeposition method are reported each quarter in the Quality Control Report for all analytical procedures. If precision is poorer than experience indicates that it should be, or if a significant bias is indicated, the cause of such problems is found and corrected.

Fluorometric Control Program: The control programs for fluorometric uranium urinalysis is a Quality Control and Laboratory effort. Three types of controls are employed for the fluorometric urinalysis program as follows:

1. Blank Determination, Frequency, and Level: Blanks consist of platinum dishes which contain only the NaF pellet and no urine. They are processed at the rate of 16 dishes (eight spiked and eight unspiked) with each day's batch of samples. Unspiked readings provide a laboratory contamination index and are determined by placing the blanks in the fluorometer and obtaining the gross reading with the instrument set at "zero". (No-blank reading zeroed out for net value.)

2. Instrument Background: Instrument background is set by manually adjusting the background to zero.

3. Spike Samples, Frequency, and Recovery Factors: Twenty-four samples are selected at random each quarter. These samples are split and half of them are spiked with a known amount of uranium and sent to the laboratory under a fictitious name. Data from these samples

are used to estimate the precision and bias of the fluorometric method. Corrective action is taken if these results indicate a lack of proper laboratory control.

Plutonium Urinalysis - Personnel working in areas of potential plutonium exposure are requested to submit urine specimens for plutonium analysis on a monthly basis. The urinalysis procedure for plutonium requires a larger volume of sample than is submitted in the usual uranium urine sample; therefore, employees are requested to use a take-home kit and submit 24-hour composite samples. The samples are treated by chemical separation, precipitation, and evaporation of the plutonium onto a stainless steel planchet for alpha counting.

Each month the laboratory reports the results to Health Physics by memorandum. Appropriate action, if necessary, is taken on any significant results or for those who may be receiving a chronic exposure and whose indicated internal plutonium exposure shows evidence of an upward trend.

Tritium Urinalysis - Persons working with tritium or tritium-contaminated materials submit routine urine samples. In Y-12, the frequency of sampling is determined by the amount of tritium handled and the working conditions. In case of accident or where instruments indicate a possible high exposure, urine specimens are collected immediately, then a second specimen of at least 30 milliliters as soon as possible after the first voiding since the first sample may be diluted by urine in the bladder at the time of exposure.

The tritium is analyzed by reacting the urine with calcium, collecting the hydrogen evolved in an ionization chamber, and measuring the ionization caused by the tritium with a vibrating reed electrometer. The ionization chamber-electrometer tritium apparatus is shown in Figure 12.

The laboratory reports the results of these analyses to Health Physics by memorandum in terms of microcuries per liter of urine. Health Physics files these memorandums as the permanent record of indicated tritium exposure.

In Vivo Radioactivity Measurement (IVRM) Facility - The in vivo facility is used independently or as a complement to the various urinalysis programs to evaluate internal exposures to radioactive materials which have gamma radiation associated with them.

Because of the long biological half life of thorium in the body, excreta analyses cannot be used to evaluate thorium exposures. Consequently, the in vivo counter is the only method used in Y-12 for estimating the thorium internal dose. In the case of uranium it is used as a complement to the urinalysis program to estimate the dose to persons whose urinalyses indicate elevated levels.

The in vivo method can be used for many other radionuclides in addition to uranium and thorium. It is calibrated for other gamma-emitting radioisotopes as the need arises.

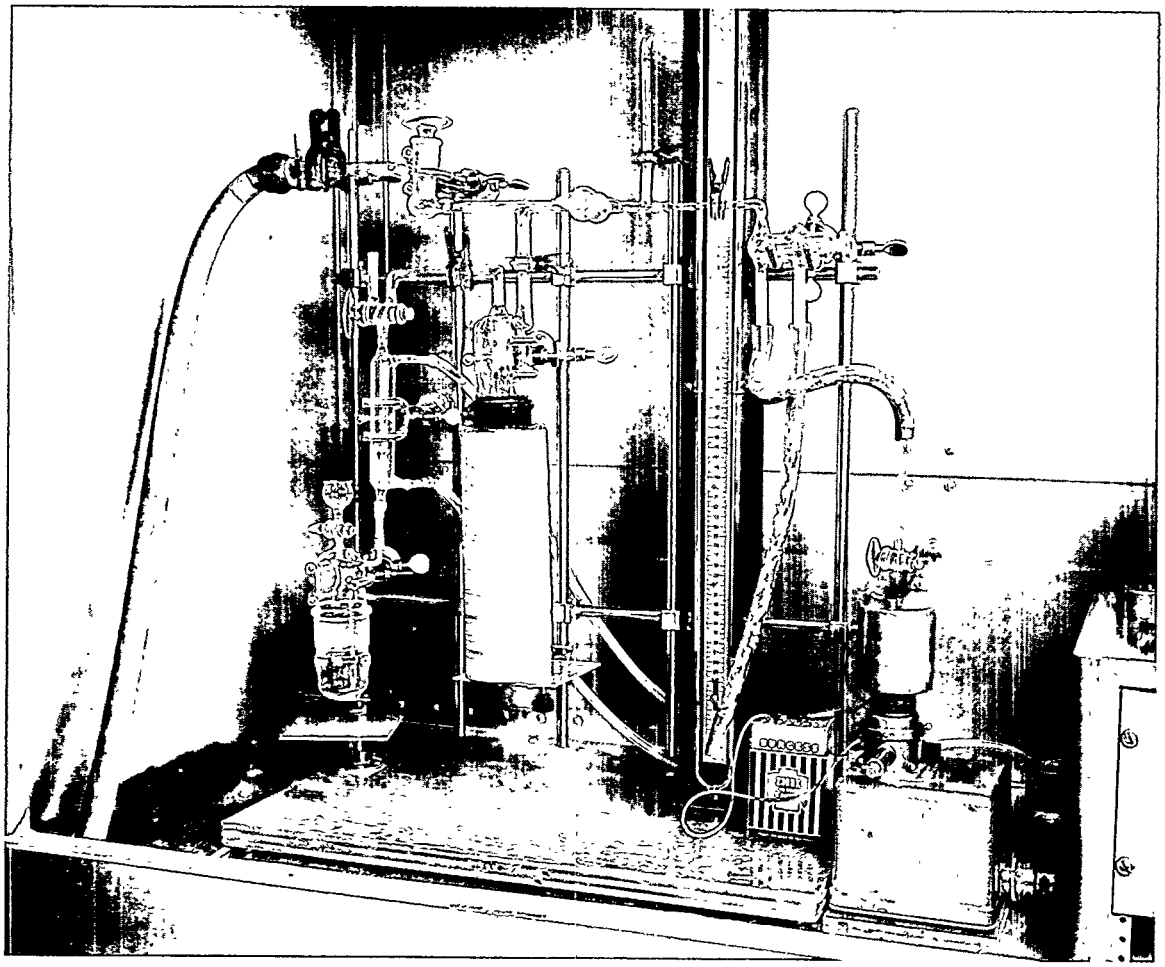

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Figure 12. TRITIUM APPARATUS. (Ionization Chamber-Electrometer)

Facility Description - The IVRM facility consists of a low-background counting chamber, two scintillation detectors, and a multichannel pulse height analyzer. This equipment is discussed in the sections that follow.

Low-Background Counting Chamber: It is necessary to keep the levels of naturally occurring radiation as low as possible since the lower limit of detectability for radioactive isotopes is governed to a large degree by the level of background radiation.

The chamber at Y-12 is constructed of 1/4-inch laminated steel sheets. Walls, ceiling, and floor are eight inches thick with internal dimensions of six feet eight inches square by seven feet eight inches high. The floor and walls to a height of 30 inches are lined with tungsten-loaded epoxy plastic tile to assist in maintaining a low background. The interior of the counting chamber is shown in Figure 13.

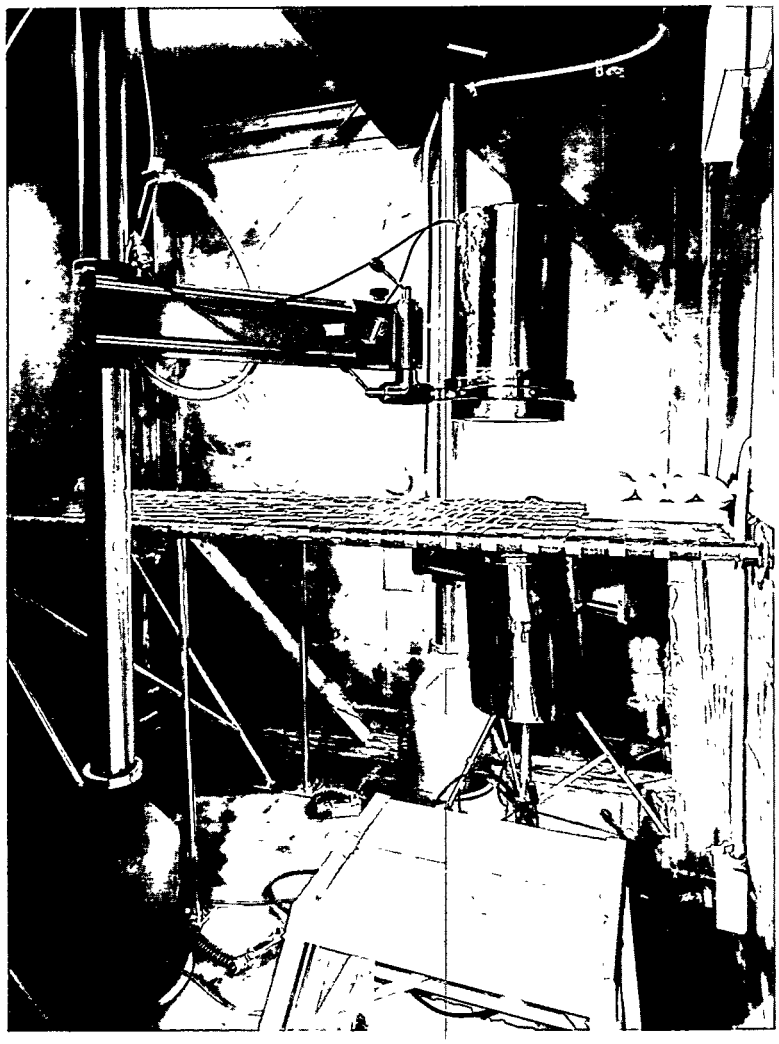

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Figure 13. INTERIOR VIEW OF THE IN VIVO COUNTING CHAMBER.

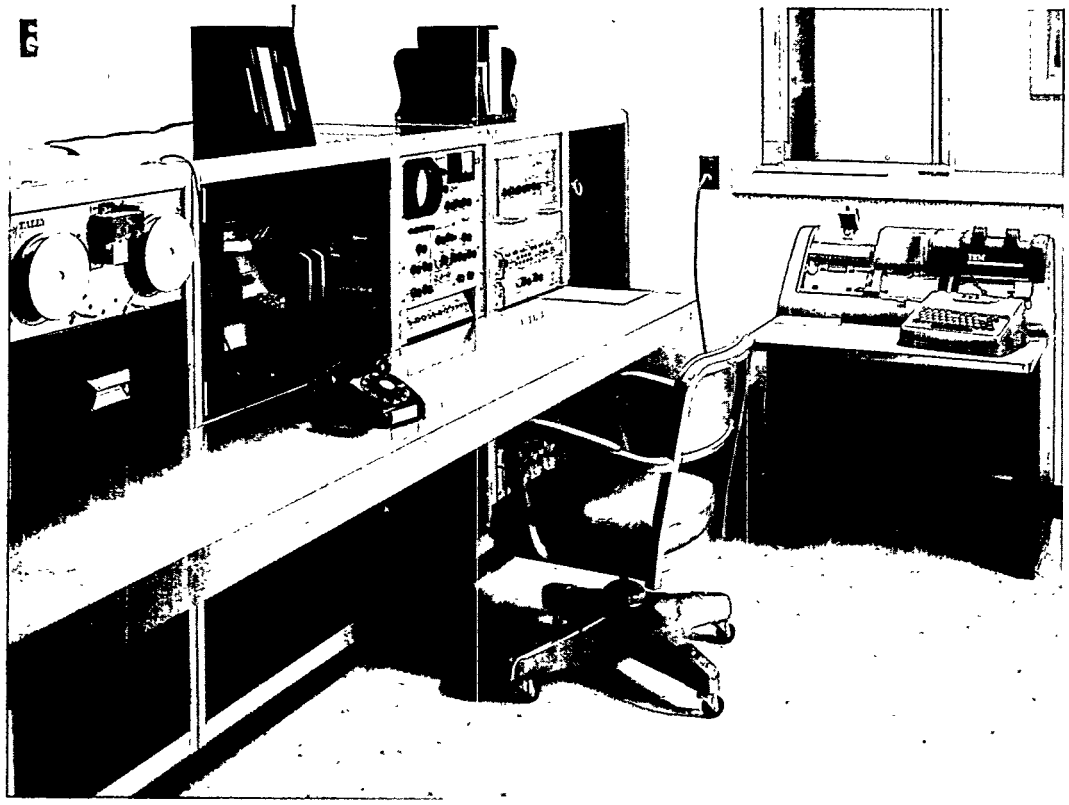
Scintillation Detectors: Two, 9-inch-diameter by 4-inch-thick thallium-activiated sodium iodide crystals are used to detect the gamma radiation from the body. Each crystal has four, 3-inch photomultiplier tubes optically coupled to the crystals to pick up the scintillations and convert them into electrical pulses which can be analyzed by the pulse-height analyzer.

Multichannel Pulse-Height Analyzer: A 400-channel analyzer sorts the pulses according to amplitude and stores them according to gamma energy. The analyzer handles the pulses from each detector separately and stores the pulses from one detector in Channel 0 - 199 and from the other detector in Channel 200 - 399. The system is calibrated to accept, sort, and store all pulses from gamma rays of energy between 0 - 1.55 Mev. This range can be increased up to 6 Mev by switch settings if necessary.

The stored data can be read out on paper tape, magnetic tape, or by an IBM electric typewriter. It can also be displayed on a cathode-ray tube.

The multichannel pulse-height analyzer and electronic accessories are shown in Figure 14. Counts from the room and equipment background are stored on magnetic tape and electrically subtracted from each run to obtain the net spectrum.

Counting Preparation Procedure - Personnel scheduled to be counted in the IVRM change into their personal clothing after leaving their work area in order to minimize the probability of transferring radioactive materials into the facility. Upon arrival at the in vivo facility, the person to be counted is directed to a change room where he must shower, shampoo, and change into the clothing furnished. Personal effects or any other clothing cannot be worn during the count as these may affect the analyses. Just prior to entering the IVRM the subject is surveyed with an alpha survey instrument and, if surface contamination is detected, the employee will be asked to return to the change room for additional cleaning with a special detergent. Prior to entering the counting room, each individual is asked to supply the information that is necessary to complete the in vivo analysis record.



110682(U)

Figure 14. MULTICHANNEL ANALYZER AND READOUT EQUIPMENT.

After entering the room, the subject reclines comfortably on a cot (Figure 15) and the in vivo analyst positions the forward crystal against the chest and the second one is positioned against the back. Both are located to count the lung region.

An intercommunication system provides constant voice contact between the subject and the analyst. An employee is counted for 20 minutes after which time he returns to the change room and prepares to return to his work area.

Uranium In Vivo Counting - The actual radiation hazard associated with uranium inhalation or ingestion is due to the energy dissipated in small volumes of tissue by the alpha particles emitted. Direct in vivo measurement of uranium

110684(U)

Figure 15. SUBJECT AND INSTRUMENTS IN COUNTING POSITION.

depends, however, on the gamma emission from the U-235 and U-238 isotopes since the alpha particles do not penetrate the body wall.

Y-12 handles uranium that is depleted in the U-235 and U-234 isotopes as well as uranium in which the U-235 enrichment is 90% or greater. Each different isotopic mixture will have its own Plant Action Limit (PAL) in terms of the weight of uranium. Body burden evaluation must take into account the alpha and gamma specific activity of the mixture. This value is obtained by calibration for the various isotopic mixtures in common usage.

This program is scheduled to cover those persons whose work categories and/or urinalysis results are indicative of the most internal exposure potential.

Personnel whose previous body counts or urinalysis results indicate levels above the PAL are given first priority on in vivo counting. Other uranium workers are scheduled as time permits.

The in vivo results are used in conjunction with urinalysis results to make decisions as to the amount of uranium body burden of exposed employees. Action points based on this combination are as outlined on Pages 14 and 15.

Thorium In Vivo Counting - In vivo counting is the only means used in the Y-12 Plant for determining thorium internal dosimetry. Urinanalysis for thorium is of no real value since the thorium biological half time for it to remain in the lung is approximately one year and, when the thorium leaves the lung, most of it is translocated to the bone which has a half time of approximately 200 years.

Personnel are scheduled for routine in vivo counts at approximately six-month intervals during the time they are working in thorium processing areas. It is the responsibility of departmental supervision to designate the employees to be scheduled. Health Physics then makes arrangements for the measurements.

Departmental supervisors are provided with prepunched IBM mark-sense cards for the persons to be counted and are informed of the date and time such measurements are to be made.

If an incident occurs or if there is any other reason to believe that an employee has received a significant thorium exposure, departmental supervision has been asked to notify Health Physics in order that the person or persons involved may be scheduled immediately for an in vivo measurement.

Any employee indicating thorium activity in the neighborhood of approximately one fourth the Radiation Protection Guide level will be scheduled for additional measurements until the Health Physics Internal Personnel Dosimetry Group determines the extent of the person's indicated exposure.

Special Measurements - The primary function of the IVRM facility is to monitor persons for possible body burdens of thorium and uranium. However, when necessary, it has been and can be utilized for monitoring any gamma-emitting

radioactive material. The facility has been calibrated for Co-60, Fe-59, Au-198, Cs-137, Np-237, and I-131. When necessary, additional calibrations will be made.

Control Programs - To insure proper operation, counts on standard sources of uranium, cesium, and cobalt are run weekly. If any count is out of control, the analyzer is examined for trouble and repaired before in vivo measurements continue. Calibration checks are made daily to insure that the instrument is in calibration.

Data Processing - As previously mentioned, data can be read on paper tape, magnetic tape, by IBM typewriter, or displayed on a cathode-ray tube (CRT).

Data is processed as follows: The spectrum is observed on the CRT display and, if it appears normal, the data are punched out and sent to Central Data Processing for calculation. If the spectrum appears abnormal it is printed out on an IBM typewriter and dose calculations are made immediately. In cases of special interest, spectrums are stored on magnetic tape and can be played back into the analyzer for view on the CRT for comparison with other spectra.

IBM cards are used in conjunction with the electronic system at the IVRM facility. The IBM cards have two purposes: (1) to get all identifying information on paper tape, and (2) to assist in scheduling persons for in vivo measurements.

Reports - In vivo radioactive measurement analyses are tabulated and reported on a weekly, monthly, quarterly, and annual basis.

At the end of each week the in vivo data sheets are summarized and for those persons from whom an indication of lung burden was detected, additional examinations are scheduled and attempts made to continue the observations until the in vivo spectrum appears normal. Persons with one or more measurements > PAL are reported weekly to their supervision.

Once each quarter in vivo measurements are summarized and included in the Radiation Safety Department's quarterly report to supervision. The report gives the number of measurements made from within the division, the divisional average, the percent of the PAL, and the number counts > the PAL.

PROCESS AREA MONITORING AND CONTAMINATION CONTROL

Air-Borne Contamination Monitoring

Radioactive elements handled in the Y-12 Plant include uranium, thorium, plutonium, and tritium. Of these four, uranium is the most frequently encountered. Air sampl-

ing programs are carried out in all areas of potential air contamination from these elements. Samples are classed as general air, breathing zone, and operation or special. The Radioactivity Concentration Guides (RCG), accepted as Y-12 Plant operating criteria, are given in Table 5.

Air Monitoring - Uranium - Monitoring air for uranium concentration is accomplished by drawing a known volume of air through an appropriate filter and counting the collected sample in a suitable alpha counter. This count along with the collection efficiency of the filter, the volume of air sampled, and the efficiency of the alpha counter are used to calculate the concentration of the contaminant in the air. The types of air sampling and a description of the method used are given in the sections that follow.

General Air Sampling - General air samples are collected to determine the general or average concentration of contaminants in the atmosphere of an area over a period of time. Collection of such samples in areas is a routine operation utilizing fixed-location samplers with a common vacuum system.

The sampler heads are usually suspended at a height of from five to seven feet above the floor and located in the area so that the samples collected are representative of the average atmosphere in the area, and not biased by any one particular operation. Typical samplers, shown in Figure 16, consist of a quick-opening holder for the 1 1/4-inch-diameter filter paper, a rotometer, and a value to adjust the air flow rate.

Sampling schedules are arranged by agreement of both supervision and Health Physics and are altered whenever a need is indicated by trends in sample data or changes in operation.

At the beginning of the sample period, the filter paper (H & V 70) is loaded into the sample holder, the vacuum is turned on, and the rotometer is adjusted to the desired air flow. At the end of the sample period, the sample is removed and placed on a 2 1/2-inch-diameter disposable cardboard planchet which is marked with the date, time, and location code to identify the sample. Often the sampler will be reloaded immediately so that it is ready for the next sampling period.

The Tabulation Services Department prepares prepunched IBM cards for each sample with the following data: location code, date, sampling time, rate of sampling, and volume of air. These cards are sent to the field offices in advance of the actual sampling date. The data handling procedure is illustrated in the flow diagram of Figure 17.

Samples are held at least 16 hours before counting to allow any short-life alpha activity to decay and not bias the intended measurement. Samples are loaded

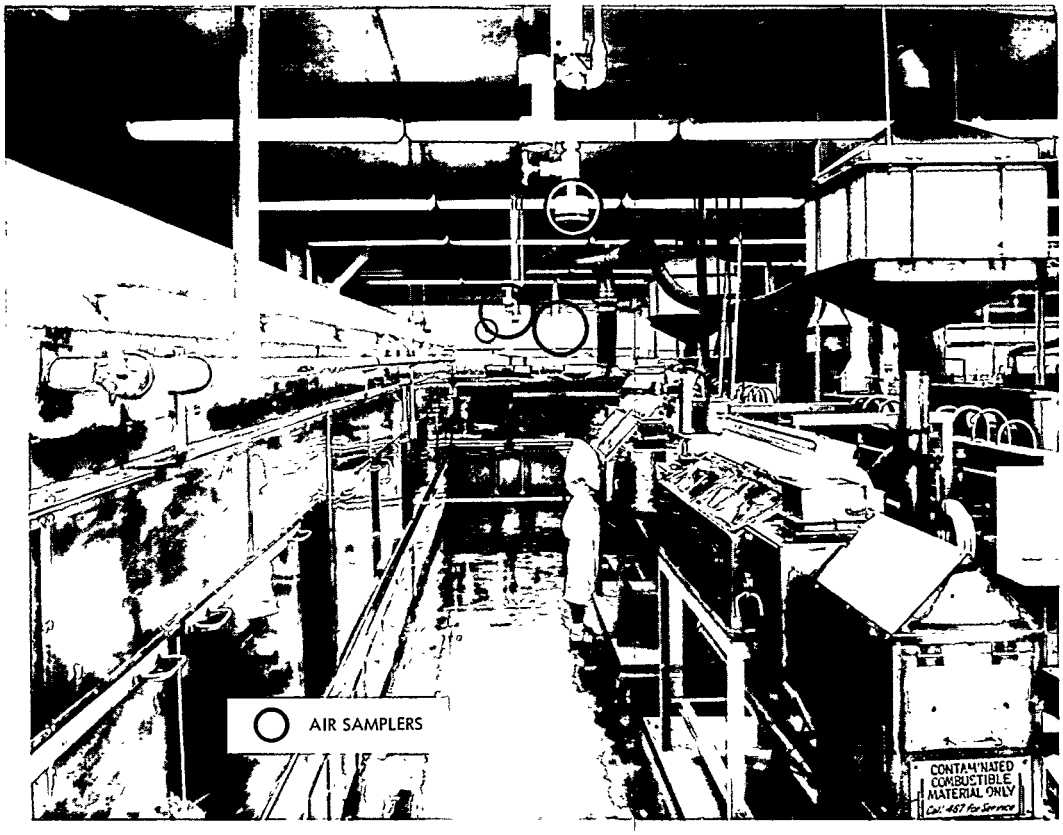


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Figure 16. GENERAL AIR SAMPLERS.

into the automatic counter and counted for two, 4-minute periods. The alpha activity in total counts is punched into the prepunched identification card by an IBM machine, shown in Figure 18, which is connected to the counter. Samples are held in the laboratory for three days after counting so that they will be available for recounting if necessary.

The completed cards are sent to the Tabulating Services Department each day. Results in d/m/M^3 are sent daily to the Health Physics Department and area supervision. At the end of each week, month, and quarter, summaries for that period are sent to the Health Physics Department and to area supervision.

Breathing Zone Air Sampling - Breathing zone samples are samples taken with portable equipment in the breathing zone of an employee while he is performing an operation. Such samples give the best estimate of the amount of air contamination that contributed to the internal exposure of the operator. This type of sample also aids in evaluating such factors as: operator technique, new equipment, ventilation changes, and changes in operating technique. Since such samples are often necessarily of short duration, the probable error of a single measurement is large, meaning that a series of samples must be taken to obtain significant data.

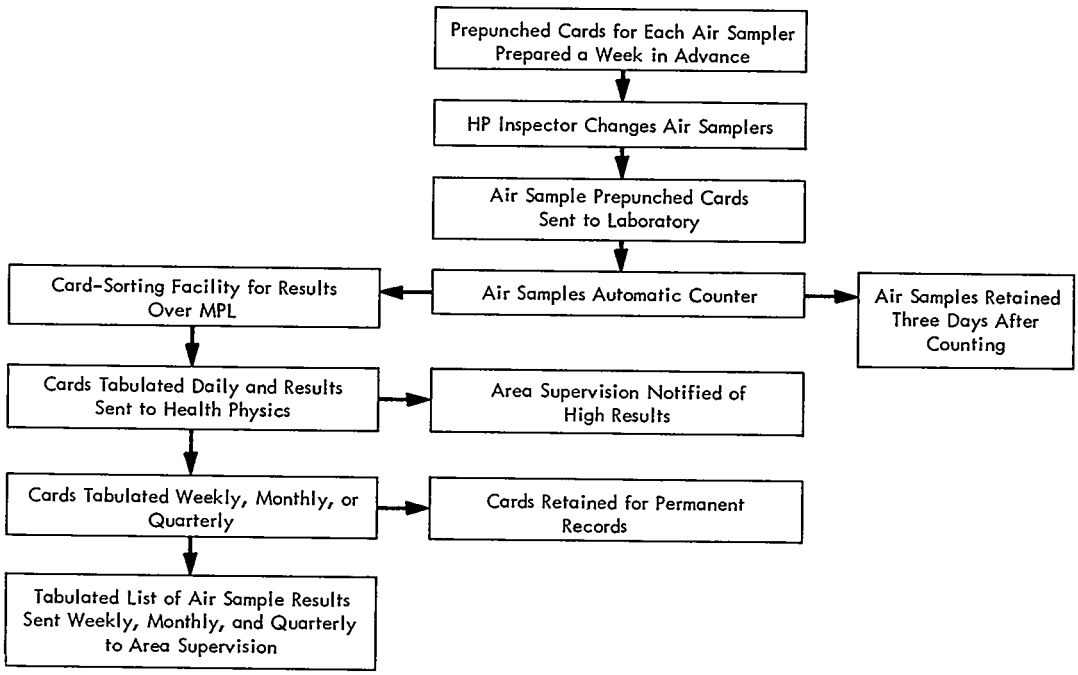

Figure 17. STEPS IN THE AUTOMATED URANIUM AIR SAMPLING PROGRAM.

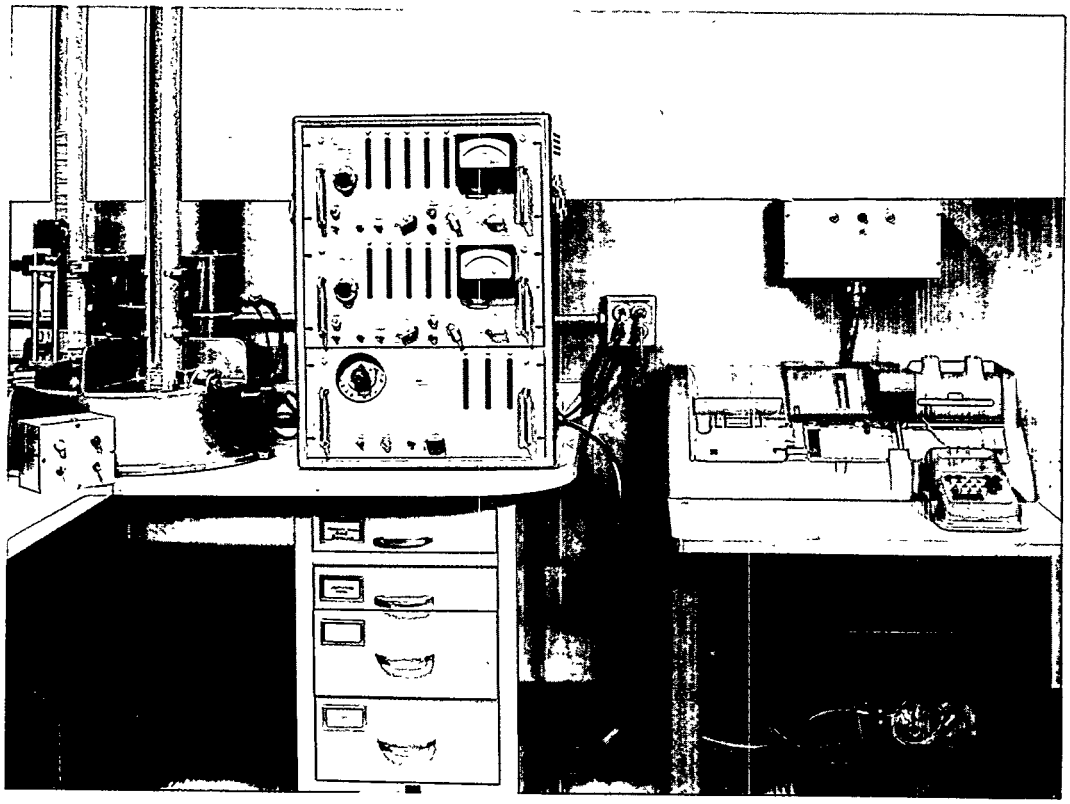

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Figure 18. AUTOMATIC SAMPLE COUNTER AND IBM MACHINE.

Breathing zone samples are taken at many uranium handling operations; however, the program is concentrated on the operations showing the highest levels of air concentration. Most breathing zone samples are collected on TFA-41 filter paper with a Hi-Volume air sampler. The sampler is held in the breathing zone position during the time of the operation. At the end of the sampling period, the sample is placed in an envelope and marked with the date, time, and identification number. Sampling information is recorded on an Operational Air-Borne Concentration Data Sheet, Figure 19, which is used for all air samples that are not routine.

Samples and data sheets are sent each day to the counting room where the samples are counted for alpha and/or beta activity. The counting data are recorded and the data sheets returned to Health Physics who forwards them, on a weekly basis, to the Tabulating Services Department for calculation and tabulation of the results.

Operational Air Sampling - Operational samples are taken with portable equipment and permanently installed air samplers to measure the air-borne contamination in the immediate vicinity of a particular operation or piece of equipment in an attempt to evaluate their contribution to the air-borne contamination problem. Figure 20 shows how a sample of this type is taken. These samplings differ from breathing zone samples both in location and the fact that they are not dependent on the presence of an operator.

Data are treated in the same manner as that for breathing zone samples.

Reporting and Recording - All air-sample results are calculated and reported daily by Tabulating Services to Health Physics. These results are composited weekly into a report which shows: (1) the activity or contamination level indicated by each sample, (2) the average contamination level for each area for the week, (3) the number of samples, and (4) the percent of samples that indicated activity in excess of the Radiation Protection Guides. At the end of each month and each quarter, Tabulating Services prepares a report summarizing all air-sample data for those periods. Summaries of these data are included in monthly and quarterly reports. Copies of all Tabulating Services reports are forwarded to supervision.

If and when samples indicate abnormal conditions they are called to the attention of supervision immediately.

Control Program - A control program is carried on by Health Physics in cooperation with the Laboratory Department in an effort to maintain better accuracy and precision in air-sample counting. The three phases of the program are:

OPERATIONAL AIR-BORNE CONCENTRATION DATA SHEET

Date _____ Inspector Code _____

Sample: Day ____ Night ____

Box Number	Room Code	Operation Code	Condition Code	Flow Rate (M^3/min)	Total (min)	Counting Efficiency	Counts Per Minute	Comments

Figure 19. OPERATIONAL AIR-BORNE CONCENTRATION DATA SHEET.

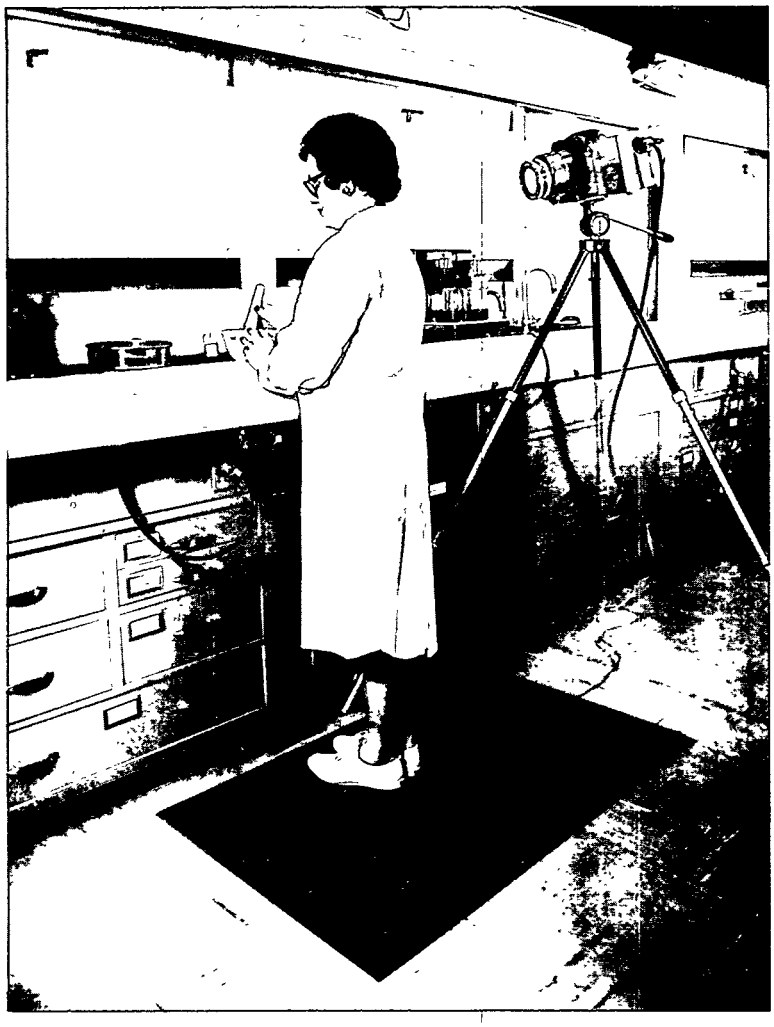

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Figure 20. TYPICAL OPERATIONAL AIR SAMPLING TEST.

1. Tabulating Services prepares a list of samples whose two-count results are not within a prescribed limit of error and forwards it to the Laboratory Department requesting a recount of samples listed. The laboratory maintains a close vigilance on their counting equipment and has been able to attain a counting agreement that averages more than 99 percent.

2. Some samples, after the initial counts, are selected at random and resubmitted under different identification. This phase of the program is used to ascertain whether any material was lost from the sample due to handling, and to check the ability of the counting instrumentation to reproduce previous results. Counting accuracy is controlled by calibrating the counters against known standards.

3. Any variability between samples is determined by comparing the results from samples obtained from dual samplers, pictured in Figure 21. Variance in the results on these samples includes both laboratory and sampling error. If the variability found is not consistent with previous experience, the cause for the discrepancy is found and corrected.

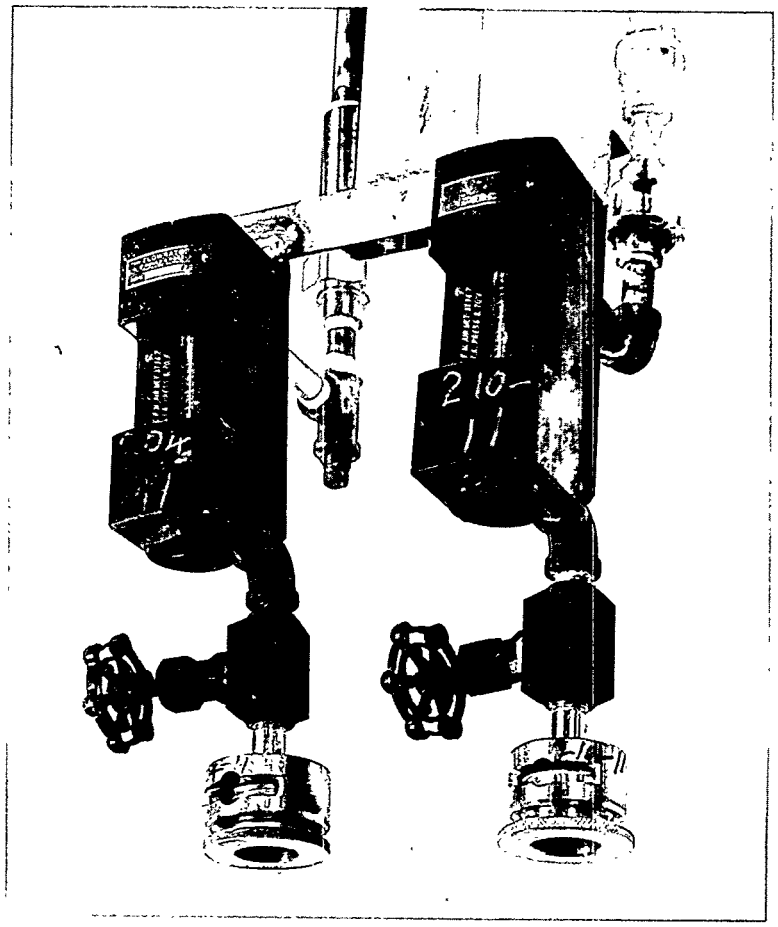

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Figure 21. DUAL AIR SAMPLERS.

Air Monitoring - Plutonium - The problem of possible air-borne plutonium contamination is confined to a special area in the Plant Laboratory where plutonium materials are analyzed for other Oak Ridge facilities. The method of collecting samples from this area and counting for alpha activity are the same as for the uranium air samples; however, any alpha activity detected in this area is assumed to be plutonium. The same control methods are used as those described under uranium air monitoring.

Air Monitoring - Thorium - Air monitoring for thorium contamination is accomplished by methods similar to those used for uranium, as indicated by the discussion in the sections that follow. After a sample has been counted for total alpha activity it may be counted for beta and analyzed chemically for the amount of thorium. Data from

such measurements are recorded on IBM sheets and reported in a manner similar to that for uranium results.

General Air Sampling - General air monitoring systems are operated in thorium processing areas. Equipment and methods are essentially the same as that used for uranium sampling.

Samples taken on Whatman 41 filter paper are placed in appropriate containers which are marked with identifying information. After allowing 48 hours for the short-life daughters of thorium to decay, the samples, along with prepunched IBM information cards, are sent to the Bioanalysis Laboratory where they are given two, 10-minute counts on a multichannel alpha counter (Figure 22). Counting information is hand marked on the IBM cards before they are forwarded to the Tabulation Services Department where results are calculated. Samples which show results > 12 d/m/M^3 are picked out, recounted for alpha, counted for beta, and analyzed chemically for their thorium content. Alpha recounts and chemical analytical information are entered on the card and returned to Tabulating Services where thorium and its daughter, Ra-224, concentrations are calculated and tabulated.

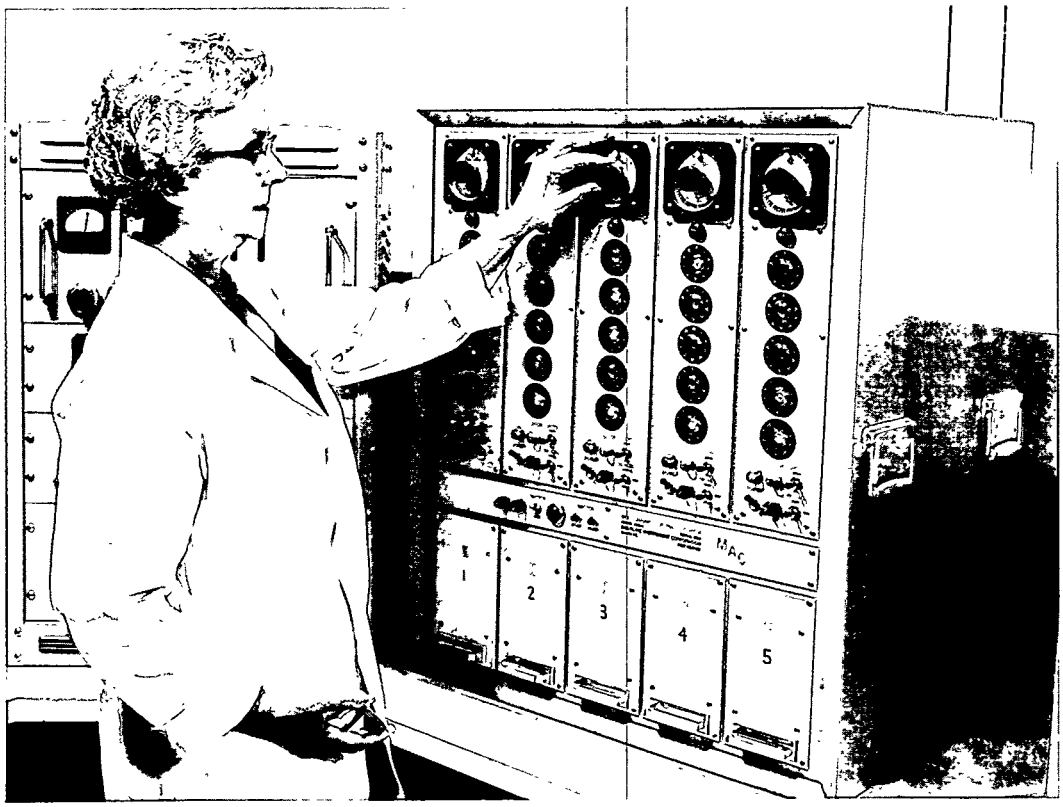

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Figure 22. MULTICHANNEL ALPHA COUNTERS.

Weekly, monthly, and quarterly summaries are sent to Health Physics and area supervision. Unusual results are called to the attention of area supervision as soon as the results are available.

Breathing Zone and Operational Air Sampling - The same sampling methods and techniques are used for thorium monitoring as for uranium. At the end of the sampling period, the sample and a hand-marked identification card, on which pertinent information has been recorded, are placed in a sample identification envelope.

After 48 hours, the samples with information cards are sent to the counting room where they are counted for alpha activity in a gas proportional chamber, shown in Figure 23. The counting data are then recorded on the IBM card which is forwarded to Tabulating Services for processing.

Results are handled in the same manner as the general air sampling results.

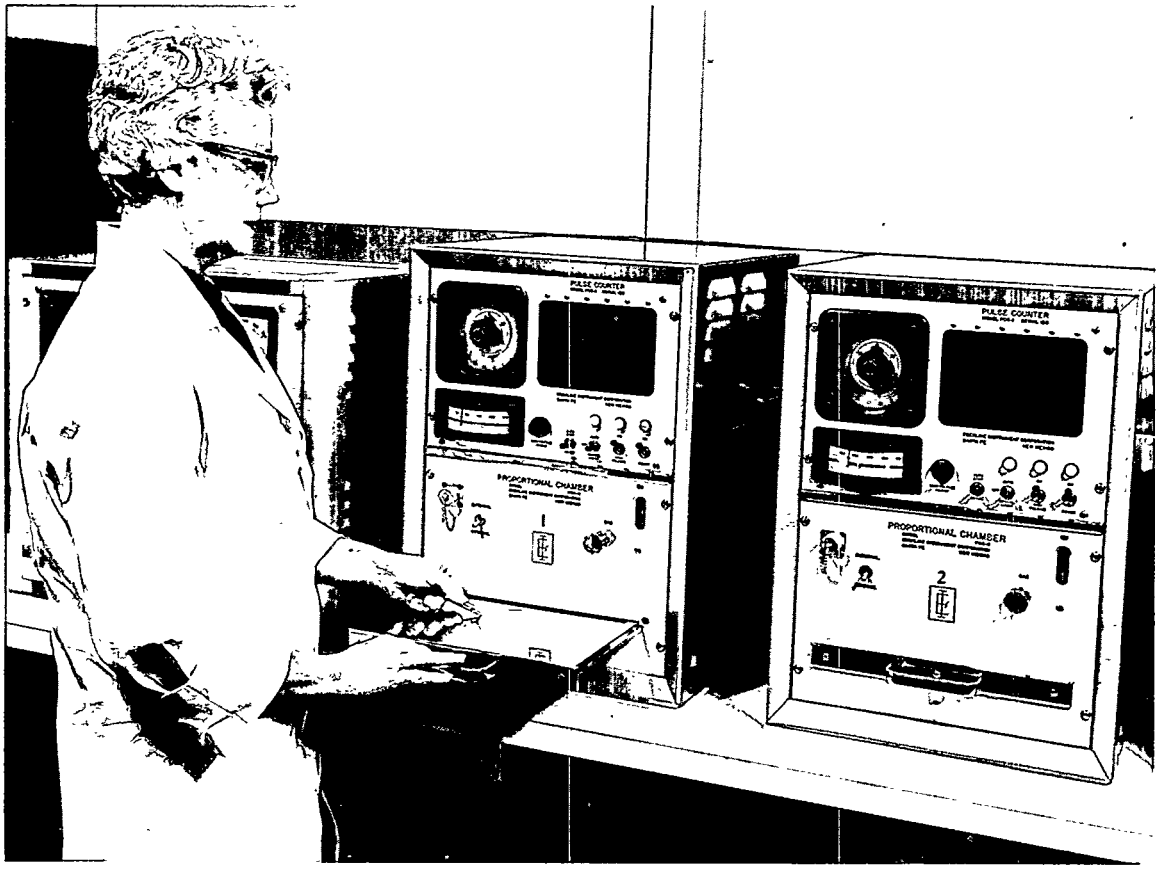

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Figure 23. GAS PROPORTIONAL COUNTERS.

Control Program - A control program is carried on to determine the accuracy of the thorium chemical air sample determination. The Quality Control Laboratory prepares "spiked" filter paper samples with known amounts of thorium.

These samples with prepared IBM cards are sent along with the regular samples to the Bioanalysis Laboratory where they are treated in the same manner as routine samples. If the results from such samples indicate a large variance or significant bias, the situation is investigated and corrected.

Air Monitoring - Tritium - Monitoring for air-borne tritium is confined to those areas where the material handled might contain tritium contamination.

The methods of sample collection and activity measurement are applicable only to the determination of tritium contamination.

Permanently installed gas monitors (Cary Model 34), used for this type of monitoring, consist of a blower to pull air through an ionization chamber and a vibrating-reed electrometer to detect the amount of current across the ionization chamber. This current is calibrated as tritium concentration and continually recorded. These monitors are set to alarm at levels above the PAL of 20 $\mu c/M^3$. Semiportable instruments of this type are used to check material and equipment, as shown in Figure 24.

A small ionization chamber-type instrument is used for taking an on-the-spot or "grab" sample. With this instrument, the chamber is evacuated and taken to the site to be monitored. The sample is collected by opening the valve and allowing the chamber to return to atmospheric pressure, then the air-filled chamber is attached to a vibrating-reed electrometer like that shown in Figure 12 which measures the conductivity resulting from the sample collected. The electrometer is calibrated so that the electrical current results are readily convertible to units of tritium concentration ($\mu c/M^3$).

Removable Contamination Monitoring

Where radioactive materials are handled or processed it is expected that work areas and/or equipment will become contaminated with these materials. Generally, such contamination is loosely fixed and may be transferred by rubbing off, tracking, or becoming air borne. Surveys are made routinely in all controlled or processing areas of Y-12 to determine the extent of removable surface contamination.

Sampling Method - The smear or wipe sampling technique is used to determine both the extent of contamination and how readily the radioactive contamination can be removed. Routine smears for surface contamination monitoring are taken on standard IBM cards which have been keypunched in advance for each area to be monitored. Prepunched cards contain such information as general area location, specific smear location, type of smear (settled dust surfaces or floor), and the control criterion for removable contamination for the specific area. An example of this card is shown in Figure 25.

An automated device for taking smears is shown in Figure 26. An IBM card is placed into the smear holder allowing a portion of the card to be exposed. Then the card

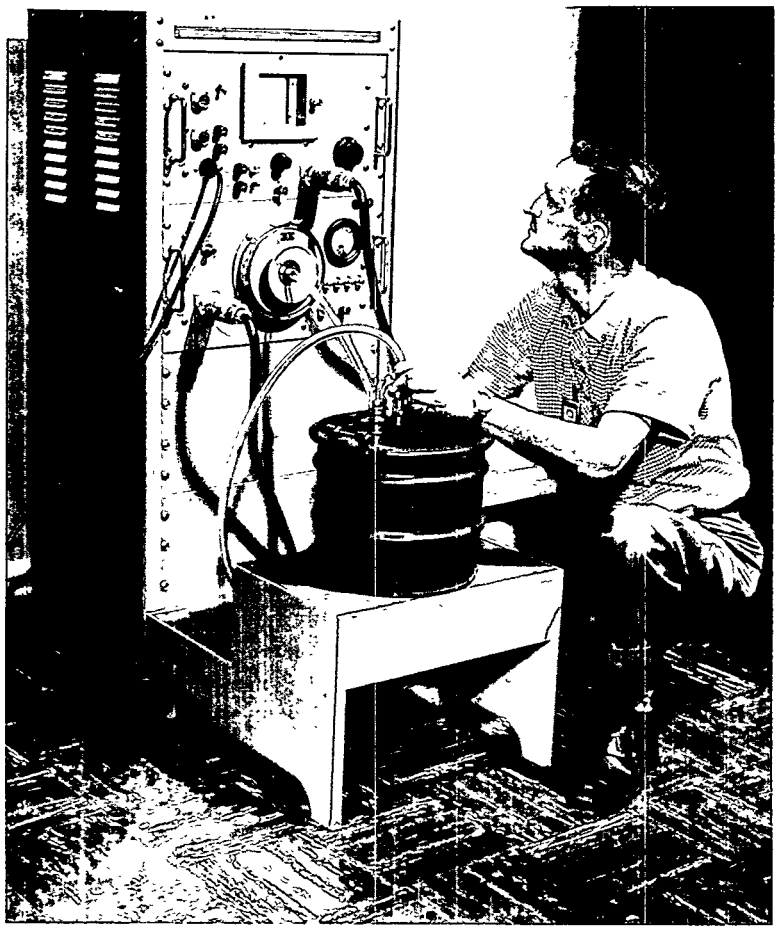

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Figure 24. SEMIPORTABLE TRITIUM MONITOR.

holder, resting on two, small, sled-like runners, is moved over the surface being smeared. (The card pressure on the surface is kept uniform by a tension spring.) An index wheel is calibrated so that one revolution of the wheel moves the smear over 100 cm^2 of surface. Samples are sent to the laboratory where they are counted on an automatic counter, shown in Figure 27, which also punches the data into the card. On completion of the counting cycle, the cards are sent to the Tabulating Services Department where the results of individual samples are tabulated on a daily report by an IBM 1401 Computer. Summaries are composited into weekly, monthly, and quarterly reports which go to supervision. Figure 28 gives a programmatic diagram of the entire system.

For specific limits and control criteria for surface contamination see Table 9.

Classification of Smears - Smears taken in processing areas are classified according to the surface on which they are taken; namely, floors and settled dust surfaces. The technique for taking the smears is the same for both classifications.

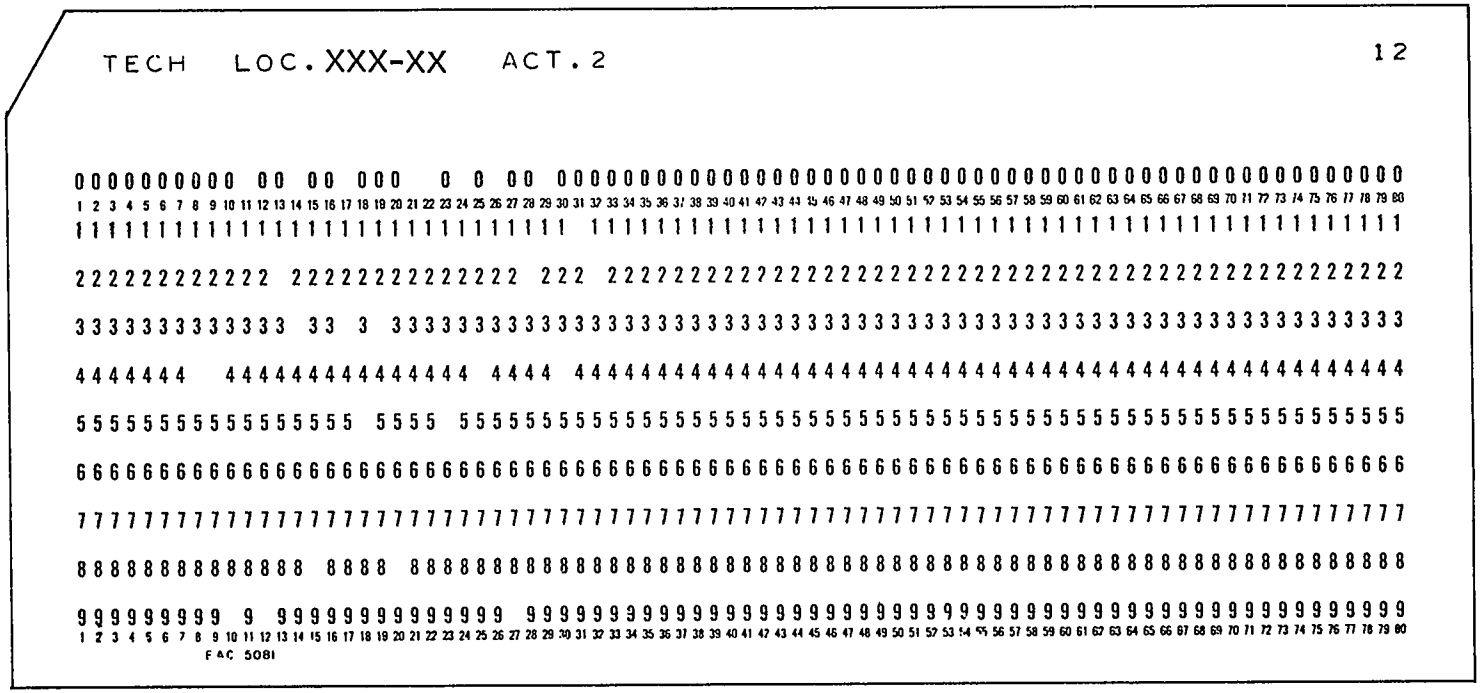
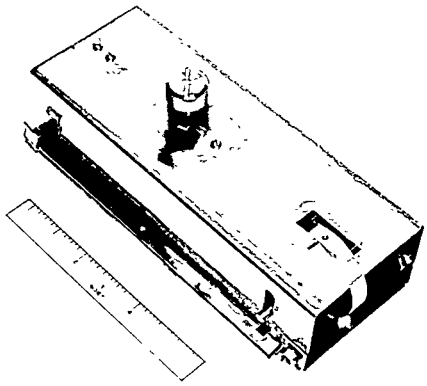
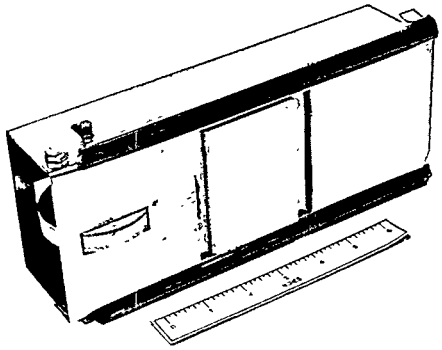


Figure 25. IBM SMEAR CARD.



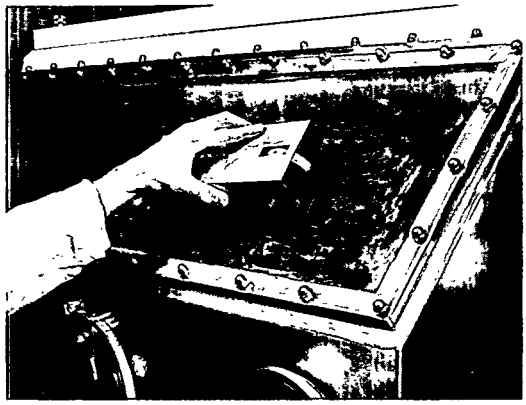
Step 1



Step 2

Step 3

Step 4



Step 5

Step 6

Figure 26. PORTABLE SMEAR DEVICE.

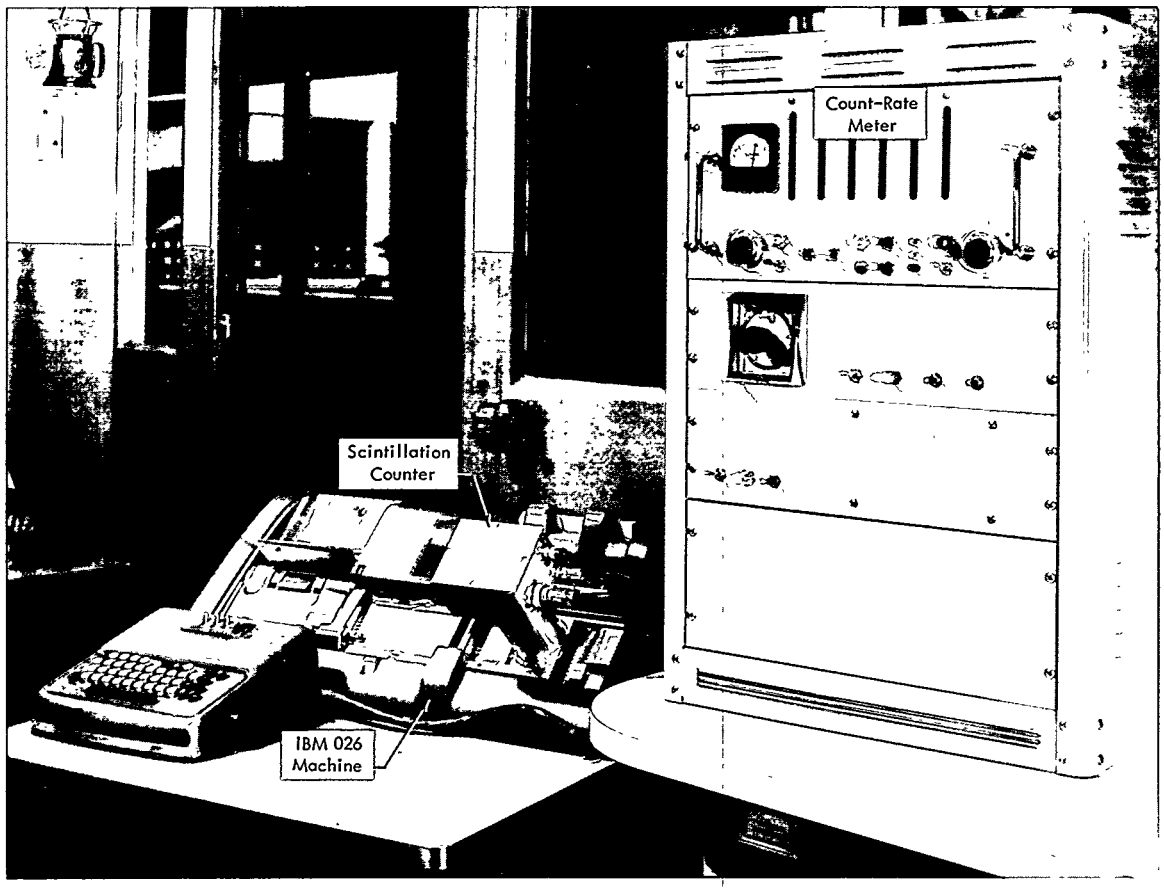


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Figure 27. AUTOMATED SMEAR COUNTING SYSTEM.

Floor Samples - Smears taken on floors are indicative of the quantities of material which can be spread to other areas by tracking. They can also be helpful in evaluating the extent of material losses from equipment leaks or poor operating techniques, and the effectiveness of housekeeping practices. Some contamination is to be expected on floors in processing areas; however, it is usually kept under control by normal housekeeping practices. Special control methods are used if increasing levels of contamination indicate the need.

Settled Dust Surfaces - Smears taken on such surfaces as pipes, window sills, and light fixtures are indicative of air-borne contamination which has settled. Loosely deposited material on these surfaces may again become air borne if disturbed.

Control Program - On a random basis, duplicate smears (approximately 2%) are taken in each area in an effort to duplicate results. Results from these duplicates are used in a statistical evaluation of the program.

In order to assure proper operation of the counting equipment and identify background buildup, known standards and blanks are counted along with routine samples.

PLANT-SITE MONITORING AND CONTAMINATION CONTROL

Introduction

It is a policy of the Y-12 Plant to control the transfer and/or disposal of materials in a way that will minimize any radiation or contamination hazard which might be encountered in the handling of such materials. The Health Physics Department monitors the process and nonprocess areas to determine the effectiveness of existing contamination control measures which, in turn, have a direct influence upon the overall health physics program.

In-Plant Transfer Monitoring

At the request of supervision, all material or equipment scheduled for transfer from a controlled area is monitored for radioactivity and/or contamination and properly tagged before removal. A controlled area is one that requires personnel protective measures due to the nature of the material being processed or handled. By this procedure the spread of contamination and the number of controlled areas are kept to a minimum. Table 10 lists the limits for transfer and in the sections to follow, the three levels of contamination are defined.

Uncontaminated Materials - Materials or equipment that have been monitored and classified as "uncontaminated" according to the limits set forth in Table 10 are tagged with a green Material Transfer Clearance Tab. This tag is shown in Figure 29.

Alpha-Contaminated Materials - An orange Contamination Tag with magenta lettering is used if a survey of materials to be transferred from a controlled area shows alpha contamination greater than the limits stated in Table 10. The Health Physics Inspector who makes the survey writes pertinent information and/or recommendations on the tag, signs it, and attaches it to the material or equipment. Both sides of this tag are shown in Figure 30.

Materials Contaminated with Beta, Gamma, or Neutron Emitters - When material or equipment is found to be emitting beta, gamma, or neutron radiation greater than the limit shown in Table 10, a yellow Radiation Tag with magenta lettering is used. The Health Physics representative making the survey writes on the tag all pertinent information such as type of radiation, dose rate, and precautionay recommendations, signs the tag, and attaches it to the material or equipment. Both sides of this tag, shown in Figure 31, may also be used to indicate a radiation hazard area.

Special Operation Monitoring - Occasionally it may be necessary to transfer to shops or other nonprocessing areas contaminated equipment (properly tagged) which cannot be decontaminated before leaving the process area; or which, because of its construction, cannot be decontaminated. Similarly, it may be necessary, because of the need for equipment or space which is unavailable in a process area, to set up a pro-

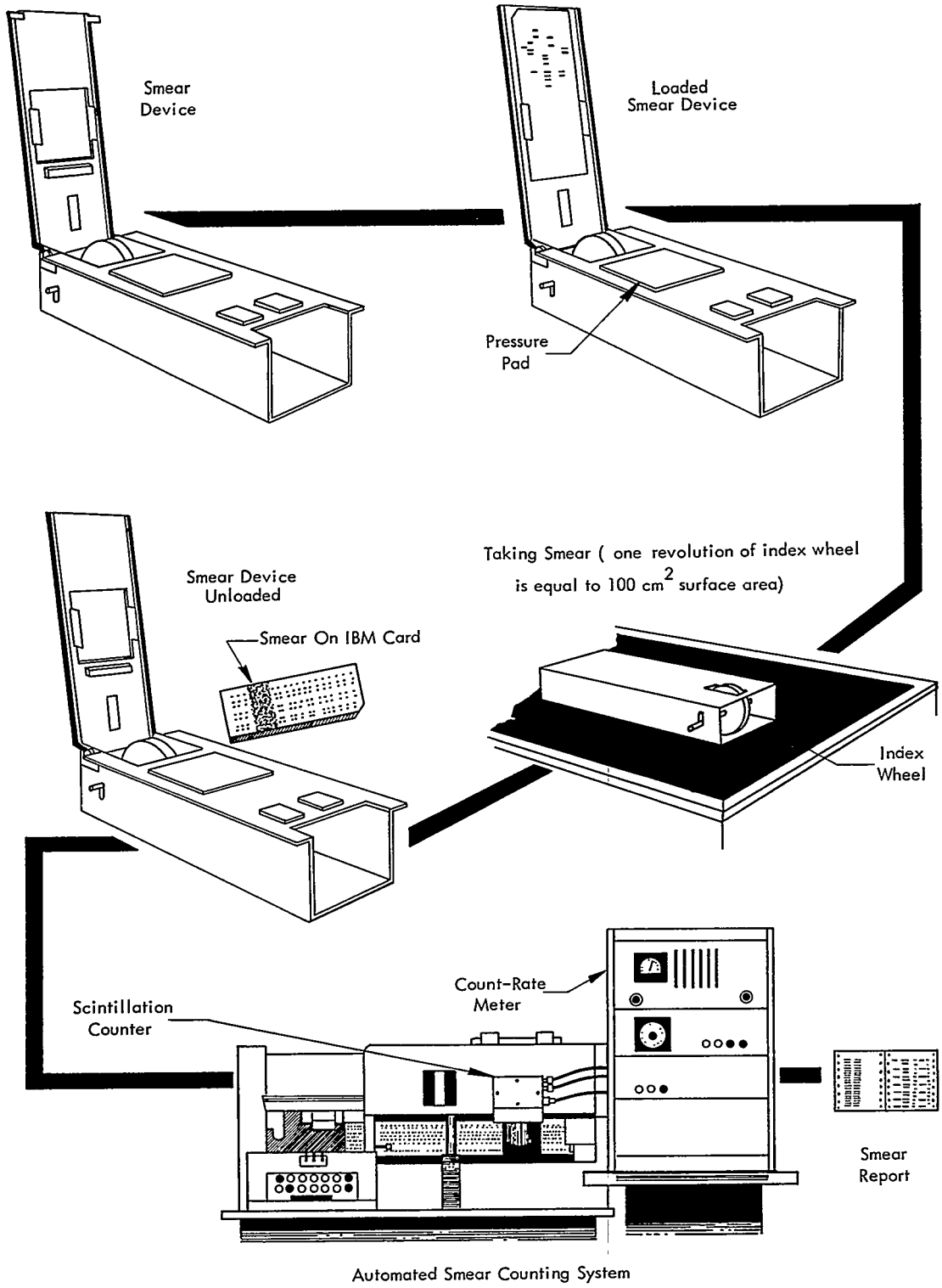
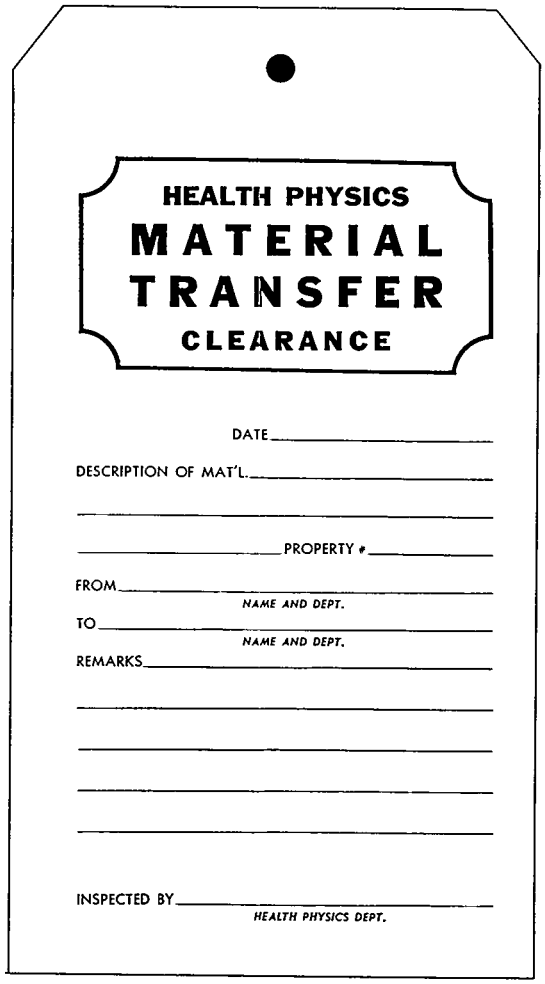


Figure 28. STEPS IN THE Y-12 SMEAR CONTROL PROGRAM.


HEALTH PHYSICS
MATERIAL
TRANSFER
CLEARANCE

DATE _____

DESCRIPTION OF MAT'L. _____

_____

_____ PROPERTY # _____

FROM _____
NAME AND DEPT.

TO _____
NAME AND DEPT.

REMARKS _____

_____

_____

_____

_____

INSPECTED BY _____
HEALTH PHYSICS DEPT.

Figure 29. MATERIAL TRANSFER TAG. (Green)

gram for processing radioactive materials in a nonprocessing area or shop. On occasions such as these, the Health Physics Department provides the necessary survey and monitoring services for the duration of the operation; utilizing the methods of film monitoring, urinalysis, air sampling, or surface contamination monitoring as required. Following the completed operation, the area is surveyed to assure that it is adequately clean.

Beryllium Transfer - Transportation of beryllium products is made in approved and properly labeled containers.

Continuous Outdoor Air Sampling

The Health Physics Department maintains 11 continuously operating outdoor air samplers located throughout the Y-12 area. They are located to be downwind from the uranium processing areas. Figures 32 and 33 are views of the outside and inside

Figure 30. FRONT AND BACK OF A CONTAMINATION TAG. (Orange with Magenta Lettering)

of one of the sampler stations. Each sampling station consists of a power-driven pump, rotometer, and an 8 by 11-inch sampling head protected from the weather. Samples are collected on Whatman 41 filter paper and are changed two times each week. All samples are identified on Air-Borne Uranium Concentration Record cards (Figure 34). The filtered sample is cut in half. One half is used by Industrial Hygiene; the other half is sent by Health Physics to the Bioanalysis Laboratory with duplicate record cards for alpha and beta counting.

The half sample (8" x 5 1/2") is counted in a PC-6 proportional counter (Figure 22) for two, 4-minute periods for alpha determination. A four-inch disc is then cut from the sample and counted in a Sharp's Beta Counter (Figure 35) for two, 5-minute periods. Sample results are adjusted for sample size and recorded on the appropriate record cards which are returned to Health Physics. Completed record cards are sent weekly to the Tabulating Services Department for machine calculation and tabulation. Air-sampling results are subsequently reported to supervision quarterly.

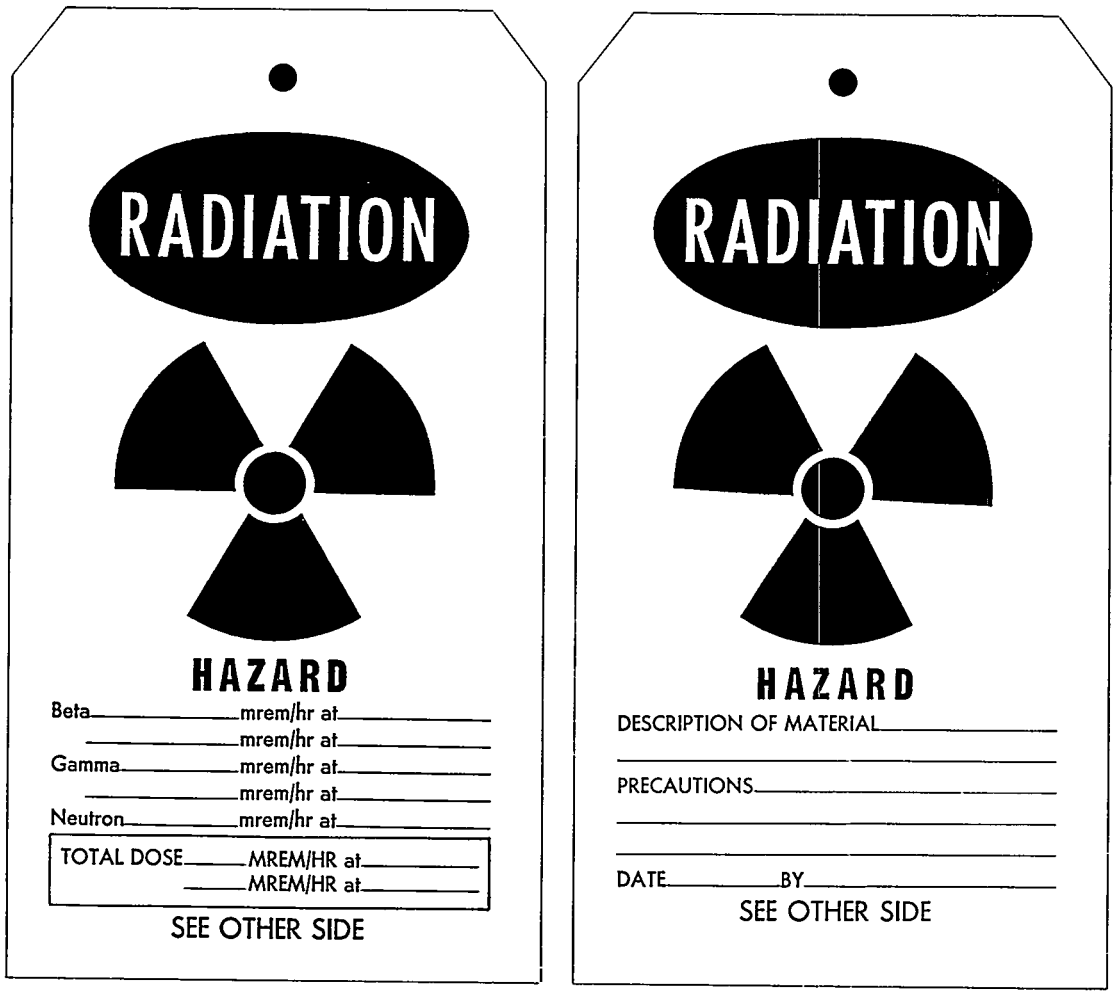


Figure 31. FRONT AND BACK OF A RADIATION HAZARD TAG. (Yellow with Magenta Lettering)

Stack Gas Sampling

Process equipment and ventilation exhaust stack gases are sampled routinely for uranium concentration as a service to operations to help them estimate the loss of accountable material. Loss of material for accountability purposes is controlled to the degree that there is little likelihood of an air-borne concentration problem in the plant atmosphere resulting from stack releases.

Sampler heads are permanently installed in those stacks of interest. A typical stack air sampler is shown in Figure 36, and consists of a quick-opening holder for the 1 1/4-inch-diameter filter paper and a rotometer to adjust the air flow. The rotometer is provided by an attachment to a vacuum manifold.

The sampling schedule is subject to review by both supervision and the Health Physics Department, and will be altered whenever the need is indicated by trends in sample data.

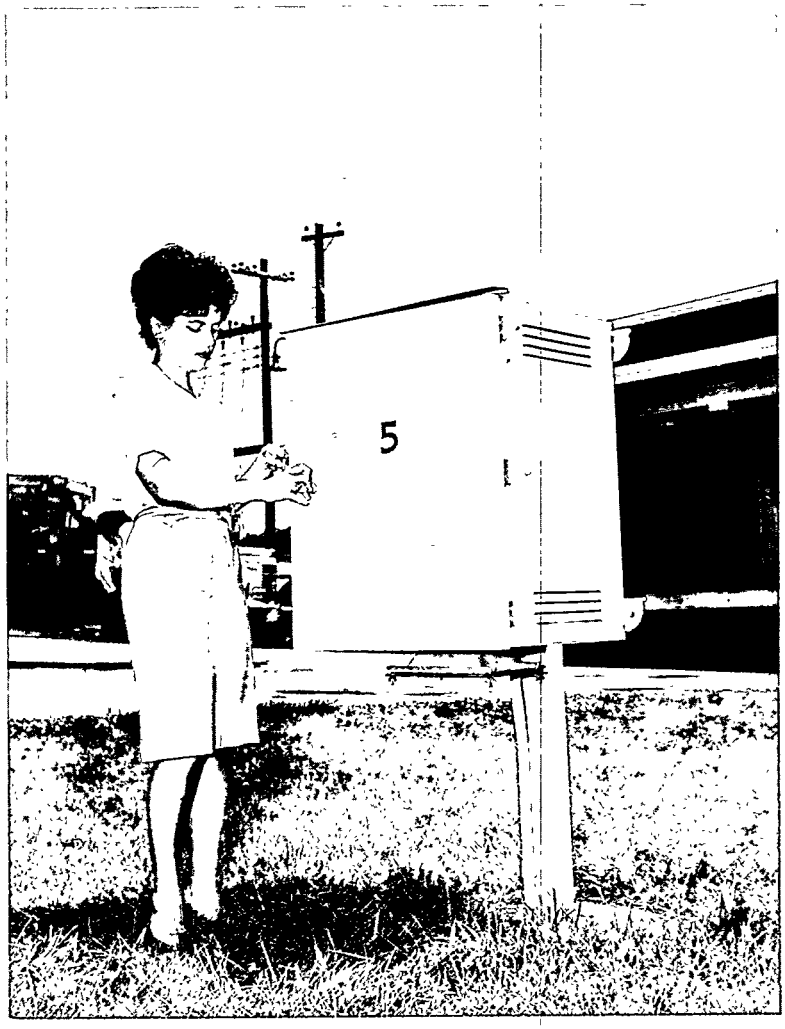


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Figure 32. ONE OF THE OUTSIDE AIR SAMPLING STATIONS.

Stack samples are counted and the data are handled in much the same manner as area permanent air samples. The results of the samples are reported to supervision in units of grams lost per day.

Annual Smear Survey

A contamination survey is made annually of all buildings in Y-12 in which personnel are assigned to regular work. This survey is conducted principally to ascertain that the nonprocessing areas are free of radioactive contamination. It also helps evaluate the effectiveness of the control programs and efforts to prevent the spread of contamination. The smear-sampling method used is that described under the section, Removable Contamination Monitoring, Page 51. Results from this survey are tabulated and reported in a routine annual report to plant supervision.

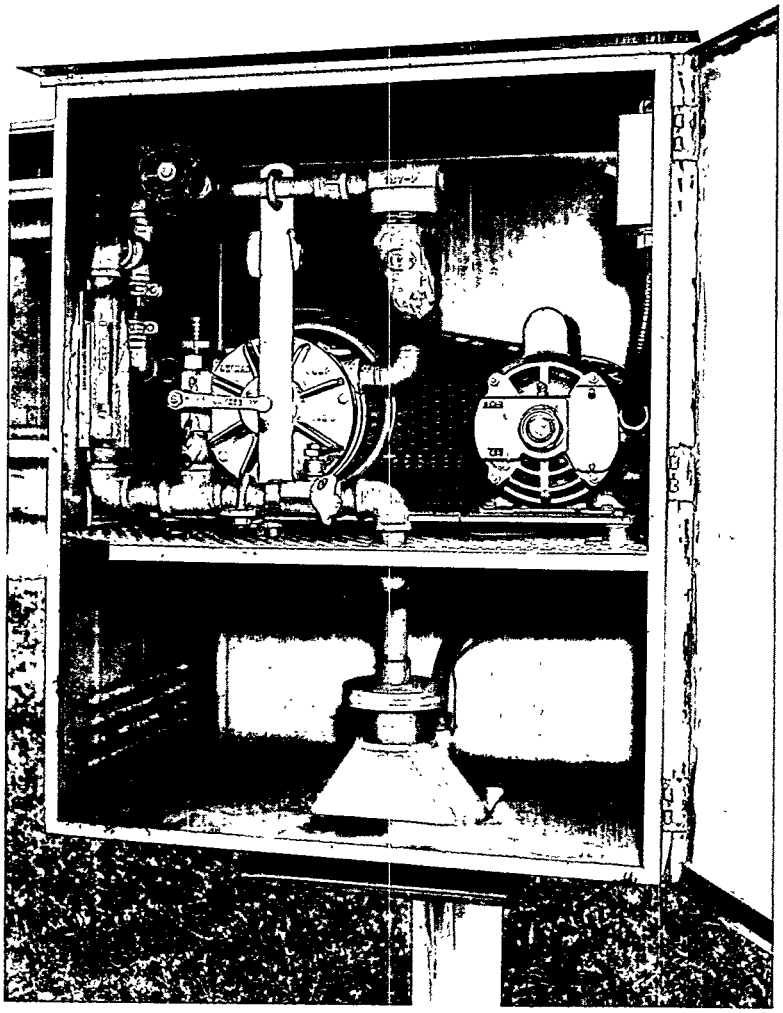

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Figure 33. INTERIOR VIEW OF AN AIR SAMPLING STATION.

OFF-SITE MONITORING AND CONTAMINATION CONTROL

Introduction

Off-site monitoring and control programs are designed to assure that exposure to population outside the plant site presents no undue hazards which are attributed to Y-12 operations.

Shipment Monitoring

All radioactive materials being shipped from the Y-12 Plant by common carrier must meet the radiation and/or contamination requirements as stated in the regulations published by the Interstate Commerce Commission, Civil Aeronautics Board, United States Coast Guard, or the Post Office Department. It is also the desire of the AEC to maintain these same criteria on all AEC modes of transportation whenever feasible.

AIR-BORNE URANIUM CONCENTRATION RECORD

DATE

OBSERVER

AVERAGE FLOW	START	FINISH	LOCATION	TOTAL MIN.	VOLUME OF AIR	COUNTING TIME	EFFICIENCY	DUPLICATE COUNTS

Figure 34. AIR-BORNE URANIUM CONCENTRATION RECORD CARD. (Yellow with Black Lettering)

These regulations are covered in detail in various government publications: The "Federal Register", the "US Postal Guide", and the "Handbook of Federal Regulations Applying to Transportation of Radioactive Materials" published by the AEC.

Shipping and Receiving - At the request of supervision, the Health Physics Department will make any surveys necessary to ascertain that shipments leaving the Y-12 Plant meet the requirements as stated in the three government publications and the limits given in Table 11. The Health Physics Department will also make any surveys necessary to ascertain that common carriers (box cars, trucks, or trailers) which have delivered radioactive shipments to the Y-12 Plant are not contaminated in excess of the recommendations contained in the aforementioned regulations when they leave the plant area. Items to be shipped from the Y-12 Plant, after having passed the necessary contamination requirements (Table 11) are approved for shipment by the Health Physics representative.

Parts and Product Shipment Surveys - Upon request of supervision, the Health Physics Department makes the necessary surveys on outgoing product material. There are certain parts or units shipped from the Y-12 Plant which, due to the type of material, destination, and eventual use, must meet certain contamination criteria; therefore, it is necessary to survey the part for removable contamination prior to packing. In most instances, however, the items to be shipped have only the external container surveyed.

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Figure 35. BETA ACTIVITY COUNTER.

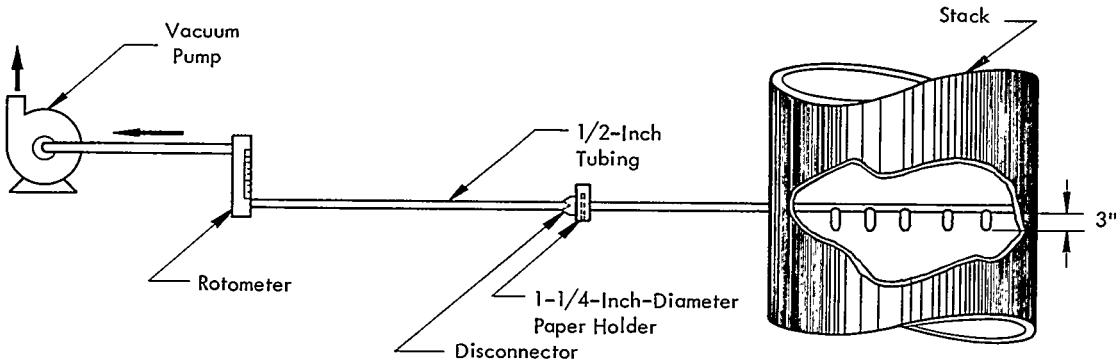


Figure 36. COMPONENTS OF A REPRESENTATIVE STACK SAMPLING APPARATUS.

When it is necessary to survey a unit or part, the entire surface of the unit and its container are smeared for removable alpha contamination. If they are within the limits as stated in Table 11, an appropriately stamped card is completed, signed, and attached to the inside container. Surveys performed upon the external container

consist of obtaining a direct and removable alpha contamination reading and a beta-gamma reading; both direct readings are at contact and at one meter. The millicurie content is determined by using the type, weight, and specific activity of the material.

If this overall survey reveals that the items comply with the criteria as stated in Table 11, the appropriate labels are attached (when applicable) and Inspection Form (see Figure 37) is completed by the Health Physics representative.

One copy of this form is sent to the SS Control Department, one to the Traffic Department, and one retained as a part of a permanent shipping file.

Liquid Waste Monitoring

Samples are taken from all effluent streams and disposal ponds in the Y-12 area. From these samples the level of contamination which is discharged into these streams from

SOURCE, SPECIAL NUCLEAR AND OTHER RADIOACTIVE
MATERIAL SHIPMENT INSPECTION REPORT

SECTION 1*

CONSIGNEE

DESTINATION

TYPE OF CONTAINERS *(Indicate ICC Specification or Other Description as required by material)*

MODE OF TRANSPORTATION

INSPECTED FOR SHIPMENT BY

NAME

DEPARTMENT

DATE

SECTION 3

TYPE LABELS APPLIED

Shipment has been surveyed and complies with radioactive limits by:

Name _____

Department _____

Date _____

SECTION 2 / SECTION 4

CONTAINER NUMBER (If Applicable)	TYPE MATERIAL	NET WEIGHT OF MATERIAL	ALPHA ACTIVITY SMEAR d/m/			DIRECT READINGS		mc's PER CONTAINER	RADIATION UNITS PER CONTAINER***	DESCRIPTION & REMARKS
			UNIT AND/OR PART	CONTAINER INSIDE	CONTAINER OUTSIDE	ALPHA d/m/100 cm2**	BETA-GAMMA mr/hr			

DISTRIBUTION: White - Traffic Department (with Shipping Request)
Pink - SS Control Department
Canary - Health Physics Department

*Complete Section 1 after completion of Sections 2, 3, and 4.
**Corrected for Counter Efficiency Only
***Radiation Unit = 1 mr/hr at one meter

Figure 37. SHIPMENT INSPECTION REPORT.

process operations may be determined. Table 12 gives an example of a sampling schedule for all streams and disposal areas.

Table 12

LIQUID WASTE SAMPLING PROGRAM

Source	Frequency	Analysis
Creek A	Weekly	NO_3^-, Cl^-, SO_4^{--}, F^-; α and $\beta + \gamma$; Hg and 39 Other Cations
	Daily	pH
	Monthly	Cations
	Quarterly	Composite for Pu, Th, U, and Fission Products
Creek B	Weekly	NO_3^-, Cl^-, SO_4^{--}, F^-; α and $\beta + \gamma$; Cations
Disposal Ponds (acid pits)	Weekly	α and $\beta + \gamma$
Test Wells	Quarterly	α and $\beta + \gamma$; Cations

Creek A - This creek originates near the west end of the Y-12 area and flows east through the plant area into a lagoon or settling basin. Since this stream carries the major portion of the Y-12 liquid waste, a continuous sampling program is maintained by means of a proportional sampler in order to give a rapid indication of unusual conditions.

The proportional sampler has sampling intakes at the influent and effluent ends of the lagoon. A diagram of the sampling system is shown in Figure 38. Depth and flow of the stream are recorded continuously. The pH value is telemetered into the Plant Shift Superintendents' office where any abnormal change may be readily noted. Water is collected, composited, and sampled weekly, monthly, and quarterly. Samples are analyzed for the materials shown in Table 12 by the Laboratory who forwards the results to Health Physics. A summary of the radiological results is included in the Health Physics quarterly report to the Plant Superintendent. The remaining results go to the Industrial Hygienist for his information and action.

Creek B - This stream flows westward from the plant and south of all disposal areas except the quarry. Samples are obtained by the dip method, or with a portable continuous sampler, approximately one mile downstream from the disposal areas. Samples are then submitted to the Plant Laboratory for the analyses shown in Table 12.

Test Wells - Fifteen geological test wells located west and southwest of the disposal yards are sampled by the dip method on a quarterly schedule to determine the seepage of contamination to the underground water table from the burial and burn yard disposal sites. Samples are analyzed for alpha, beta, and gamma, and results are reported in the same manner as those from the effluent streams

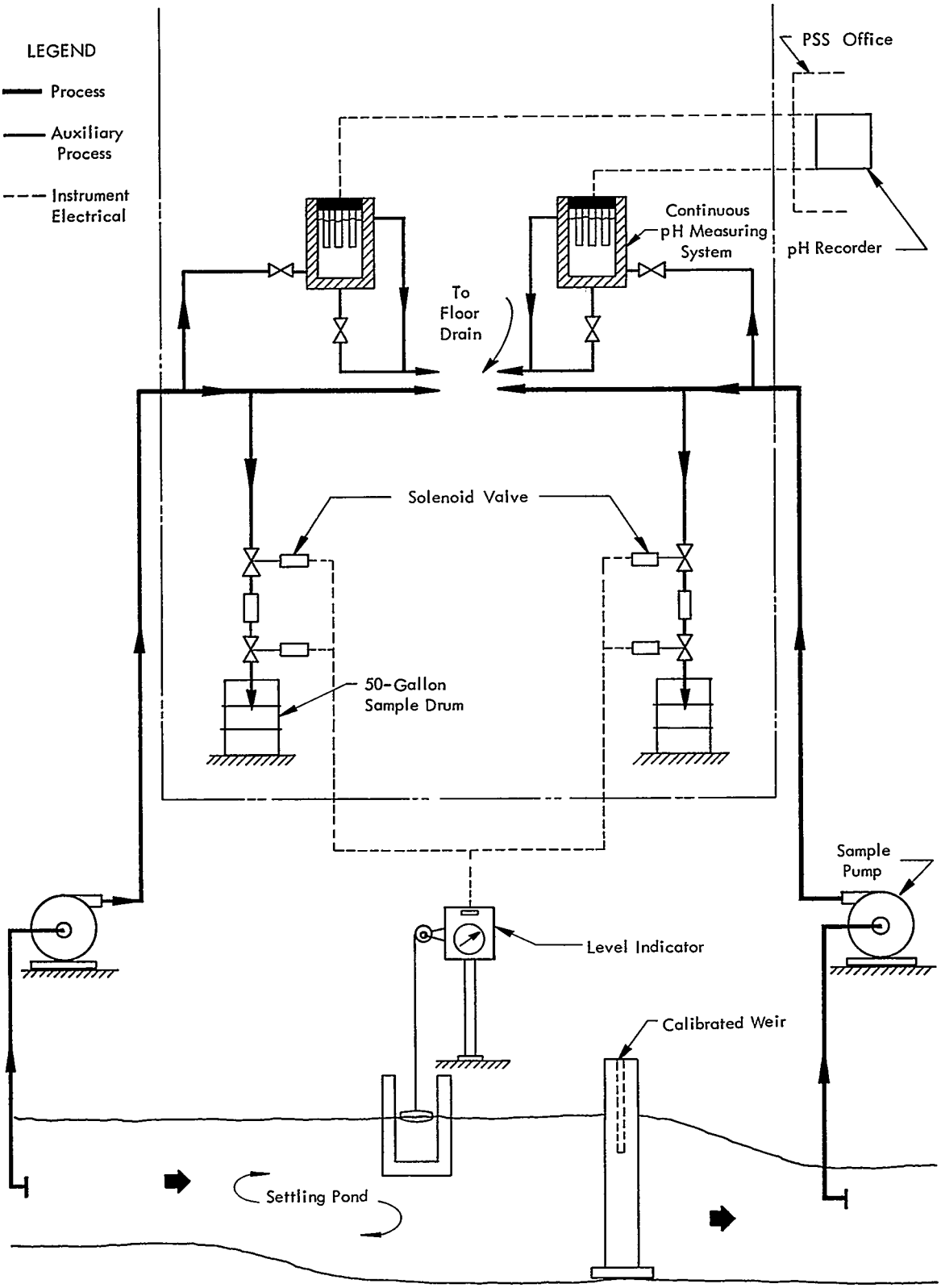


Figure 38. AUTOMATIC CONTINUOUS PROPORTIONAL CREEK SAMPLER.

Disposal Pits - Four disposal pits are located at the extreme west end of Y-12. Samples from these pits are obtained weekly by a thief-type sampler which is slowly inserted into the solution to insure better sample uniformity. Samples are sent to the laboratory and analyzed for gross alpha, beta, and gamma content.

Results from all samples are reported to supervision at the end of each quarter. When elements exceed the criteria, as is stated in Table 7, supervision is immediately notified so that corrective action may be taken.

Disposal of Surplus and Waste Materials and Equipment

To prevent the release of radioactive or toxic materials to nonprocessing areas within the plant or to the general public, checks or surveys are made on all equipment, materials, and scrap which are salvaged or sold to the public. It is Company policy to offer for sale to the public only those materials which are not contaminated or which are within the AEC permissible limits for contamination. Limits and procedures for the proper disposal of such materials are specified in an internal procedure. It is the responsibility of the Material Control Department to offer only those items of surplus material for sale to the public which fall within the established procedures and regulations.

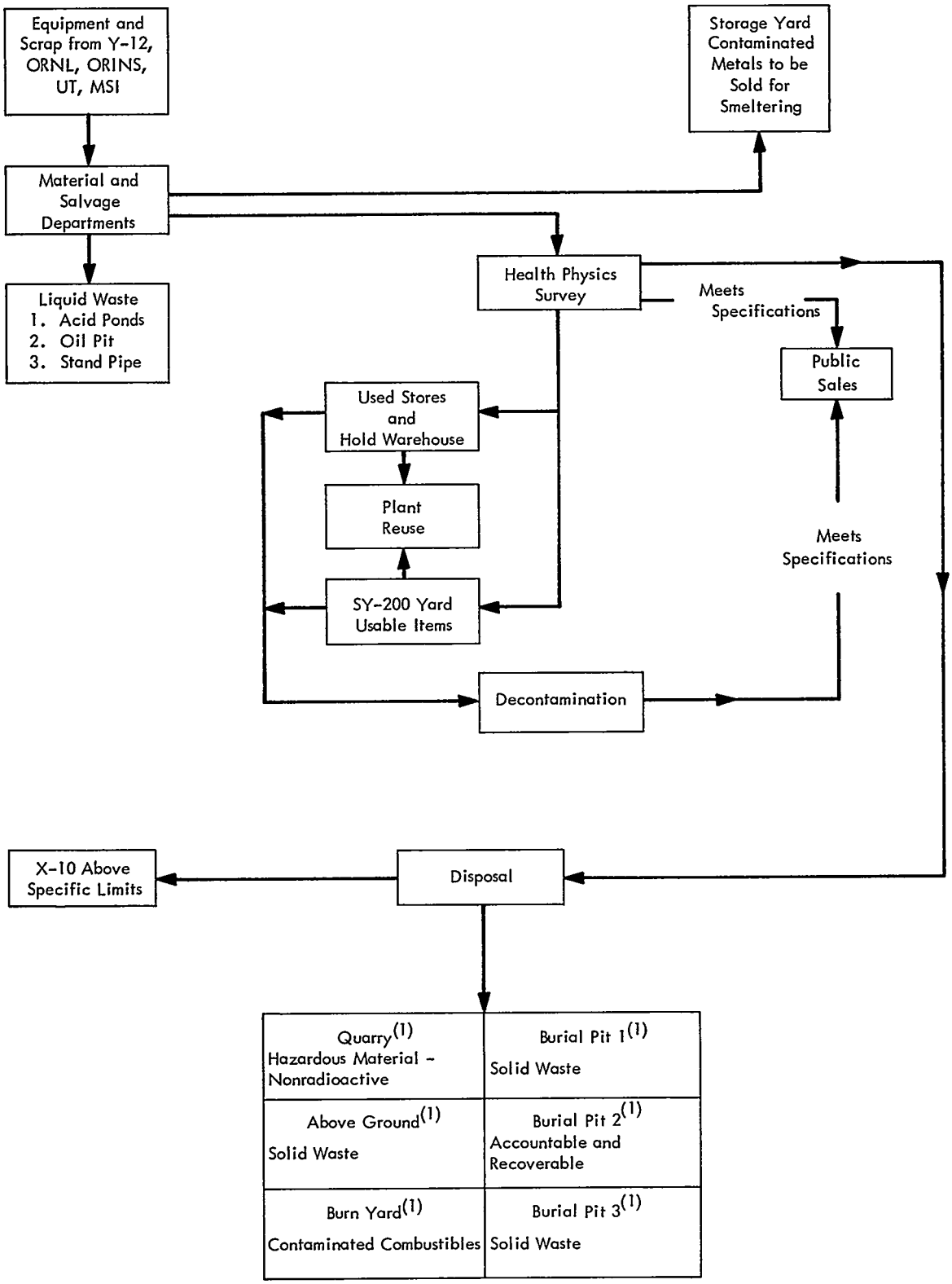
Hazardous chemicals, gases, and radioactive wastes are disposed of according to internal procedures. The Radiation Safety Department makes appropriate investigations upon request and submits recommendations and advice to the Safety Department which completes the arrangements for disposal.

All surplus or waste materials and equipment are disposed of through channels as diagrammed in Figure 39, using the suggested limits for waste disposal as given in Table 13 as guides

Uncontaminated Material Disposal Locations - All materials, equipment, or scrap that are classed as uncontaminated are sent to one of the following locations (see Figure 39):

> Used Stores - Materials or equipment that may be of future use in the Y-12 area are sent to Used Stores.
>
> Public Sales - Materials that have no future use in the plant and have been declared surplus are sent to the Public Sales headquarters where they are offered for sale to the general public
>
> Burn Yard - Uncontaminated combustible scrap or waste such as wood, paper, and rags are sent to the Y-12 burn yard.

Contaminated Material Disposal Locations - Contaminated materials or equipment may be sent to one of the following locations, depending on their usefulness and the degree and type of contamination.



(1) See Table 13 for specific limits.

Figure 39. CHANNELS FOR SURPLUS AND WASTE MATERIALS DISPOSAL.

Table 13

SUGGESTED GUIDE LINE LIMITS FOR WASTE DISPOSAL

Location	Contaminant	Limits: Homogeneous Mixture	Limits: Surface Reading	Comments
			Solids	
Quarry	U	< 40 d/m/gm	Container: < 0.3 mrad/hr < 2000 d/m/100 cm^2	For the disposal of hazardous but nonradioactive materials.(1)
	Other(2)			Should not be disposed of in this location.
Above-Ground Disposal	U	< 6000 d/m/gm	< 3.5 mrad/hr < 25,000 d/m/100 cm^2	For the disposal of voluminous quantities of materials which are not economical to bury.
	Other			Should not be disposed of in this location.
Y-12 Burn Ground	U	< 150,000 d/m/100 cm^2	< 150,000 d/m/100 cm^2 < 20 mrad/hr	For the disposal of contaminated combustibles.
	Other			Should not be disposed of in this location.
Burial Pit 1	U	< 150,000 d/m/gm	< 150,000 d/m/100 cm^2 No limit on $\beta + \gamma$ as long as they are associated with uranium.	For the disposal of low-level (equivalent to 10% by weight of normal uranium) uranium-contaminated waste.
	Other			Should not be disposed of in this location.
Burial Pit 2	U	$< 1.5 \times 10^6$ d/m/gm	No limit as long as the radiation is associated with uranium.	For the disposal of large lots of uranium which may be accountable(1) and/or recoverable.
	Other			Should not be disposed of in this location.
Burial Pit 3	U	$< 1.5 \times 10^6$ d/m/gm	No limit as long as the radiation is associated with uranium.	For the disposal of medium-level (equivalent to 100% normal uranium) materials which are not recoverable.(1)
	Th	$< 3.4 \times 10^5$ d/m/gm	No specified limit.	Thorium and beryllium greater than specified limits are disposed of at the X-10 Burial Ground.
	Be	$< 2 \times 10^4$ µgs/gm	No specified limit.	

(1) Requires special form.
(2) Other - such as Np, Th, Be, and Pu.

Table 13 (cont'd)

Location	Contaminant	Limits: Homogeneous Mixture	Limits: Surface Reading	Comments
X-10 Burial Ground	All Contaminants	No upper limits.	No upper limits.	Materials which exceed limits for Burial Pits 2 or 3[1].
			Liquids	
Quarry	U	< 40 d/m/gm	Container: < 0.3 mrad/hr < 2000 d/m/100 cm^2	For the disposal of hazardous but nonradioactive materials.[1]
	Other[2]			Should not be disposed of in this location.
Acid Pits	U	< 1.5×10^6 d/m/gm Average concentration of water in pit not to exceed 6000 d/m/ml.		Disposal of waste in water or acid solution.
	Other			Should not be disposed of in this location.
Burial Pit 1A	U	< 150,000 d/m/gm		Liquid waste which cannot be disposed of in acid pits, such as oils.
	Other			Should not be disposed of in this location.
Liquid Salvage Sump	Be	< 2×10^4 μgs/ml		For the disposal of Be-contaminated liquid.
	Th	7.3×10^5 μgs/ml		
X-10 Burial Ground	All Contaminants	No upper limits.		Materials which exceed limits for Acid Pit or Burial Pit 1.
Creek A			No specified limit.	Uranium solutions may be disposed of in creek as long as as they are in such quantity and released at such a rate that the creek concentration does not exceed 65 d/m/ml alpha. Other materials should not be disposed of in this manner.

(1) Requires special form.
(2) Other - such as Np, Th, Be, and Pu.

Used Stores - Some items of equipment that appear to have further usefulness are retained by Used Stores, and made available for plant use. Such items are properly tagged to indicate the type and amount of contamination.

Public Sales - Materials with some surface uranium contamination may be offered for public disposal provided they meet the limits and specifications as set forth in internal procedures.

Storage Yard - Contaminated scrap metals are stored in the Storage Yard and eventually sold provided they are smelted before further use.

Y-12 Burial Grounds - Y-12 has three burial areas.

1. Yard A is used for burying low-level (or < 10% by weight of normal uranium) materials.

2. Large lots of uranium which may be accountable or reclaimable are put into Yard B.

3. Material contaminated with medium-level contamination (equivalent to 100% normal uranium) are disposed of in Yard C. This yard is also used for the disposal of thorium and beryllium-contaminated materials.

Burn Yard - Combustible materials that are contaminated with alpha activity $< 1.5 \times 10^5$ d/m/100 cm^2 are burned in the Burn Yard.

X-10 Burial Ground - Contaminated materials that cannot be disposed of in any of the other areas are sent to the X-10 Burial Ground. Some elements with the limits that require burial at X-10 are:

Uranium - $> 1.5 \times 10^6$ d/m/gm

Thorium - $> 3.4 \times 10^5$ d/m/gm

Plutonium - Any Detectable

Neptunium - Any Detectable

Beryllium - $> 2 \times 10^4$ μgms/gm

All other materials with high specific activity and/or high health hazard index.

SPECIAL SURVEYS

Abnormal Result or Condition Investigations

When unsatisfactory conditions are found, or when the results indicated by either personnel or environmental monitoring are abnormally high, special surveys to isolate the causes may be indicated. Personnel radiation exposures, either external or in-

ternal, in excess of Radiation Protection Guide levels are always investigated in an attempt to explain the indications. Some of the special surveys which may be performed are as follows:

1. Special intensive film or instrument surveys or special film calibrations may be used to investigate abnormal external exposures.

2. Increased frequency of urinalyses or in vivo measurements, 24-hour elimination samples, or fecal samples may be used to investigate abnormal indications of internal exposure.

3. Special breathing-zone or operational samples, or the installation of additional permanent sampling heads, may be used to investigate abnormally high air-sample results or unsatisfactory trends in air levels.

4. Special surveys involving problems of an industrial hygiene nature may be made using specific monitoring equipment peculiar to the nature of the situation.

New-Operation Investigations

New operations with radioactive materials are always the subject of intensive air sampling programs. Additional permanent sampling heads, portable-equipment general air samplers, and many breathing-zone or operational samples all may be used to evaluate the air-borne contamination potentialities of a new operation. Special film programs or special urinalysis programs may be used to assist in the evaulations.

Special-Operation Investigations

Special monitoring programs are set up to evaluate the hazards generated by special operations. These operations may be short-duration emergency operations and may have great hazard potential, or they may be operations that are carried on temporarily in nonprocessing areas. Any of the methods of film monitoring, urinalysis, in vivo measurements, air sampling, or surface contamination monitoring may be used as required to protect personnel or evaluate environmental conditions.

Source and X-Ray Surveys

At the request of supervision, the Health Physics Department will make any surveys necessary to evaluate the shielding requirements, radiation intensities, or operating techniques used around source installations or X-ray generators. Special surveys are made during the changing of sources, startup operations of source or X-ray installations, or during the special or unusual use of such equipment.

CALIBRATION PROGRAMS

Introduction

The purpose of the Radiation Safety calibration program is to maintain the accuracy of monitoring and sampling instruments. All radiation survey and sampling instruments are calibrated routinely. In addition, instruments are always recalibrated after repair.

Radiation Survey Instruments

Radiation survey instruments are calibrated using appropriately calibrated sources as standards. A Victoreen R-Meter, which has been calibrated by the National Bureau of Standards, is used as a primary standard.

Air Chamber-Type Instruments - These instruments which are used for intermediate and high-range gamma monitoring are calibrated with a Co-60 source which is itself calibrated quarterly against the primary standard. Figure 40 shows the surface of the deep-well calibration facility used for this purpose. The instrument to be calibrated is positioned on the lucite slide covering the well in which the source is positioned to the desired distance by a power-driven mechanism. The counter at the right shows the distance in centimeters from the source to the top of the lucite platform. The well is approximately 500 centimeters deep. In addition to varying the dose rate with distance, a two-inch sliding lead shield is used in the open and closed positions. Calibration curves are drawn for dose rates as a function of distance with the lead shield in each position.

Some air chamber-type instruments; namely, the Samson and the Juno, are calibrated for alpha. A set of alpha-source discs, which are checked periodically against the primary standard in the Plant Laboratory, are used for this purpose. Calibration is accomplished by placing an appropriate source disc against the open window screen of the instrument and making necessary adjustments to the instrument.

Geiger-Mueller Tube-Type Instruments - These instruments are calibrated with a 1.01-millicurie radium source. The activity of the source is checked against a radium standard certified by the National Bureau of Standards. The facility for this purpose is shown in Figure 41. As shown, the source is mounted in a lead shield exposed by opening the end door of the shield and extending the source from the shield into a fixed position by means of a hand-driven screw mechanism. The instrument detector tube is clamped in the carriage holder which is positioned at the desired measured dose distance from the source. The instrument is adjusted to the calculated dose rate at that distance.

Neutron Survey Instruments - An americium-beryllium source containing 3.14 curies of Am-142 and emitting 7.607×10^6 n/sec, as certified by the National Bureau of

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Figure 40. INSTRUMENT CALIBRATION FACILITY FOR INTERMEDIATE AND HIGH-GAMMA RADIATION.

Standards, is used as a primary standard for calibrating neutron survey instruments. The instrument to be calibrated is placed at a measured distance from the source which is suspended in free air. Adjustments are made, as needed, to show a dose rate corresponding to the calculated neutron flux at that distance.

Films for Personnel Monitoring Meters

In order to interpret personnel radiation exposures by means of film dosimetry it is necessary that film be calibrated. This calibration is done by exposure to known doses of radiation and plotting and writing equations for film response as a function of the dose. Personnel film exposure can then be compared with the calibrated film, and dose measurements determined. Separate calibrations are made for beta and gamma exposures. Dose from a given source can be controlled by varying either time or distance. This control is currently accomplished by varying time.

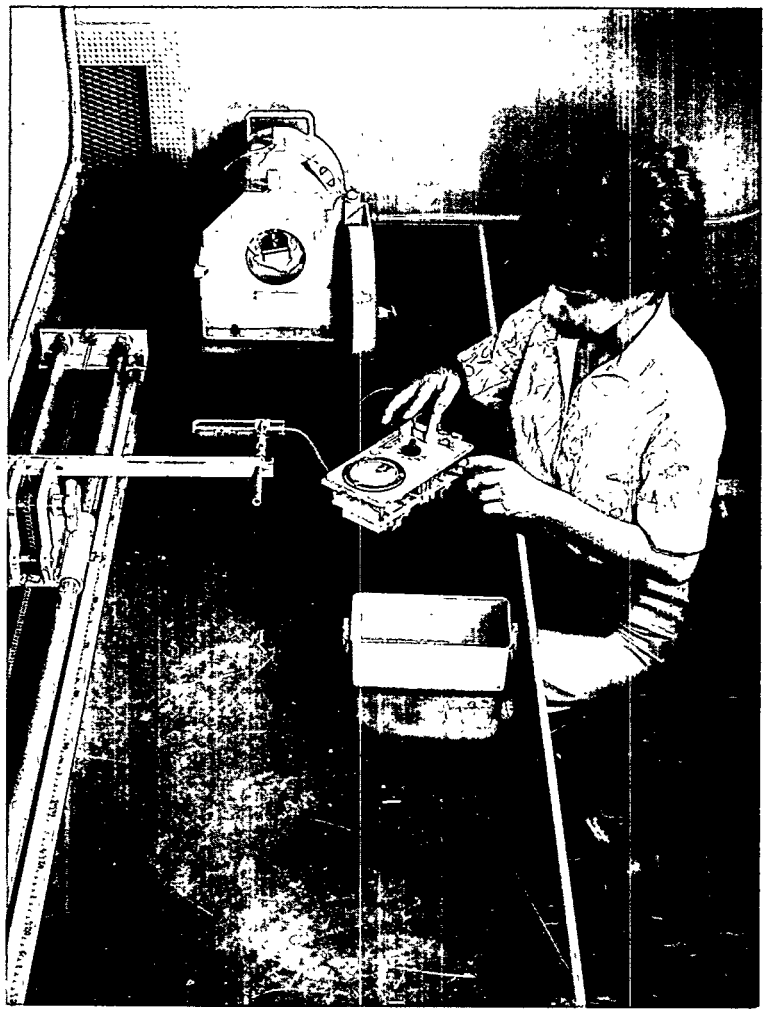

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Figure 41. INSTRUMENT CALIBRATION FACILITY FOR LOW-GAMMA RADIATION.

Beta-Sensitive Films - Films are calibrated for beta dose by exposure to uranium beta radiation. The beta dose rate at the surface of the uranium slab is taken as 240 mrads per hour. Three sets of films, with twelve each, are exposed in plant-type badges. One badge from each set (three badges) is given one of 12 doses ranging from 0 to 5000 mrads. The badges are placed in an automatic timer-controlled holder (Figure 42) which positions them on the uranium slab and removes them at the end of the predetermined exposure time. The films are then unloaded from the badges and given to the Bioanalysis Laboratory for processing.

Gamma-Sensitive Films - Gamma rays from cobalt-60 are used to calibrate gamma films. The Co-60 source is calibrated quarterly using a Victoreen R-Meter. Dose rate is determined by placing the R-Meter chamber in juxtaposition with the badges and reading the dose over a measured period of time. Figure 43 shows the facility

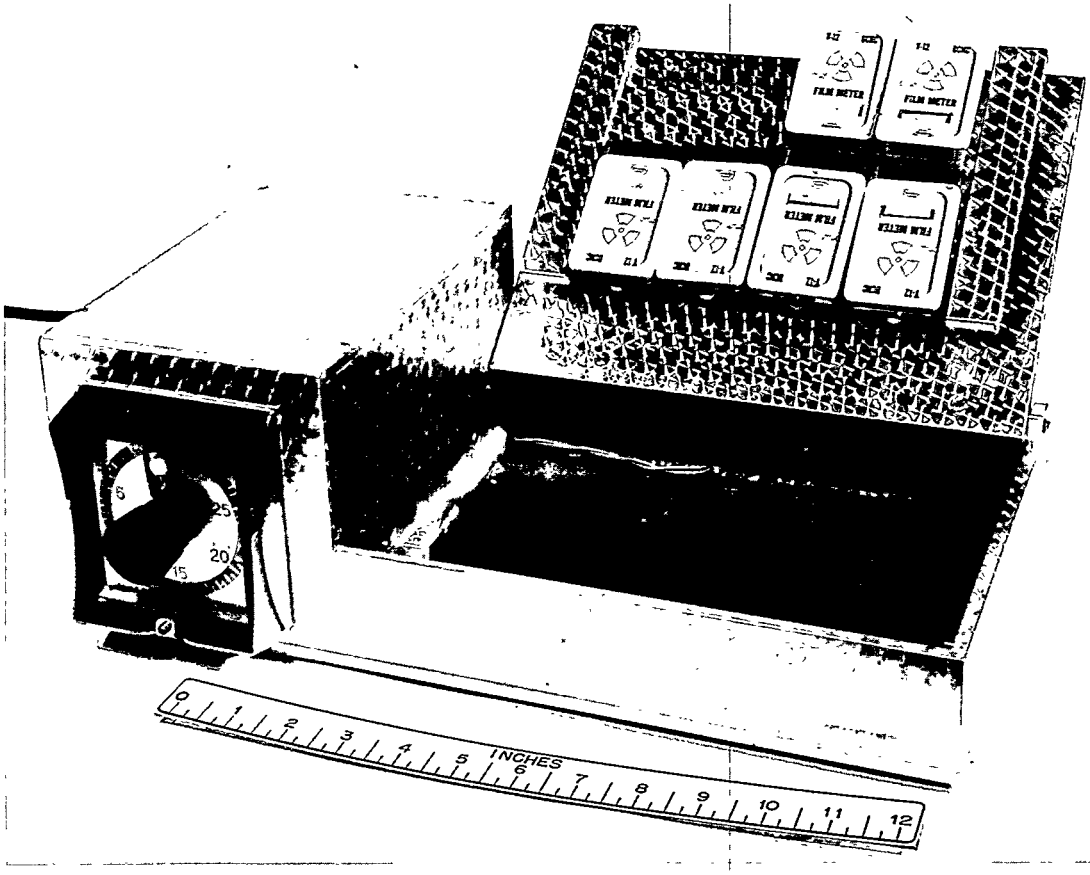

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Figure 42. FILM CALIBRATION INSTRUMENT FOR BETA RADIATION.

used for this purpose. Three sets of films, with 12 films in each set, are loaded into badges which are placed onto the lucite disc three at a time. Vacuum is used to raise the source into position in the center of the disc. The badges which are backed up by four inches of lucite are one foot from the source when it is in position. Dosage is varied with time which is controlled by an electric timing device. When the vacuum pump (shown in upper left corner of Figure 43) stops, the source drops by gravitational force back into the shield. Three badges at a time (one from each set) are given one of the following doses in mrads: 0, 30, 120, 240, 480, 720, 960, 1440, 1920, 2880, 3840, or 5000. The films are unloaded from the badges and sent to the Bioanalysis Laboratory for processing.

All calibration films are processed by standard processing procedures along with routine films. After the films have been read, the results are given to the Statistical Services Department who determines the dose-determination equations to be used by Tabulating Services in calculating personnel exposures from routine film badges.

Neutron-Sensitive Films - An americium-beryllium source is used as a primary neutron standard for neutron film calibration. Films are placed at measured distances from the source (suspended in air) and dose calculations made for these distances.

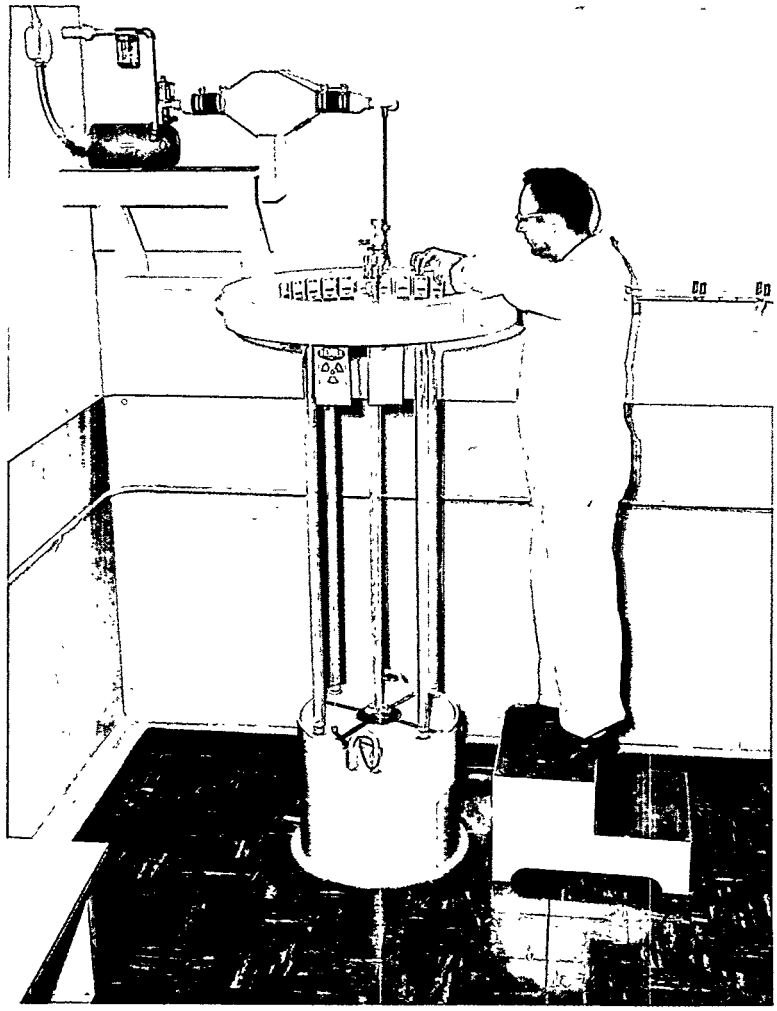

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Figure 43. GAMMA FILM BADGE CALIBRATION FACILITY.

Air Monitoring Instruments

In order to determine the concentration of a contaminant in air it is necessary to know the volume of air sampled. This value is easily calculated if the sampling rate is known. For this reason, air sampling equipment is calibrated routinely.

Hi-Volume Air Samplers - The calibration facility shown in Figure 44 is used to calibrate Staplex Hi-Volume air samplers which are used extensively in the air-sampling program. The facility consists of a Roots Connersville blower and a 2 M^3/min rotometer with a U-tube pressure gage attached. The sampler is mounted, as shown, into the air stream. Both the blower and sampler are started and the resulting air stream regulated by a control valve so that the U-tube indicates a static pressure equal to the atmospheric pressure in the sampling area of the instrument. The flow rate is read from the rotometer for each of several types of filters used on this sampler. Both the flow rate and the calibration date are attached to the instrument.

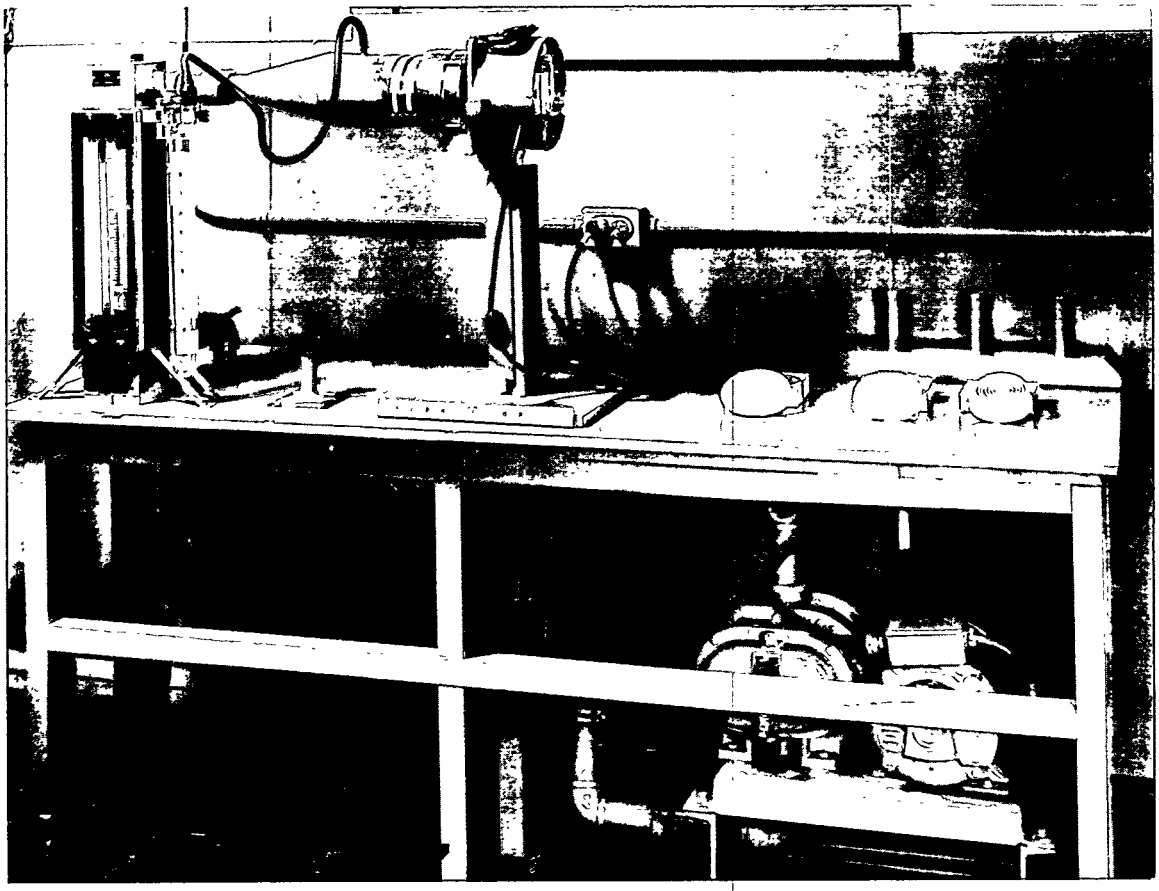

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Figure 44. HI-VOLUME AIR SAMPLER CALIBRATION FACILITY.

Mercury Vapor Detectors - The mercury vapor detector calibrating facility is shown in Figure 45. This station has a generator (a flask and hot plate) in which mercury vapors are produced. A measured flow of nitrogen passing over the heated mercury picks up the mercury vapor and carries it through a condenser used to convert the excess mercury back to a liquid, leaving the nitrogen stream saturated with the vapor. Knowing the temperature of the saturated nitrogen stream, reference can be made to the mercury vapor ratio curves to determine the dilution ratio to get approximately the desired mercury concentration at this temperature. The vapor-laden nitrogen is passed into a mixing flask where it is diluted with a predetermined quantity of uncontaminated nitrogen which has been measured through a second rotometer. The temperature of the vapor in the mixing flask is measured so that a volume correction for temperature changes can be made. Vapor readings at various mercury concentrations are taken with the instrument and are calibrated and recorded against the concentrations to give a calibration table. A plotted curve of vapor readings vs concentrations is attached to the instrument for use in field operations.

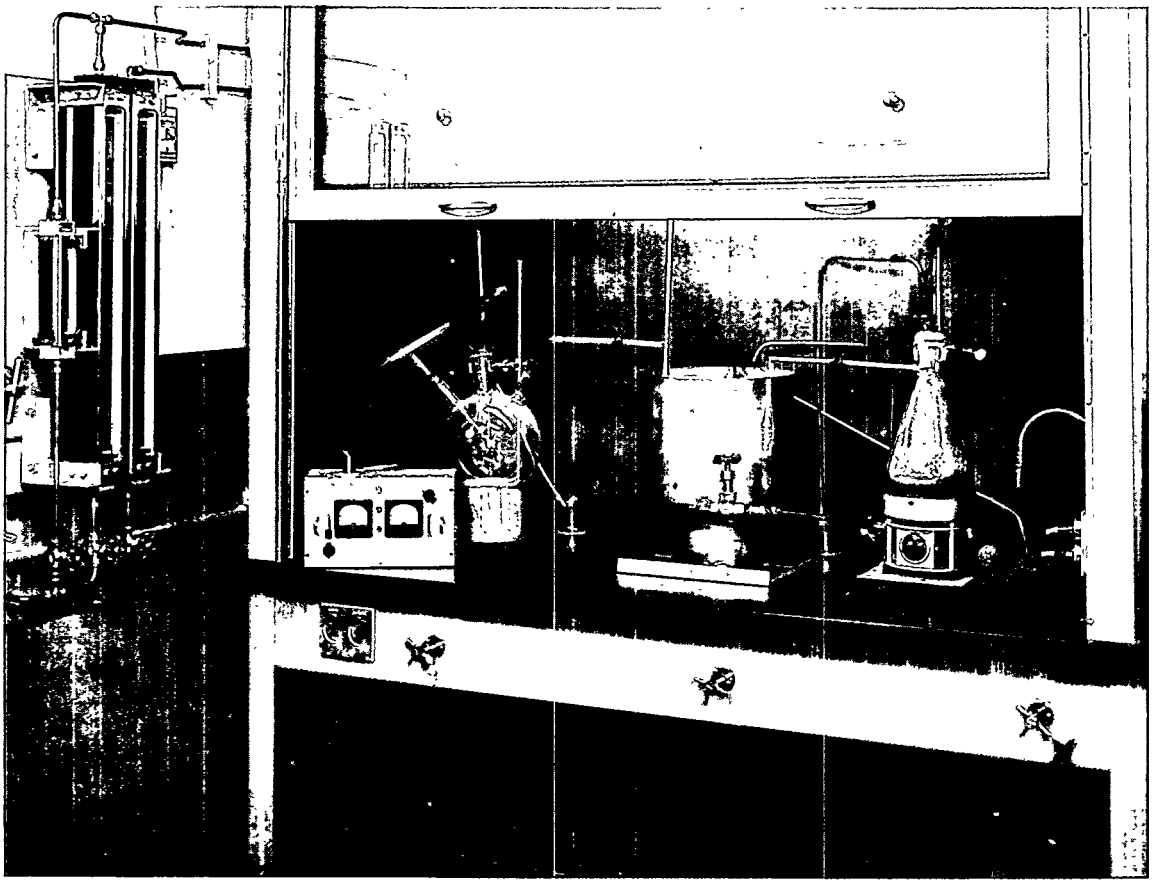

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Figure 45. MERCURY VAPOR DETECTOR CALIBRATION FACILITY.

MISCELLANEOUS SERVICES

Consultation and Advisory Services

As was indicated in the INTRODUCTION, one of the main functions of the Health Physics Group is to provide consultation with line supervision or other staff groups on any phase of health physics, investigate and estimate the hazard potential of new or special operations, and advise supervision of pertinent problems which are anticipated and recommend means of combatting them. Health Physics may be able to help circumvent some of the problems and operating difficulties by timely consultation and advice during the engineering or planning stage of the proposed operation or revision.

Education and Training

Health Physics provides extensive plant education and training programs. Assistance is given in the training or education of employees in the various aspects of their jobs as they pertain to health physics problems or radioactivity. These efforts include

short talks given to a group of employees during a regularly scheduled safety meeting, or specially called discussion meetings with groups of employees or supervisors to gain a better understanding of the problems of radioactivity, the entire health physics program, one particular phase of the program, or one particular operating problem.

RADIATION SAFETY EMERGENCY MONITORING PROGRAM

INTRODUCTION

The aim of the radiation emergency organization of the Y-12 Radiation Safety Department is to provide the capabilities for combatting and evaluating the consequences of a radiation incident. To accomplish this aim, Radiation Safety personnel have been organized into five functional teams which have detailed operating procedures to be followed in the event of an emergency. These teams report to departmental directors who, in turn, report to the Y-12 Plant Emergency Director. This organizational structure integrates team capabilities into an overall plant emergency plan. The complete organization, or any one of the five teams, may be called into service depending on the nature and/or magnitude of the incident.

The program designed to handle a nuclear accident is discussed as functions of the five teams in some detail. Other types of radiation incidents could be handled in a similar manner as required.

PERSONNEL MONITORING

In the event of a nuclear accident, personnel are screened by measuring the activation of indium contained in their security meter badges to determine if they have received a significant exposure. This task is performed by the Indium Foil Counting Team at two separate monitoring depots, one located near the east end of the plant area and the other near the west end. Each of these locations is fully equipped to perform personnel screening and other team activities which include:

1. Assist with the segregation and interrogation of personnel.

2. Perform any personal decontamination that may be necessary prior to sending people to the plant dispensary.

3. Determine the orientation of individuals who might have been near the incident.

4. Segregate as soon after the incident as feasible those individuals who show significant badge activity.

5. Assist in transferring personnel showing high badge activity to the plant dispensary.

Monitoring Techniques

Indium-foil counting is initiated as soon as possible after an incident. As plant personnel arrive at the monitoring depots they are aligned and quickly scanned for

possible clothing and body contamination. Following the preliminary scanning, badge activities are measured, using an appropriate beta-gamma survey meter. Readings are recorded on a data sheet (Figure 46) along with the time between the incident and the measurement and other pertinent information which is used to make a rough estimate of the individual's neutron dose.

Reporting Results

Badge readings above the action points shown on the data sheets are relayed to the plant emergency squad leader at the monitoring site. Individuals with indicated exposures are escorted to the plant dispensary. All data collected by this monitoring team are submitted to the Radiation Safety departmental director who, in turn, relays it to the Plant Emergency Director.

Action Points

Indium foil action points for the instruments used in monitoring are shown on the data sheets. These data are based on information from Report Y-1092[11] and indium foils contained in the security meter badges.

Operational Control

Routine inspection of the survey instruments and equipment at each location is maintained by members of the Radiation Safety Department. In the event of faulty instrumentation or missing equipment, immediate action is taken to correct the condition.

Readiness control is maintained by periodically performing intraplant and interplant emergency radiation drills within the Oak Ridge area. These drills familiarize team members with conditions that can be expected in an emergency situation.

PERSONNEL SURVEY

Introduction

The Personnel Survey Team is assigned to assist the Y-12 Medical Director and Staff in personnel decontamination and dose evaluation resulting from any external radioactive contamination (dust, spills, splashes).

Monitoring Sites

Members of the team may be dispatched to operate one of the facilities described in the sections that follow.

EMERGENCY BADGE MONITORING DATA

PAGE NO.

DATE	READING STATION
READER'S SIGNATURE	INSTRUMENT USED
RECORDER'S SIGNATURE	INSTRUMENT NUMBER
TIME OF INCIDENT _____ AM _____ PM	INSTRUMENT BACKGROUND _____ mr/hr

TIME SINCE INCIDENT (Min)	JUNO RDG. (mr/hr) γ Shield Open	2610 A RDG. (mr/hr) (Shield Open)	MODEL 700 RDG. (mr/hr) (Shield Open)
≤ 30	2.0	6.0	13.5
≤ 60	1.0	3.0	6.75
≤ 120	.25	.75	1.5

NOTE:
Personnel whose badges have readings equal to or greater than those in the above table will be transported to Medical Building for further processing. If feasible, a decontamination bath and fresh clothing is preferred prior to arrival at Medical.

NO.	BADGE NO. LOCAL PLANT	BADGE NO. OTHER	EMPLOYEE'S NAME	BADGE READING mr/hr	TIME OF READING Hr. : min.	ELAPSED TIME INCIDENT TO READING	LOCATION OF EMPLOYEE		
							BUILDING	ROOM or WING	SECTION
Instrument Check - Time									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
Instrument Check - Time									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									

Figure 46. SHEET FOR REPORTING EMERGENCY BADGE MONITORING DATA.

Decontamination Facility at the Y-12 Plant Dispensary - The scintillation counter and decontamination equipment for use in a radiation emergency are shown in Figure 47. Results from the personnel surveys and decontamination efforts are evaluated by the Medical Director. A general survey of beta-gamma radiation is made using portable instrumentation to determine if conditions permit operation in this locale.

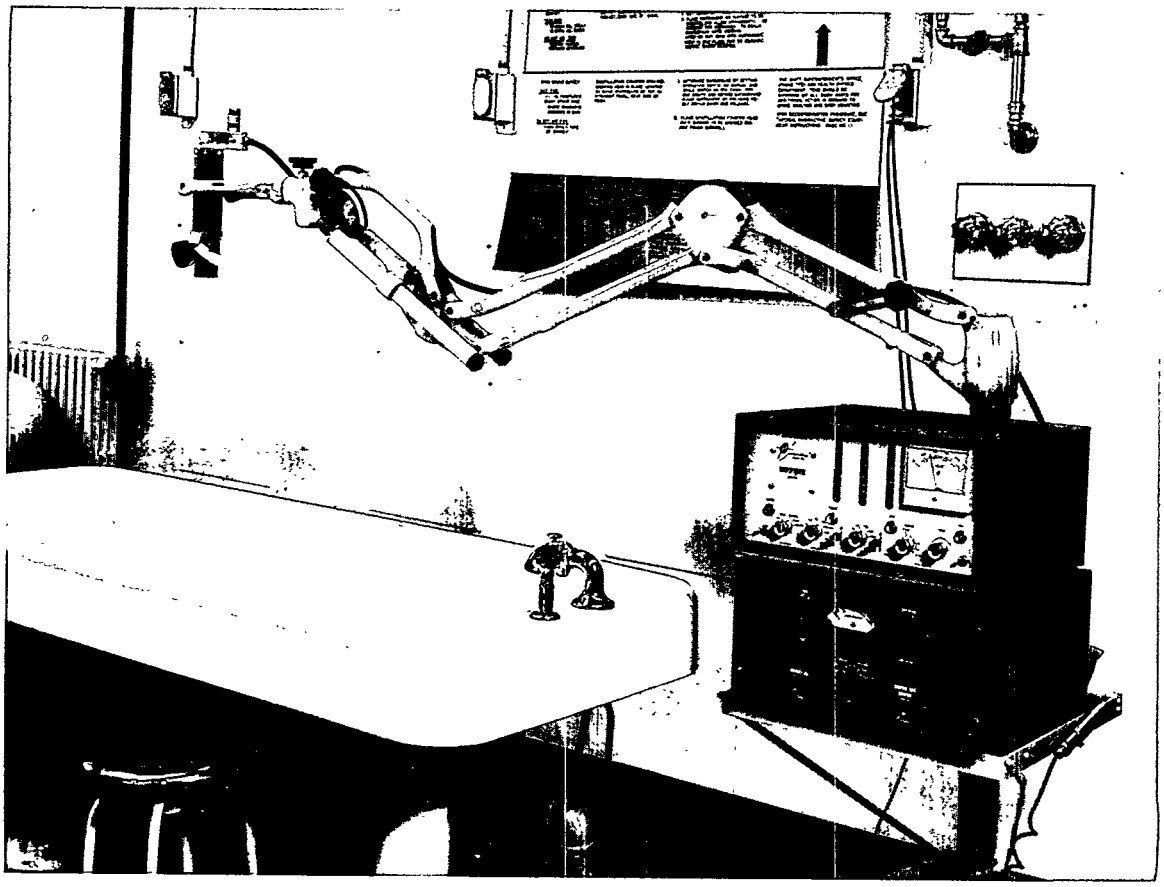

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Figure 47. PERSONNEL DECONTAMINATION FACILITY. (Y-12 Dispensary)

In Vivo Counter - This facility, which is described on Pages 35 through 41, is used for any whole-body radiation measurements that may be required. The instrument will be operated by standard procedures with possible recalibration for a particular radioisotope to which the individual may be exposed.

Portable Instruments Calibration Station - A supply of portable radiation survey instruments is maintained at the instrument calibration facility. These instruments are checked and issued by a member of the personnel survey team for monitoring purposes as needed.

Reporting Results

Although most of the information collected by this team is submitted to the Medical Director as it becomes available, the final tabulation of all data is submitted to the

departmental director for evaluation. This information includes the results of personnel readings collected at the in vivo counter and at the dispensary.

Operational Control

The in vivo counter is used routinely for making whole-body indication measurements; consequently, additional controls are not necessary for emergencies.

Daily operational checks using appropriate calibration sources are made on the decontamination facility located at the plant dispensary.

PERSONNEL DOSIMETRY

Introduction

Radiation-sensitive elements are used as personnel and area dosimeters to measure exposure doses received by plant personnel in the event of a radiation incident. Evaluation of personnel exposure may include the use of individual blood-sodium analyses, components in security meter badges, primary and secondary threshold detectors, and/or any combination of these depending on the circumstances involved in a particular incident.

Neutron Monitoring and Dose Determination

The dose received by a person from the neutron radiation resulting from a nuclear incident can be determined using several techniques. The basic method used in Y-12 is described in Report ORNL-2748.(8) In essence, this method utilizes the neutron-sensitive components of the primary and secondary threshold detectors (Figures 48 and 49) to determine the various energy ranges of neutron flux and subsequent calculation of the "free air" neutron dose in rads. The neutron dose to the individual is obtained from measurements of the Na-24 content in the blood and the spectrum of incident neutrons as determined from the nearest threshold detectors. If the neutron spectrum at these detectors is considered to differ from that to which an individual is exposed, adjustments are made using security-meter badge components.

The best way to estimate an individual's neutron exposure dose would be by the method just described. However, quicker and less accurate estimates can be made if time is a factor and/or all information for making the estimate is not available. A reasonable estimate can be made if the following data are available:

1. Blood sample results plus an assumed neutron spectrum.

2. Blood sample results plus secondary threshold detector data.

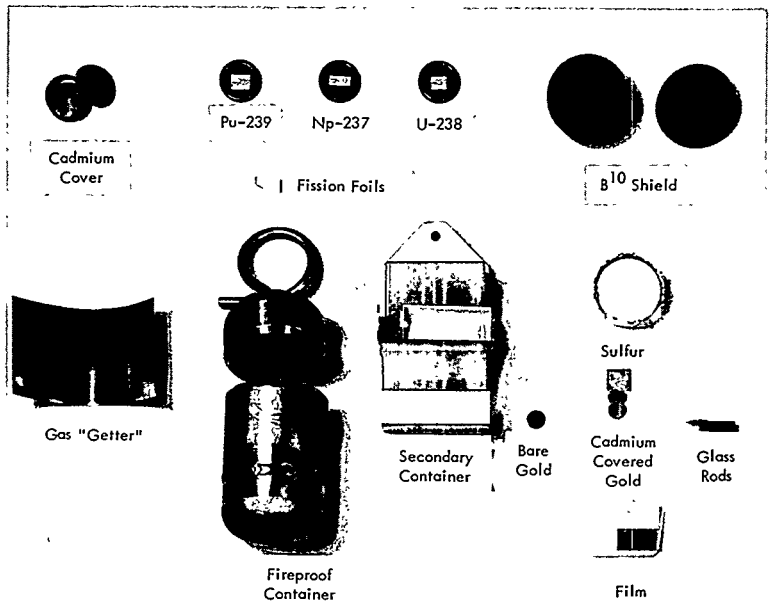

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Figure 48. COMPONENTS OF A PRIMARY THRESHOLD DETECTOR.

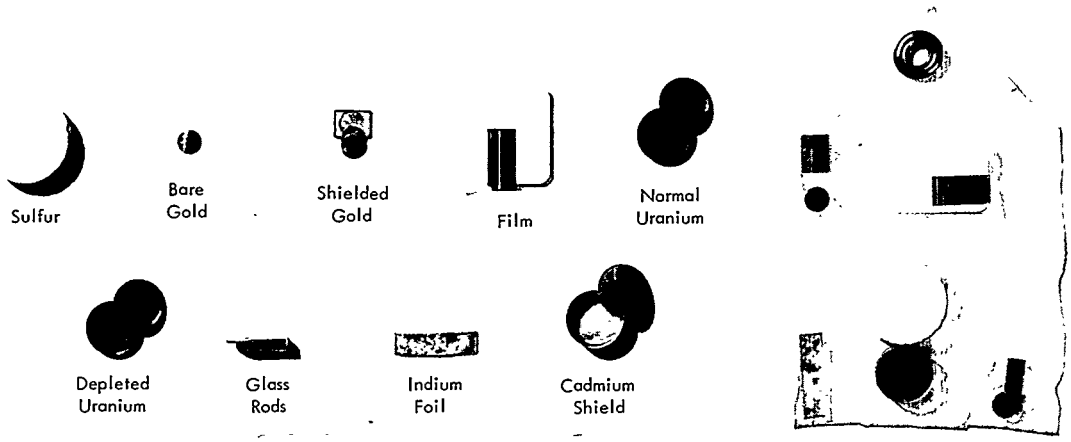

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Figure 49. COMPONENTS OF A SECONDARY THRESHOLD DETECTOR.

3. Primary and/or secondary threshold detector data extrapolated to the location of an individual.

Gamma Monitoring and Dose Determination

Gamma-sensitive film and silver metaphosphate glass rods are the basic dosimeters used to measure gamma-ray exposure doses in the event of a nuclear accident. Packets containing film are incorporated in all security meter badges and area dosimeter stations, while glass rods are located only in the latter.

The sections that follow describe three techniques that are used to determine gamma doses.

Film Packet - Films are collected from the security meter badges and the involved area dosimeters and processed using standard techniques.

Glass Rods - Distance Method - The three glass rods in each area dosimeter are collected from the appropriate dosimeter stations and processed for the gamma dose. Appropriate corrections are made for differences in distances from the incident of the dosimetry station and the individual.

Gamma-Neutron Ratio - The gamma-neutron dose rates at dosimeter stations may be determined by dividing the gamma dose (as determined by film or glass rods) by the neutron dose (as determined by the technique described on Page 87). The gamma dose to an individual can be determined by using this technique if the individual's neutron dose is known and there is a nearby dosimetry station with a determined D_γ/D_n ratio.

Emergency Radiation Dosimetry Laboratory (ERDL)

The facilities of a complete Mobile Dosimetry Laboratory are utilized in evaluating the consequences of a nuclear incident. The laboratory is provided with an electrical power plant and water supply so that an independent operation can be maintained. All processing equipment needed for the analysis of the various components used in the emergency program is contained within this facility. The major components and maintenance procedures of the ERDL are discussed in the sections that follow.

Neutron-Activated Elements - Six sets of counting systems, as shown in Figure 50, are incorporated in the laboratory. All of the neutron-detecting elements used in the emergency program can be counted on any one of these sets by using the appropriate detector and calibration procedure. The neutron dose is determined from the data obtained on these counting systems by using various calibration factors.

Gamma-Measuring Elements - The film processing area of the ERDL is shown in Figure 51. This section includes the equipment for processing radiation film, an independent water supply, and a film dryer. The film is processed by standard developing techniques. Film densities are determined with a densitometer and referred to an appropriate calibration curve to obtain the gamma dose.

In addition to film, silver-activated metaphosphate glass rods are used in area dosimeters as gamma monitors. Since the instrument used in Y-12 for reading these rods is calibrated to read in terms of Co-60 roentgen equivalent, a direct interpretation of the gamma dose is obtainable.

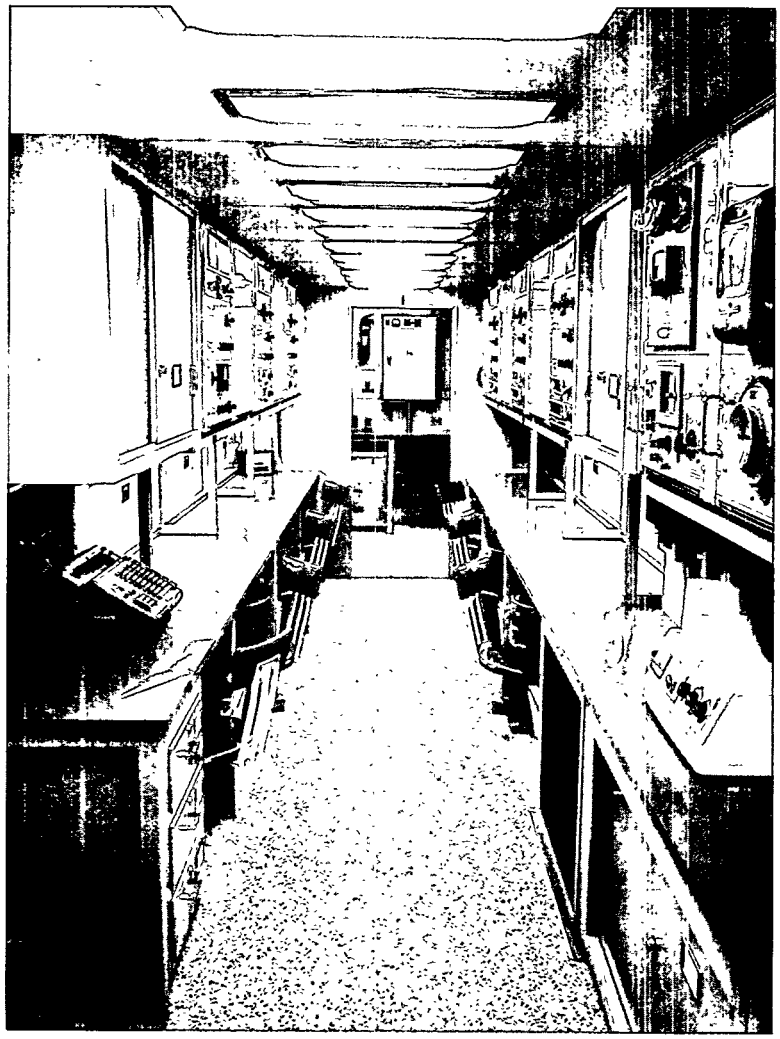

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Figure 50. EMERGENCY RADIATION DOSIMETRY LABORATORY.

Environmental Monitoring - A variety of continuous monitors are provided to insure an incident radiation level compatible with the performance of the various ERDL facilities. Shown in Figure 52 is the arrangement of instruments which includes an incident gamma monitor, a beta-gamma particulate monitor, and a radioactive gas monitor. Each monitor is equipped with a graphic recorder and audio annunicators to indicate abnormal radiation levels.

Program Control - To assure that the ERDL stays in a continuing state of readiness, routine inspection programs have been established.

Personnel from the Maintenance Division and the Radiation Safety Department decide the type and frequency of routine maintenance to be performed on the equipment in the facility. The Radiation Safety Department notifies the Maintenance Division personnel of any equipment failure between routine checks. Checks are made daily, weekly, and monthly, and the findings recorded on appropriate inspection forms.

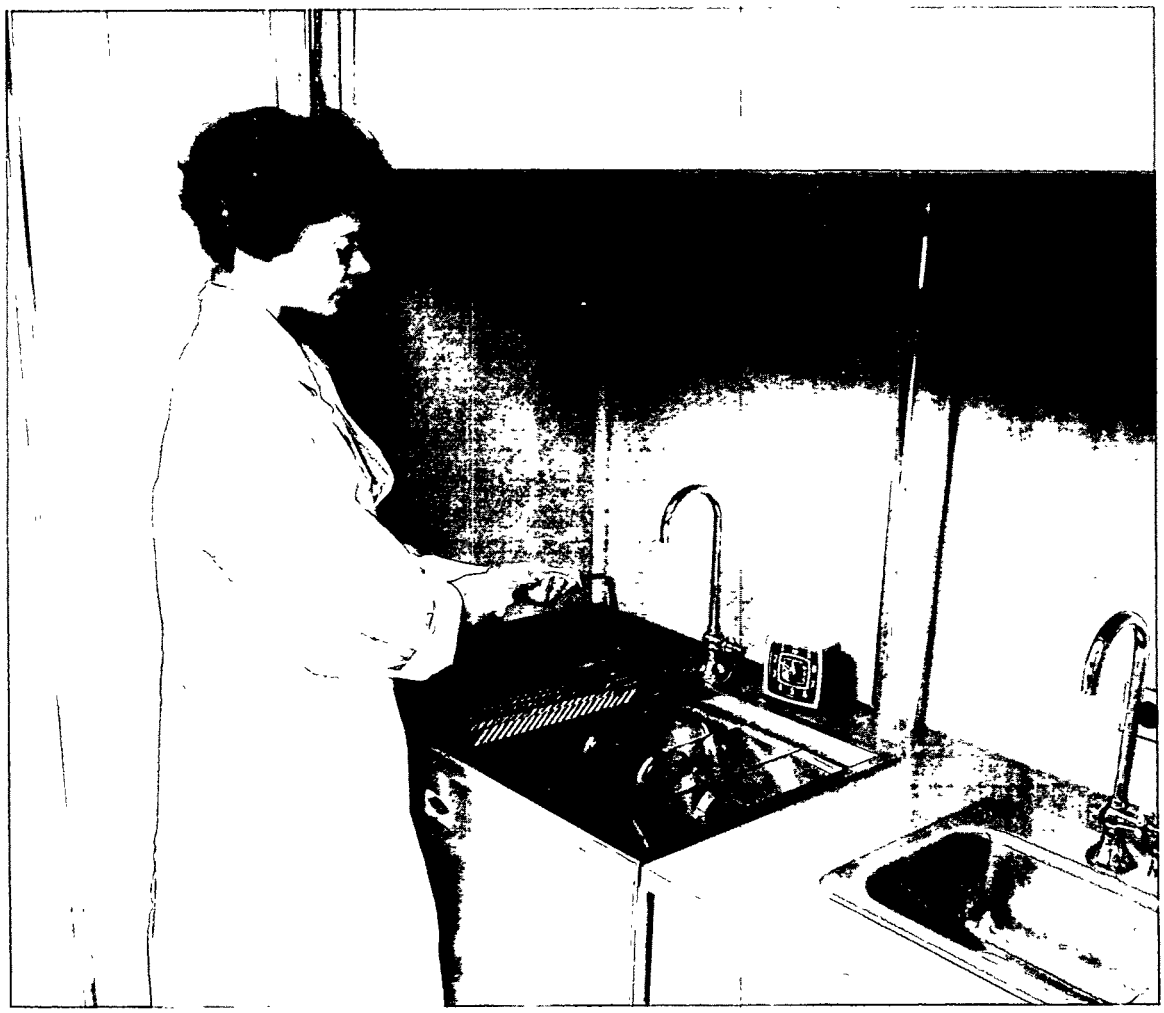

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Figure 51. FILM PROCESSING AREA IN THE ERDL.

The ERDL is used in both interplant and intraplant emergency activities. One important activity has been and will continue to be interplant emergency monitoring experiments and drills.

The ERDL is also used for any special gamma and beta counting jobs as the need arises.

Sample Processing and Evaluation - As the samples arrive at the ERDL they are sorted and appropriately identified in the sample preparation area. Then samples are distributed to process areas within the laboratory.

The components from individual area dosimeters and badges are kept together so that all information from a particular unit is available as soon as feasible.

Dose Determination

Samples are analyzed by the method described in the standard operating procedures and the results tabulated on duplicate data sheets. This procedure continues until

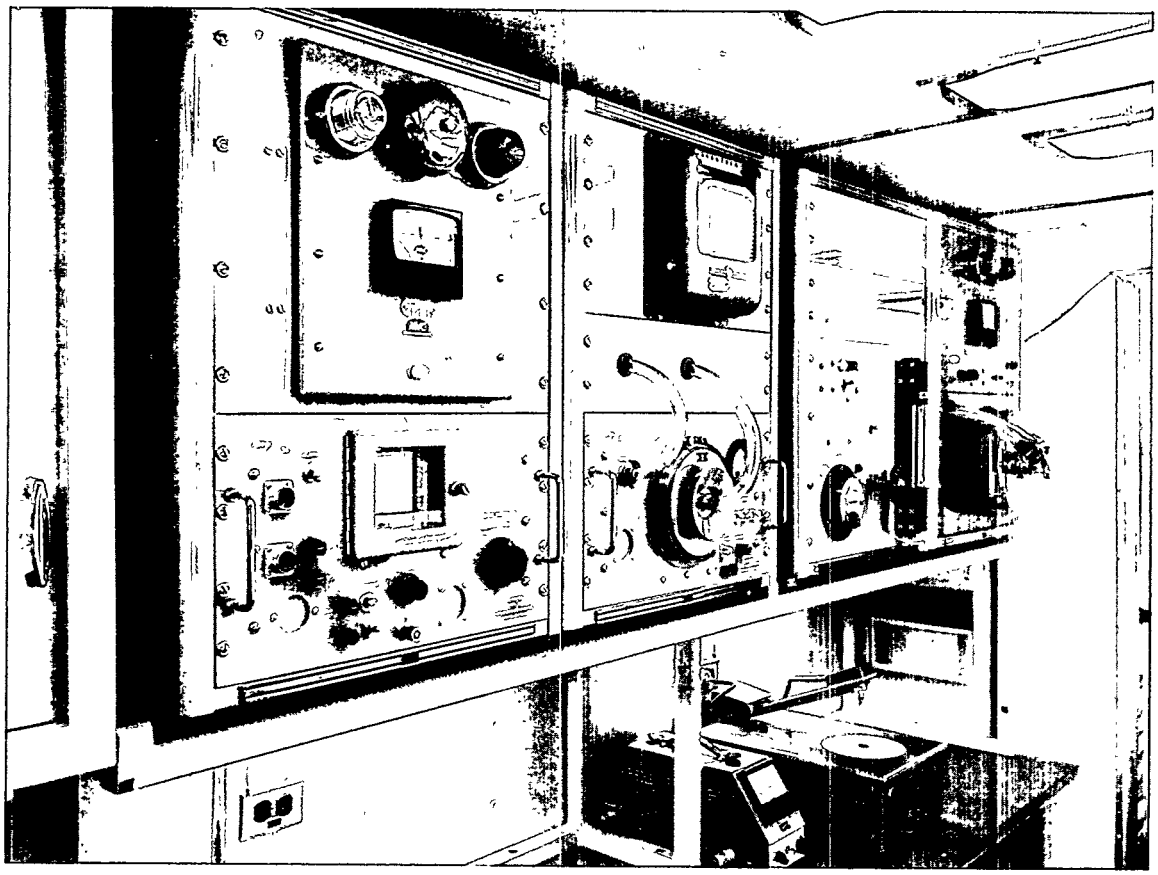

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Figure 52. CONTINUOUS RADIATION MONITORS IN THE ERDL.

all samples brought to the ERDL have been analyzed. All samples are kept following processing for such purposes as rechecking and weighing. As information from an area dosimeter, meter badge, or blood sample becomes available it is submitted to two individuals assigned as dose computers who add to the data sheet all the information necessary to obtain the dose estimates. The action taken is as follows:

1. Hand calculations are made to determine the neutron and gamma doses from the available information.

2. The necessary information on specially prepared data sheets is submitted to the Y-12 IBM Keypunch Section. The punched information is transferred to the Central Data Processing Facility for computation of the neutron dose. The program computes doses for each individual and dosimeter station for every combination of available data. This technique is described in Report Y-1386.[9]

3. After all doses are computed and checked, the assignment of the best estimate of total dose to the people involved completes the picture.

Reporting Results

To get a dose from the results generated by the ERDL requires special calculations either by individual dose computers or by the IBM 7090 computer. The IBM 7090 is used to establish the final and best estimate of an individual's dose; however, any information concerning the neutron or gamma dose resulting from a nuclear incident is reported to the departmental directors as soon as it is obtained.

PLANT SURVEY

Introduction

Two 4-man teams have the responsibility of providing information relative to the levels and types of radiation associated with a radiation incident. One team is assigned to evaluate the conditions in the proximity of the incident while the other team is concerned with any dispersal of contamination to areas inside and/or outside the plant environs.

On-Site Monitoring

It is the responsibility of the On-Site Monitoring Team to locate the incident and provide radiation measurements in the area near the radiation incident. The results of these measurements along with information concerning the potential hazard of the source of radiation are transmitted by portable two-way radio to the departmental director. Members of this team provide the Plant Emergency Director (PED) with on-the-spot information that may assist him in making decisions concerning a particular incident.

In the event of a nuclear accident, the members of this team collect area dosimeters which may be located near the accident. These units are brought to the ERDL for use in evaluating personnel exposure doses. Shown in Figure 53 is a member of the team completely dressed for answering an emergency call.

Although this team is primarily concerned with informing the PED of their current findings via two-way radio, a more comprehensive report covering their overall survey is compiled and submitted later to the departmental directors for further evaluation.

Area Monitoring

In the event of a radiation accident, nuclear or otherwise, it is possible that radioactive contaminants will be present in the atmosphere in significant quantities. The degree of contamination depends on the size and nature of the incident. It is the responsibility of the Area Monitoring Team to determine the levels that are present in the atmosphere at selected locations. The team is composed of two units, each of which is equipped with a vehicle and means of collecting additional air samples if desired. Predetermined locations are described in the sections that follow.

108609(U)

Figure 53. ON-SITE MONITORING TEAM MEMBER FULLY EQUIPPED.

In-Plant Monitoring - Eleven outside air samplers are operated continuously in the plant area to obtain a measure of the day-to-day alpha and beta radiation background levels. In the event of an accident, members of this team change the samples, make a general survey, and record any indicated levels of beta-gamma contamination. The samples are then placed in a container and appropriately marked so that a more refined analysis may be made later.

This team is responsible for evaluating the alpha and beta background levels throughout the Y-12 Plant and recording the time of reading and their findings on an area map. An additional responsibility includes the establishment of outer boundary limits for direct radiation as specified in the Y-12 Plant Emergency Manual.

Outside-Plant Monitoring - The team also goes outside the plant area if and when contaminated fallout is present and performs the following duties:

1. Measures and records the level of contamination on cars and parking lots near the Y-12 Plant.

2. Collects water samples and makes a surface contamination survey at the Oak Ridge filtration plant located near Y-12.

3. Makes a general radioactive survey on the roads in any area where traffic may spread contamination.

The teams report immediately to the departmental director via two-way radio any significant findings. However, all data collected are recorded on data sheets or specially prepared area maps.

INDUSTRIAL HYGIENE PROGRAM

INTRODUCTION

This section describes the current control programs conducted by the Industrial Hygiene Section to protect the health of the personnel in Y-12 from nonradioactive hazards. The scope of these programs varies in size from small pilot-plant and development operations to entire building operations. The programs must be flexible and subject to changes that normally take place in a large, diversified plant.

BERYLLIUM PROGRAM

Introduction

Both personnel and area monitoring programs are carried out in all beryllium processing areas.

Personnel Monitoring

Those employees whose work involves the processing of beryllium, beryllium alloys, or beryllium compounds, must first be cleared by the Medical Department. Once assigned to a beryllium area, the employee is examined by the plant physician at regular intervals, depending upon the type and frequency of exposure. The accumulated hours of work in beryllium areas by each individual and the dates of his last chest X-ray and medical examination are recorded on IBM sheets.

All personnel working in processing areas are given a complete change of clothing and required to shower at the end of each work period. Change-house facilities are provided with individual lockers for street clothing only. Clean work clothes are kept in individual bins; soiled clothes are placed in special containers that have wet-down features to minimize dust and prevent the spread of contamination to the laundry.

Respiratory protection is not only provided but required where the degree of contamination is unknown and/or when contamination cannot be controlled by the usual methods. However, the continued use of respirators, in lieu of proper control measures, is not permitted.

Area Monitoring

In order to stay within the established contamination limits, specially designed containment and ventilation systems have been installed for specific operations. Such systems may consist of a laboratory hood, dry box, locally filtered exhaust system, or individual machine hoods ventilated through high-velocity cyclone chip collectors

and exhausted to the outside atmosphere through an absolute filter system. Since air contamination control tends to minimize the surface contamination problem, sampling programs are maintained to determine the levels of air and surface contamination in all beryllium areas.

Air Sampling - Air samples are generally classified into the three types discussed previously (Pages 41 through 45).

The air samples for beryllium are collected by drawing a measured quantity of air through Whatman 41 filter paper. The permanent-type samplers use a 1 1/4-inch disc, and high-volume samplers use a 4-inch disc from which 1 1/4-inch discs are cut after a sample has been taken. Each sample disc is then placed into a 1/2-ounce metal pill box in which it is transported to the laboratory for analysis. Sample location, air flow, and sampling time are recorded on the analysis request form. At the laboratory, the discs are individually pelletized, placed in graphite electrodes, and ashed by placing the electrodes in a muffle furnace. Upon removal from the furnace, 40 electrodes are placed in magazine-type holders and loaded into an automatic beryllium spectrograph, shown in Figure 54. The instrument automatically analyzes

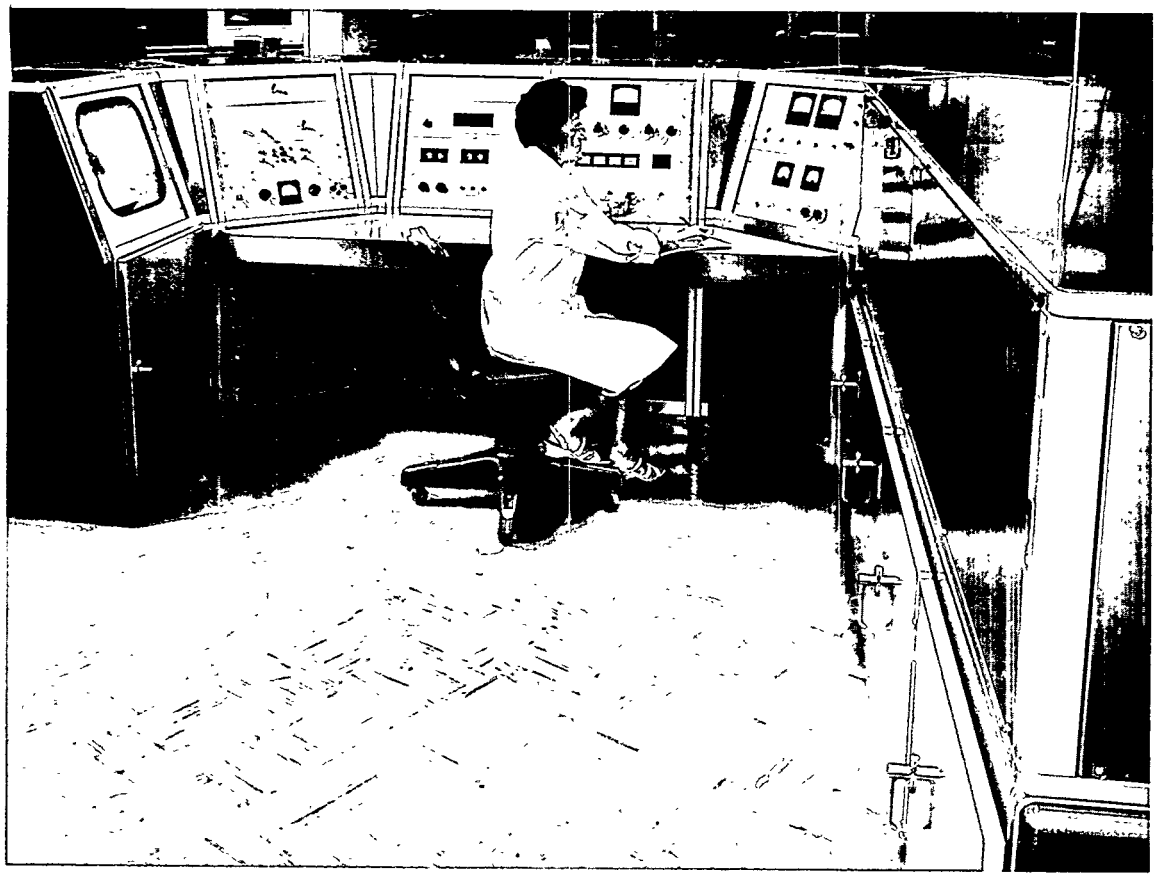

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Figure 54. BERYLLIUM AUTOMATIC SPECTROGRAPH CONSOLE.

the 40 samples and prints the total micrograms of beryllium for each electrode on a strip chart. The data are then recorded on the original request form which is returned to the Industrial Hygiene Group. These forms are checked for results above 50% of the Threshold Limit Value (TLV) of 2 μgs/M^3/8 hrs or 25 μgs/M^3 if < 30 minutes. Supervision is notified of all results above the TLV so that corrective action can be taken. Each month these forms are sent to Tabulating Services Department where results are recorded on permanent record sheets.

Within the general air sampling program, two auxiliary studies are made:

Particle-Size Studies - Particle-size determinations are made with the use of a two-stage sampler which consists of a miniature cyclone followed by a high-volume air sampler fitted with millipore filter paper, as shown in Figure 55. Particles greater than 10 microns are retained by the cyclone; those less than 10 microns are collected by the millipore paper. Each fraction can be analyzed for particle size as well as beryllium content. The electrostatic air sampler, Figure 56, is also used to collect samples for particle studies.

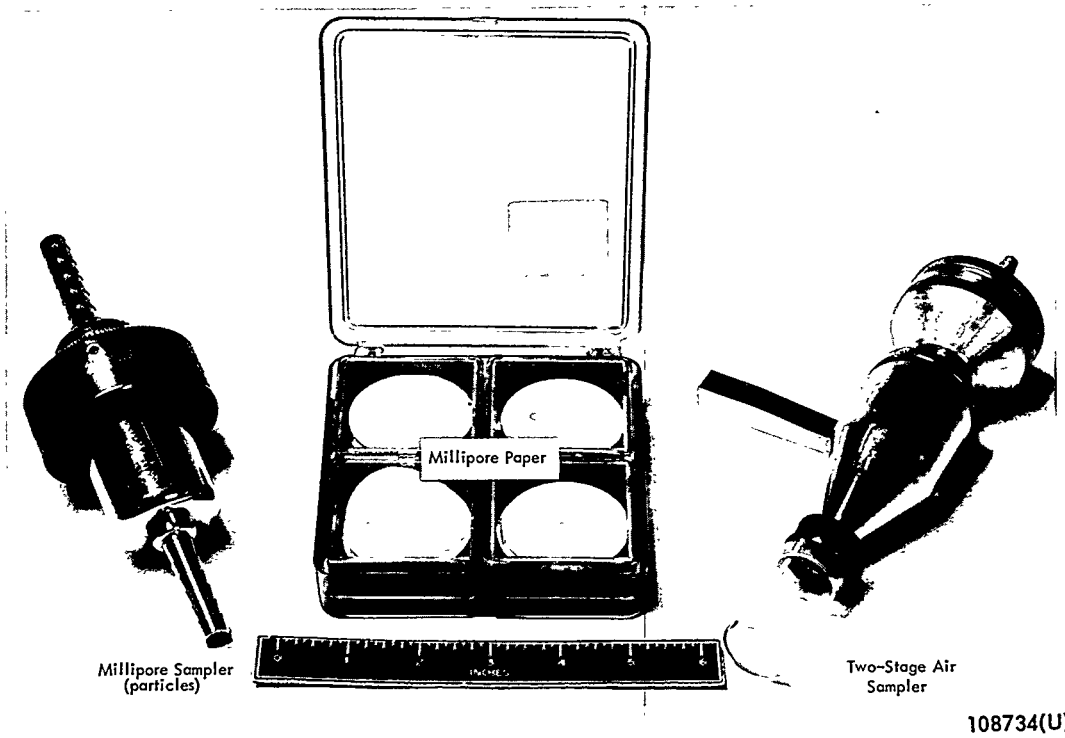

Figure 55. TWO-STAGE AIR SAMPLER.

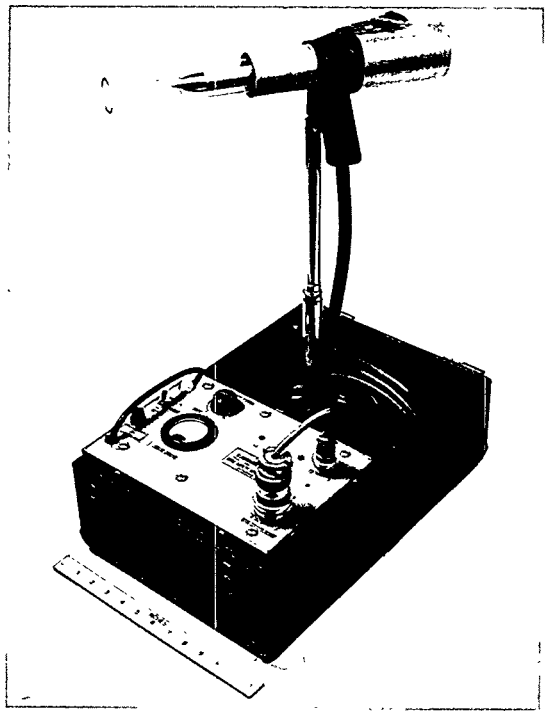

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Figure 56. ELECTROSTATIC AIR SAMPLER.

Analysis Control Program - A control program is maintained by the Industrial Hygiene Group to evaluate the precision of the laboratory. Special samples are prepared by the Quality Control Laboratory with values of 1, 10, and 25 total μgs of beryllium per paper disc. These control samples are submitted daily with the routine beryllium air samples. The results are recorded on a beryllium control form and sent to the Quality Control Department for evaluation. Adjustments are made as the need indicates.

Surface Monitoring - Surface contamination samples are taken in the beryllium areas to check the effectiveness of housekeeping and control the spread of contamination. The results are always accepted as relative values and not absolute. Limit values used in the Y-12 Plant are: 25 μgs/12 in^2 in areas where routine air samples are taken (process areas), or 4 μgs/12 in^2 in those areas where no routine air samples are taken (nonprocess areas). A value of < 4 μgs/12 in^2 is also used on equipment being removed from a beryllium area to a nonberyllium area or leaving the plant. Smear samples are handled in the same manner as air samples for laboratory analysis.

MERCURY AND LEAD PROGRAMS

Introduction

The mercury and lead programs are administered in the Y-12 Plant by the joint efforts of the Industrial Hygiene Section and the Medical Department. The Industrial Hy-

giene Section is responsible for monitoring operating areas for mercury vapors and advise area supervision of the air concentration in their respective areas. The Medical Department conducts quarterly industrial health checks which include urine sampling and physical examination of all employees assigned to areas in which mercury is used.

Air Monitoring

A routine mercury vapor sampling program is maintained in buildings in which mercury is handled on a continuing basis. Samples are collected in other areas as the need arises.

A portable, battery-powered instrument (Figure 57), which was designed and built by Y-12 Development, is used for detecting and measuring the concentration of mercury vapor in the atmosphere. This instrument utilizes the absorption characteristic of mercury vapor to ultraviolet light with a wave length of 2537 angstroms. The amount of absorption is proportional to the concentration of mercury vapor in the atmosphere.

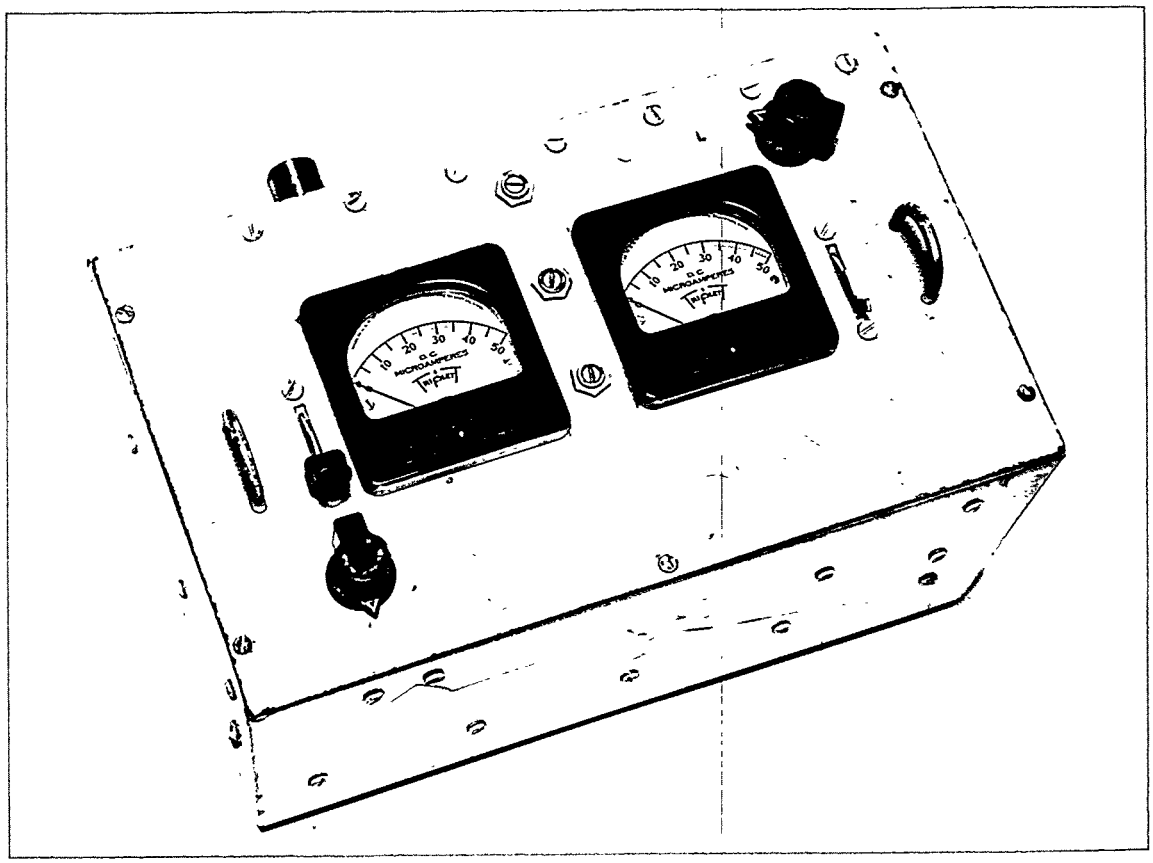

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Figure 57. MERCURY VAPOR DETECTOR.

Scheduling of the routine sampling programs and sampling frequency is accomplished by agreement between the Industrial Hygienist and area supervision. Survey Summary Sheets which show the sampling frequencies are provided to guide the persons doing the sampling and serve as checks for work completed and work yet to be done.

Mercury vapor samples are classified as either Spot General Air Samples (SGA) or Source Samples. The SGA samples are collected to determine the average concentration of the contaminant in the atmosphere of a given area. Such samples are taken approximately at the height of the breathing zone at predetermined, fixed locations. Source samples are taken while the instrument is moved from place to place near such places as equipment and floor drains in an effort to locate sources of high mercury vapor concentration.

The Mercury Air Analysis Report form (Figure 58) is used to record and report the information obtained by the survey. Indications of unusually high vapor concentrations are reported immediately to area supervision. Otherwise, copies of the report are sent to the Industrial Hygiene office and area supervision at the end of the day.

MERCURY AIR ANALYSIS REPORT

BUILDING: _____

DEPARTMENT OR PROGRAM _____

DATE: _____ TEMP. _____

TEST NO.	OPERATION	LOCATION	SCALE READING	CONC. mg/M³	REMARKS

OBSERVER _____

Figure 58. REPORT FORM FOR MERCURY AIR ANALYSIS.

Personnel Monitoring

Determination of the toxic materials in urine is an applicable biochemical test for personnel exposure monitoring and often gives a more accurate measure than can be obtained from environmental air samples.

Routine programs for determining mercury and lead in urine are conducted by the Industrial Hygiene Group with assistance from the Tabulating Services Department, the Bioanalysis Laboratory, and the Medical Department.

A personnel participation schedule is prepared quarterly by the Industrial Hygiene Section and sent to Tabulating Services, Medical, and all participating departments. From this schedule, Tabulating Services prepares a participation notification card and an IBM mark-sense data card for each employee in the program. The participation cards indicating the date on which the employee will submit his urine sample are sent to the different departments which, in turn, acknowledge the notification by forwarding them to the Industrial Hygiene office. Next, the mark-sense cards are sent to the Medical Department Laboratory where employees on the program submit their urine samples. The samples are then matched with the cards and sent to the Bioanalysis Laboratory for analysis. Finally, after the samples have been analyzed, the IBM cards containing the complete sample data are sent to the Industrial Hygienist who checks them for results greater than the maximum allowable concentrations for mercury (0.3 mg/l) or lead (0.15 mg/l). Employees who exceed the threshold value for mercury or lead in urine, or in which some abnormality is detected during examination, are restricted from the mercury areas until their test conditions return to normal.

The Medical Department and area supervision are notified immediately of high results and resamples are scheduled. If the followup resample indicates high excretion levels, the employee is removed from the area until subsequent samples indicate levels well below the allowable concentration.

All mark-sense cards are sent to the Tabulating Services Department where results are tabulated monthly by department and badge numbers. Each quarter a complete list, including current quarter results plus the last three preceding quarters, is compiled and sent to the Industrial Hygiene Section and the Medical Department.

NOISE CONTROL PROGRAM

Introduction

An effective noise control program initiated by the Y-12 Medical Department and the Industrial Hygiene Group has been approved and adopted by plant management.

Noise Determination and Classification

The Industrial Hygiene Group measures the noise level (frequency and intensity) with a sound level meter and analyzer, shown in Figure 59. Noises are classified as either a pure-tone or a wide-band type. A pure tone exists if any single octave band exceeds the two adjacent bands by five decibels or more. When no single octave band exceeds the two adjacent bands by as much as five decibels or more, the noise is known as wide band.

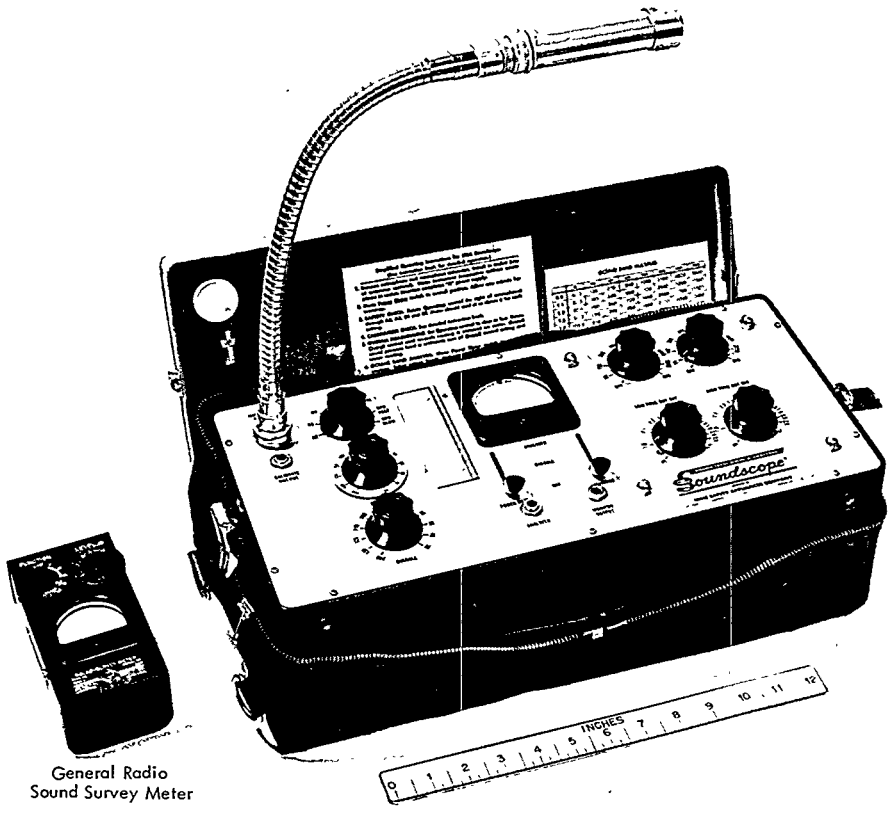

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Figure 59. SOUND LEVEL METER AND ANALYZER.

A noise problem exists: (1) if there is a pure-tone noise in the 300 - 4800 vps frequency range which exceeds 82 decibels; (2) if there is a wide-band noise in which any octave band in the 300 - 4800 vps frequency range exceeds 85 decibels; or (3) if either a pure-tone or a wide-band noise in any octave band below 300 vps frequency exceeds 95 decibels.

Area Control

If the noise level in any area exceeds the criteria just stated, the area is declared a Noise Risk Area by the Medical Director and steps are taken to correct the condition

by engineering improvement. Until the condition is corrected, suitable signs are placed in the area to notify employees of the need to wear ear protection. It is the responsibility of area supervision to inform their personnel of the condition and see that they wear ear protection.

Personnel Protection

Employees assigned to work four or more hours during a 24-hour period in an area designated as a Noise Risk Area are required to wear ear protection. In most cases, ear plugs afford adequate ear protection. There are two types of plugs available. One is a multifit rubber plug; the other is an impregnated cotton plug for those who are unable to wear the rubber plug. In most instances these are available at the dispensary and at Stores.

Temporary occupants or transients are required to wear ear protection under the following conditions:

1. If a broad-band noise has an intensity of 85 to 89 decibels and they are in the area three hours or more in any 24-hour period.

2. If a broad-band noise has an intensity of 90 to 95 decibels and their time in the area is one hour or more in any 24-hour period.

3. If the noise is a broad-band type exceeding 95 decibels, or pure-tone type equal to or exceeding 82 decibels, regardless of the time spend in the area.

OTHER SIGNIFICANT CONTROL PROGRAMS

Stream Pollution Sampling Program

Before the liquid effluent leaves the plant area by way of a creek water samples are taken by a continuous sampling system, as described on Page 66. Samples received from the Health Physics Section are analyzed chemically for suspected contaminants and the results forwarded to area supervision. Values used for the chemicals in discharge water are given in Table 8.

Disposal of Toxic Materials

Hazardous and toxic materials are disposed of under the rules as outlined in an internal procedure. This procedure (discussed on Pages 68 through 72) delegates specific responsibilities and outlines methods of disposal.

Potable Water

A potable water sampling program is routinely maintained for the 400 or more drinking water fountains in the plant area. The chlorine content is analyzed at the point

of sampling by the standard orthotolidine method, while the bacteriological content is determined by the membrane filter procedure. All results are reported to the Industrial Hygienist and the Sanitary Engineer who determine when resamples or other sampling techniques are needed.

The Industrial Hygiene Group is notified of any new drinking fountain installations or changes in the present potable water system so that tests can be made before the changed installation is placed into operation.

Atmospheric Enrivonmental Samples

In order to determine the amount and nature of air pollution in the atmosphere, 11 air samplers are operated continuously in and around the Y-12 Plant area. This monitoring program and the equipment are described on Pages 60 and 61.

The Industrial Hygiene Section receives a half portion of the filtered air sample which is sent to the laboratory for analysis of the pollutants listed in Table 14.

Table 14

POLLUTANTS CHECKED IN ENVIRONMENTAL AIR SAMPLES

Cations Analyzed by Emission Spectrograph		Anions Analyzed by Chemical Methods
Antimony	Lithium	Nitrates
Barium	Manganese	Fluorides
Beryllium	Molybdenum	Sulfates
Bismuth	Nickel	Chlorides
Cadmium	Titanium	
Chromium	Thorium	
Cobalt	Tin	
Copper	Uranium	
Iron	Vanadium	
Lead	Zinc	

Results are reported routinely to supervision.

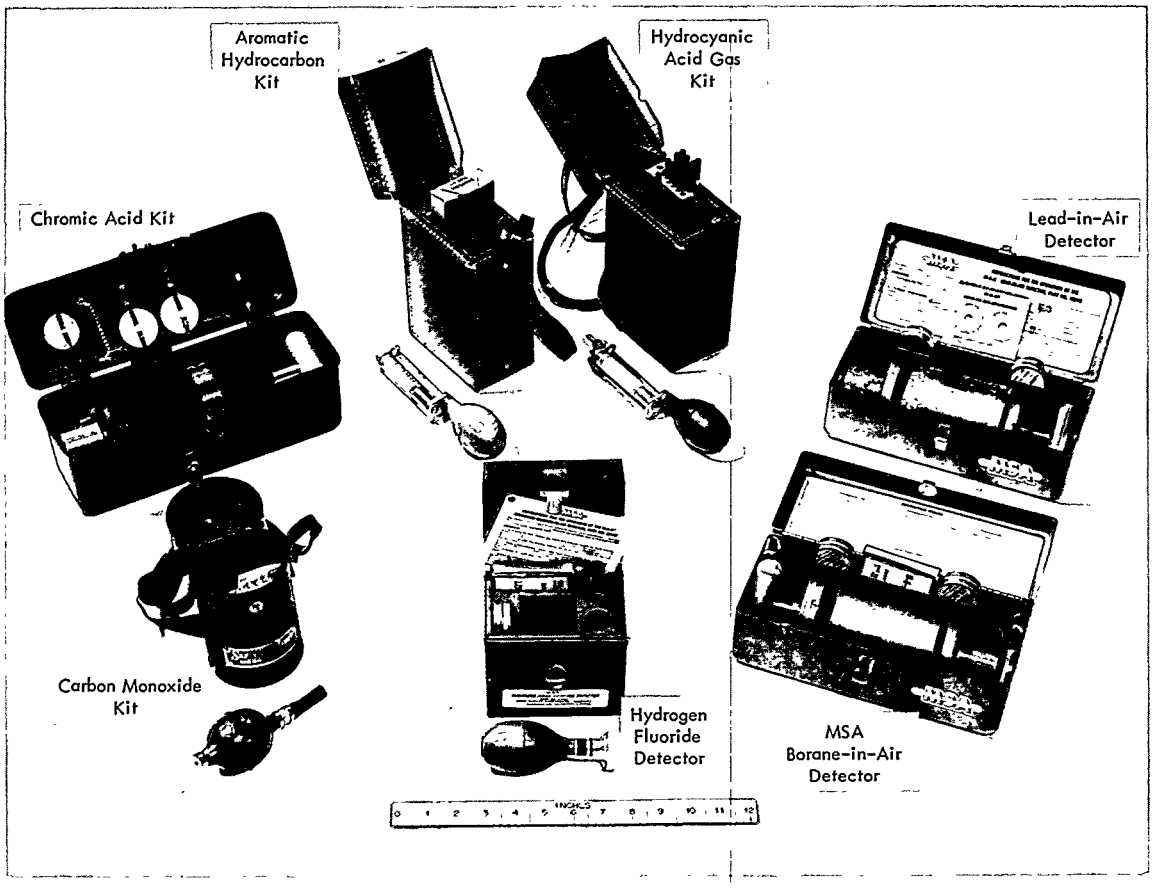
Monitoring Contaminants with Detector Kits

Short-range processes where highly toxic materials are used are monitored as the occasion demands with portable detector kits which permit quick, safe assessments of the problems. More accurate and detailed types of sampling are used if a more serious problem is indicated by these methods. Equipment used for this type of sampling is pictured in Figures 60 through 64.

Some of the elements or compounds which are analyzed with these detector kits are:

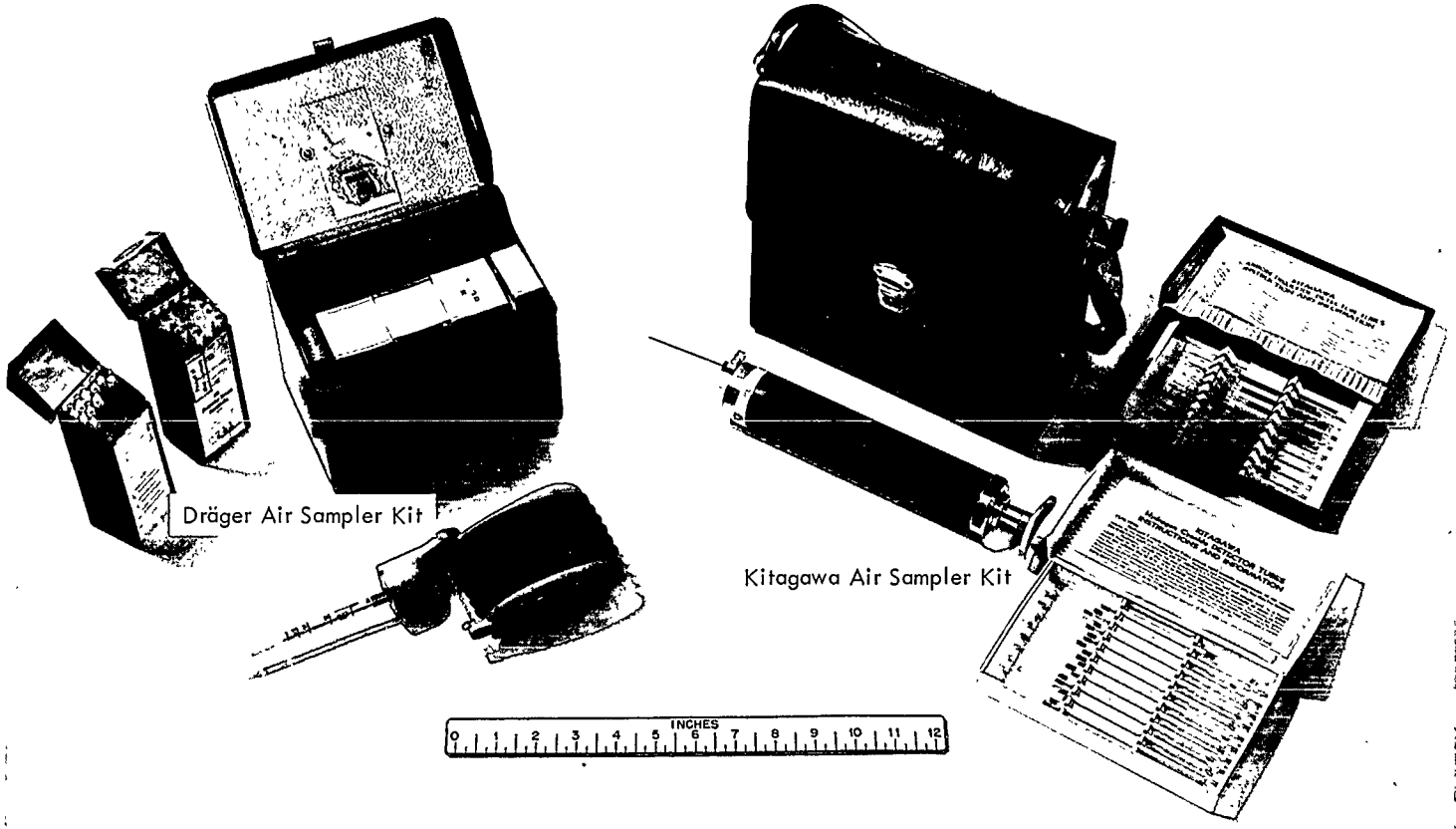
Benzene	Tolylene 2, 4 Diisocyanide
Phosgene	Nitrogen Dioxide
Chlorine	Lead
Fluorine	Mercury
Perchloroethylene	Dichlorobenzene

Trichloroethylene
Arsine
Carbon Disulfide
Carbon Monoxide
Chromic Acid
Hydrogen Cyanide
Toluene
Sulfur Dioxide
Phosphine
Chlorobenzene
Nickel Carbonyl
Methyl Chloroform
Xylene
Boranes
Ammonia
Acetone
Bromine



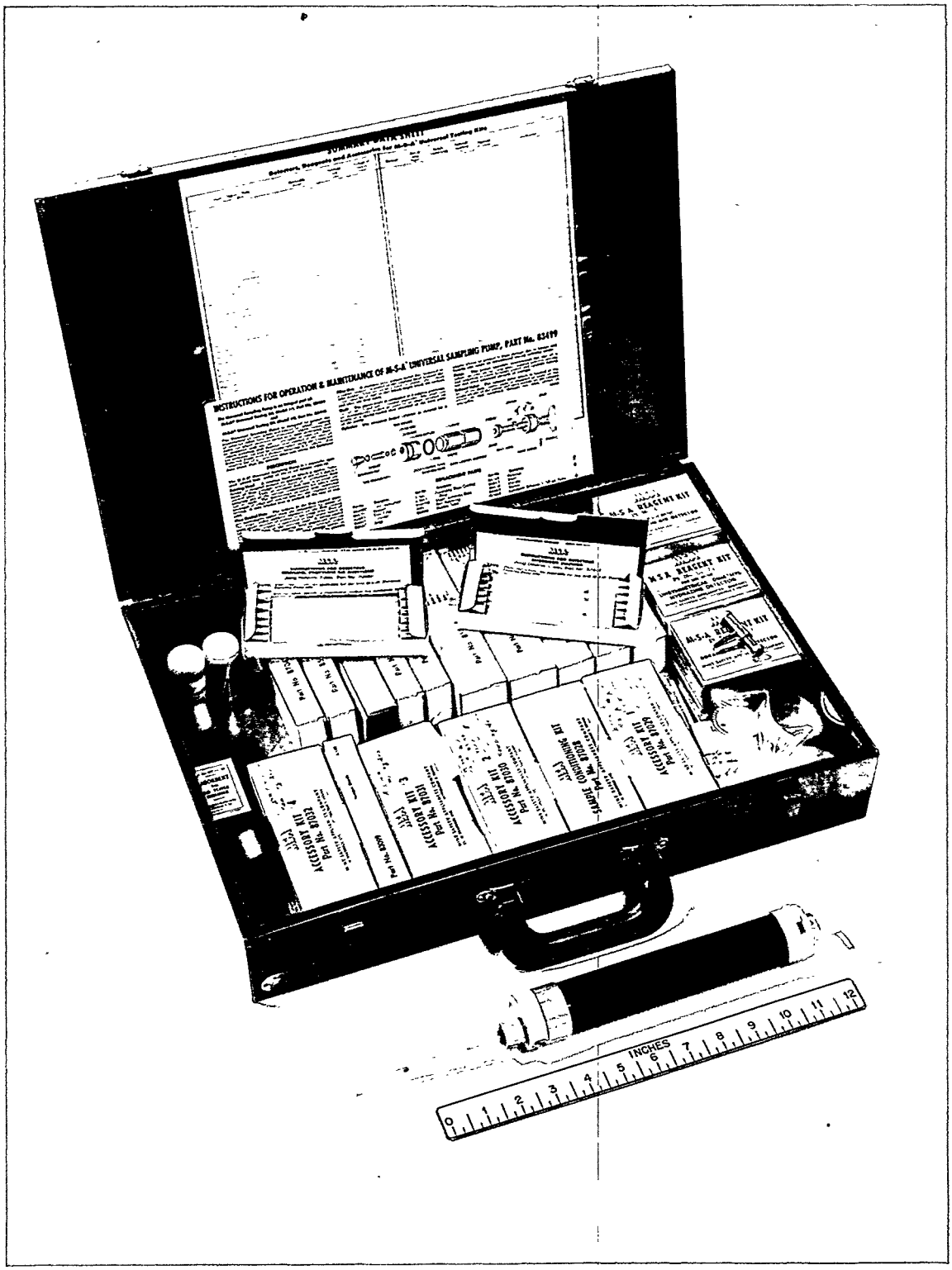
108741(U)

Figure 60. DETECTOR KITS USED IN Y-12 FOR AIR-BORNE CONTAMINANTS.



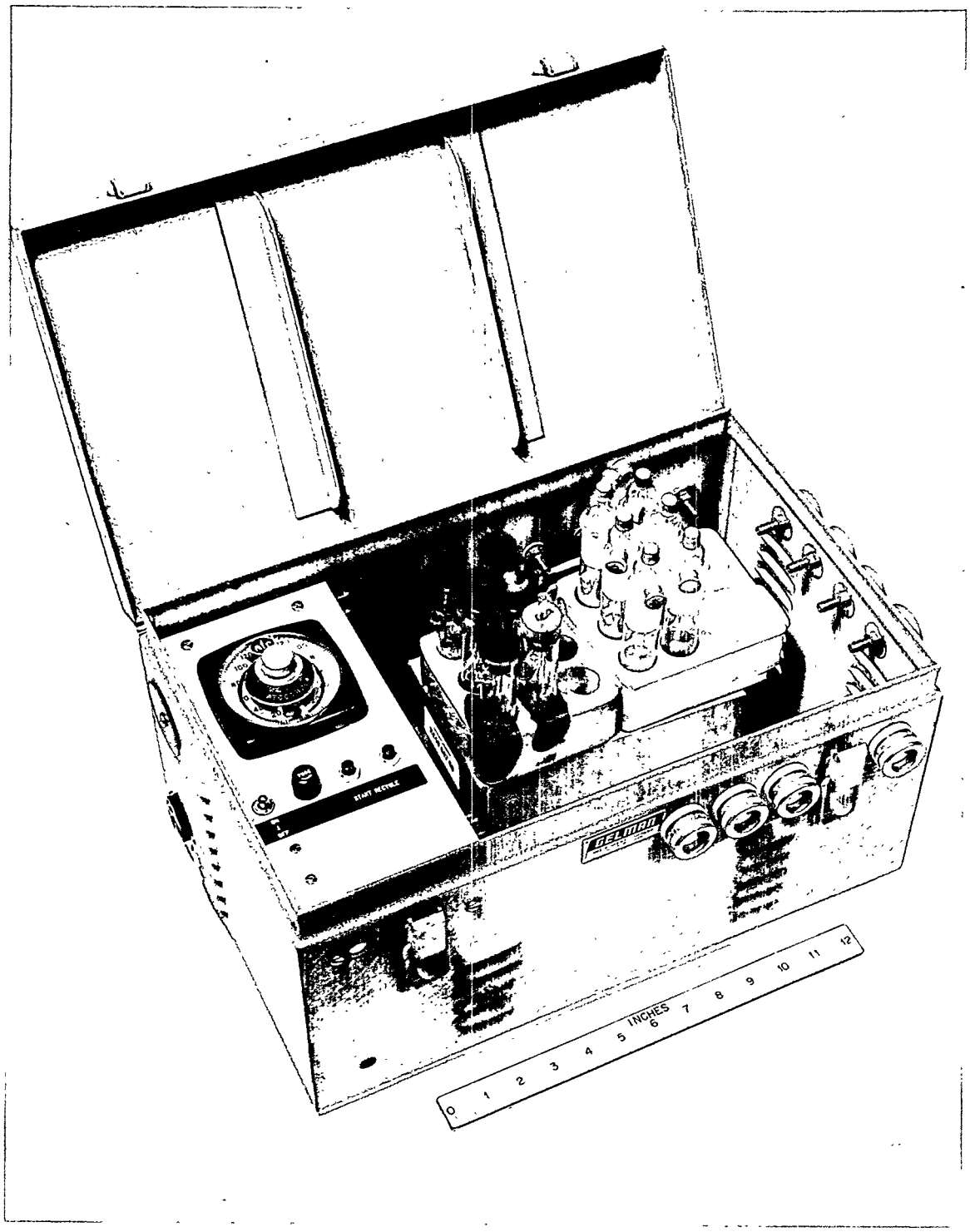
108735(U)

Figure 61. OTHER DETECTOR KITS USED IN Y-12.



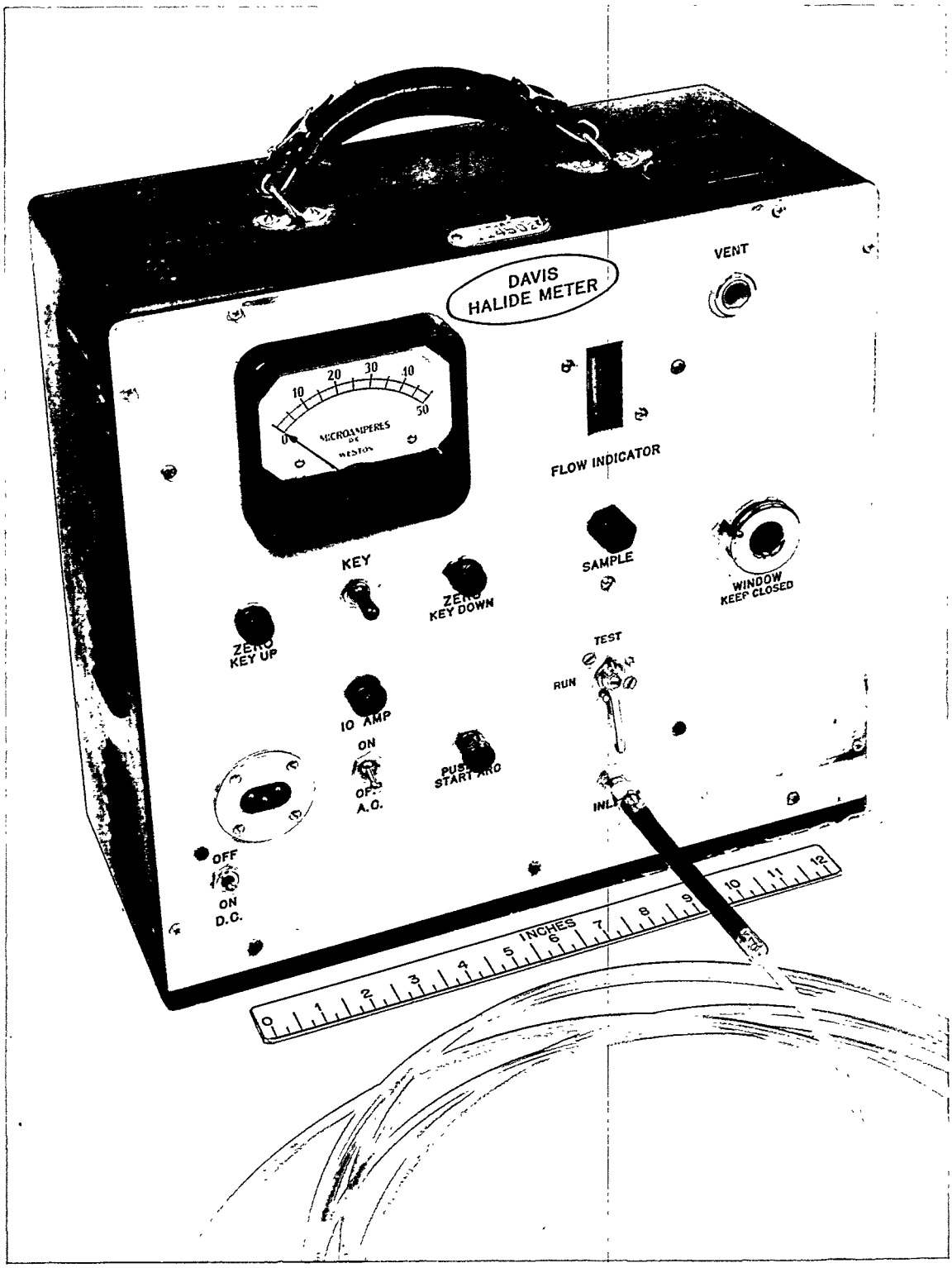
108743(U)

Figure 62. UNIVERSAL SAMPLING KIT.



108737(U)

Figure 63. SEQUENTIAL AIR SAMPLER.



108749(U)

Figure 64. HALIDE METER FOR DETECTING CHLORINATED HYDROCARBONS IN AIR.

ACKNOWLEDGEMENTS

The editors wish to acknowledge the contributions from other members of the Radiation Safety Department and express an appreciation for their cooperation. Details of the Personnel Internal Monitoring program were contributed by L. M. Scott and B. F. Rutherford. M. Sanders and M. B. Edwards supplied the information for the Area Monitoring program. The Emergency Monitoring program was described by E. Roberts, Jr. and the Industrial Hygiene program by J. F. Morehead, Jr. and J. S. Brown, Jr.

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OAK RIDGE Y-12 PLANT INFORMATION CONTROL FORM

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MERCURY SAMPLING PLAN

y 4

DAY 1

7 PM

1,2

1,2

① STAGE HEIGHT & VELOCITY (4 READINGS BY 2 PEOPLE)

② TOTAL MERCURY (PREPARED BOTTLES)

③ SAMPLE FOR MERCURY (UNPREPARED BOTTLE

- TOTAL MERCURY $\boxed{\text{2 LITER}}$
- FILTERED
  - SUSPENDED SOLIDS
  - MERCURY IN WATER PHASE
  - MERCURY IN FILTERED RESIDUE

	DAY 1		DAY 2			DAY 3			DAY 4 (HO
LOCATION	9AM	7PM	9AM	7PM	4AM	9AM	7PM	4AM	9AM
IN NHP	1,2,3	1,2,	1,2,3	1,2,	1,2	1,2 3	1,2	1,2	1,2
OUT NHP	1,2,3	1,2,	1,2,3	1,2,	1,2	1,2,3	1,2	1,2	1,2
NORTH PIPE	1,2,3	1,2,	1,2,3	1,2	1,2	1,2,3	1,2	1,2	1,2
SOUTH PIPE	1,2,3	1,2,	1,2,3	1,2	1,2	1,2,3	1,2	1,2	1,2
#915	—	—	1,2,3	—	—	1,[illegible]	—	—	—
E9811(N)	—	—	1,2,3	—	—	1,[illegible]	—	—	—
SW 9201-4(W)	—	—	1,2,3	—	—	1,[illegible]	—	—	—
SW9201-4(N)	—	—	1,2,3	—	—	1,[illegible]	—	—	—
SW 9201-4(NE)	—	—	1,2,3	—	—	1,[illegible]	—	—	—
NE 9720-5(W)	—	—	1,2,3	—	—	1,[illegible]	—	—	—
NE 9720-5(N)	—	—	1,2,3	—	—	1,[illegible]	—	—	—
[redacted]									
SE 9720-5(W)	—	—	1,2,3	—	—	1,[illegible]	—	—	—

D = dia of pipe

d = H

TABLE 8
SEGMENTS OF CIRCLES

$\frac{H}{D}$	$\frac{\text{area}}{D^2}$	$\frac{\text{wet. per.}}{D}$	$\frac{\text{hyd. rad.}}{D}$	$\frac{H}{D}$	$\frac{\text{area}}{D^2}$	$\frac{\text{wet. per.}}{D}$	$\frac{\text{hyd. rad.}}{D}$
0.01	0.0013	0.2003	0.0066	0.51	0.4027	1.5908	0.2531
0.02	0.0037	0.2833	0.0132	0.52	0.4127	1.6108	0.2561
0.03	0.0069	0.3482	0.0197	0.53	0.4227	1.6308	0.2591
0.04	0.0105	0.4027	0.0262	0.54	0.4327	1.6509	0.2620
0.05	0.0147	0.4510	0.0326	0.55	0.4426	1.6710	0.2649
0.06	0.0192	0.4940	0.0389	0.56	0.4526	1.6911	0.2676
0.07	0.0242	0.5335	0.0451	0.57	0.4625	1.7113	0.2703
0.08	0.0294	0.5735	0.0513	0.58	0.4723	1.7315	0.2728
0.09	0.0350	0.6094	0.0574	0.59	0.4822	1.7518	0.2753
0.10	0.0409	0.6435	0.0635	0.60	0.4920	1.7722	0.2776
0.11	0.0470	0.6761	0.0695	0.61	0.5018	1.7926	0.2797
0.12	0.0534	0.7075	0.0754	0.62	0.5115	1.8132	0.2818
0.13	0.0600	0.7377	0.0813	0.63	0.5212	1.8338	0.2839
0.14	0.0668	0.7670	0.0871	0.64	0.5308	1.8546	0.2860
0.15	0.0739	0.7954	0.0929	0.65	0.5404	1.8755	0.2881
0.16	0.0811	0.8230	0.0986	0.66	0.5499	1.8965	0.2899
0.17	0.0885	0.8500	0.1042	0.67	0.5594	1.9177	0.2917
0.18	0.0961	0.8763	0.1097	0.68	0.5687	1.9391	0.2935
0.19	0.1039	0.9020	0.1152	0.69	0.5780	1.9606	0.2950
0.20	0.1118	0.9273	0.1206	0.70	0.5872	1.9823	0.2962
0.21	0.1199	0.9521	0.1259	0.71	0.5964	2.0042	0.2973
0.22	0.1281	0.9764	0.1312	0.72	0.6054	2.0261	0.2984
0.23	0.1365	1.0003	0.1364	0.73	0.6143	2.0483	0.2995
0.24	0.1449	1.0239	0.1416	0.74	0.6231	2.0714	0.3006
0.25	0.1535	1.0472	0.1466	0.75	0.6318	2.0944	0.3017
0.26	0.1623	1.0701	0.1516	0.76	0.6404	2.1176	0.3025
0.27	0.1711	1.0928	0.1566	0.77	0.6489	2.1412	0.3032
0.28	0.1800	1.1152	0.1614	0.78	0.6573	2.1652	0.3037
0.29	0.1890	1.1373	0.1662	0.79	0.6655	2.1895	0.3040
0.30	0.1982	1.1593	0.1709	0.80	0.6736	2.2143	0.3042
0.31	0.2074	1.1810	0.1755	0.81	0.6815	2.2395	0.3044
0.32	0.2167	1.2025	0.1801	0.82	0.6893	2.2653	0.3043
0.33	0.2260	1.2239	0.1845	0.83	0.6969	2.2916	0.3041
0.34	0.2355	1.2451	0.1891	0.84	0.7043	2.3186	0.3038
0.35	0.2450	1.2661	0.1935	0.85	0.7115	2.3462	0.3033
0.36	0.2546	1.2870	0.1978	0.86	0.7186	2.3746	0.3026
0.37	0.2642	1.3078	0.2020	0.87	0.7254	2.4038	0.3017
0.38	0.2739	1.3284	0.2061	0.88	0.7320	2.4341	0.3008
0.39	0.2836	1.3490	0.2102	0.89	0.7384	2.4655	0.2996
0.40	0.2934	1.3694	0.2142	0.90	0.7445	2.4981	0.2980
0.41	0.3032	1.3898	0.2181	0.91	0.7504	2.5322	0.2963
0.42	0.3130	1.4101	0.2220	0.92	0.7560	2.5681	0.2944
0.43	0.3229	1.4303	0.2257	0.93	0.7612	2.6061	0.2922
0.44	0.3328	1.4505	0.2294	0.94	0.7662	2.6467	0.2896
0.45	0.3428	1.4706	0.2331	0.95	0.7707	2.6906	0.2864
0.46	0.3527	1.4907	0.2366	0.96	0.7749	2.7389	0.2830
0.47	0.3627	1.5108	0.2400	0.97	0.7785	2.7934	0.2787
0.48	0.3727	1.5308	0.2434	0.98	0.7816	2.8578	0.2735
0.49	0.3827	1.5508	0.2467	0.99	0.7841	2.9412	0.2665
0.50	0.3927	1.5708	0.2500	1.00	0.7854	3.1416	0.2500

Table 10.—Discharge of standard Cipolletti weir in second-feet. Values computed from the formula $Q=3.367LH^{3/2}$. (See sec. 19.)—Continued

Head H, feet	Length of weir, L, feet [1]				Head H, feet	Length of weir, L, feet [1]			
	6.00	7.00	8.00	9.00		6.00	7.00	8.00	9.00
0.01	0.02	0.02	0.03	0.03	0.46	6.30	7.35	8.40	9.45
.02	.06	.07	.08	.09	.47	6.51	7.59	8.68	9.76
.03	.11	.12	.14	.16	.48	6.72	7.84	8.96	10.08
.04	.16	.19	.22	.24	.49	6.93	8.08	9.24	10.39
.05	.23	.26	.30	.34	.50	7.14	8.33	9.52	10.71
.06	.30	.35	.40	.45	.51	7.36	8.58	9.81	11.04
.07	.37	.44	.50	.56	.52	7.57	8.84	10.10	11.36
.08	.46	.53	.61	.69	.53	7.79	9.09	10.39	11.69
.09	.55	.64	.73	.82	.54	8.02	9.35	10.69	12.02
.10	.64	.75	.85	.96	.55	8.24	9.61	10.99	12.36
.11	.74	.86	.98	1.11	.56	8.47	9.88	11.29	12.70
.12	.84	.98	1.12	1.26	.57	8.69	10.14	11.59	13.04
.13	.95	1.10	1.26	1.42	.58	8.92	10.41	11.90	13.38
.14	1.06	1.23	1.41	1.59	.59	9.15	10.68	12.21	13.73
.15	1.17	1.37	1.56	1.76	.60	9.39	10.95	12.52	14.08
.16	1.29	1.51	1.72	1.94	.61	9.62	11.23	12.83	14.44
.17	1.42	1.65	1.89	2.12	.62	9.86	11.51	13.15	14.79
.18	1.54	1.80	2.06	2.31	.63	10.10	11.78	13.47	15.15
.19	1.67	1.95	2.23	2.51	.64	10.34	12.07	13.79	15.51
.20	1.81	2.11	2.41	2.71	.65	10.59	12.35	14.11	15.88
.21	1.94	2.27	2.59	2.92	.66	10.83	12.64	14.44	16.25
.22	2.08	2.43	2.78	3.13	.67	11.08	12.92	14.77	16.62
.23	2.23	2.60	2.97	3.34	.68	11.33	13.21	15.10	16.99
.24	2.38	2.77	3.17	3.56	.69	11.58	13.51	15.44	17.37
.25	2.53	2.95	3.37	3.79	.70	11.83	13.80	15.77	17.75
.26	2.68	3.12	3.57	4.02	.71	12.08	14.10	16.11	18.13
.27	2.83	3.31	3.78	4.25	.72	12.34	14.40	16.45	18.51
.28	2.99	3.49	3.99	4.49	.73	12.60	14.70	16.80	18.90
.29	3.15	3.68	4.21	4.73	.74	12.86	15.00	17.15	19.29
.30	3.32	3.87	4.43	4.98	.75	13.12	15.31	17.49	19.68
.31	3.49	4.07	4.65	5.23	.76	13.38	15.61	17.84	20.08
.32	3.66	4.27	4.88	5.48	.77	13.65	15.92	18.20	20.47
.33	3.83	4.47	5.11	5.74	.78	13.92	16.23	18.55	20.87
.34	4.00	4.67	5.34	6.01	.79	14.18	16.55	18.91	21.28
.35	4.18	4.88	5.58	6.27	.80	14.45	16.86	19.27	21.68
.36	4.36	5.09	5.82	6.54	.81	14.73	17.18	19.63	22.09
.37	4.55	5.30	6.06	6.82	.82	15.00	17.50	20.00	22.50
.38	4.73	5.52	6.31	7.10	.83	15.27	17.82	20.37	22.91
.39	4.92	5.74	6.56	7.38	.84	15.55	18.14	20.74	23.33
.40	5.11	5.96	6.81	7.67	.85	15.83	18.47	21.11	23.74
.41	5.30	6.19	7.07	7.95	.86	16.11	18.80	21.48	24.17
.42	5.50	6.41	7.33	8.25	.87	16.39	19.12	21.86	24.59
.43	5.70	6.65	7.59	8.54	.88	16.68	19.45	22.23	25.01
.44	5.90	6.88	7.86	8.84	.89	16.96	19.79	22.61	25.44
.45	6.10	7.11	8.13	9.15	.90	17.25	20.12	23.00	25.87

See footnote at end of table.

N HP weir

UCN-7721B
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OAK RIDGE Y-12 PLANT INFORMATION CONTROL FORM

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CONTROL OF MERCURY VAPOR IN COLEX OPERATIONS

J. E. Perry
J. M. Napier

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J. E. Perry
J. M. Napier

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DETECTION OF MERCURY VAPOR

VAPOR DETECTION EQUIPMENT

As soon as large quantities of mercury were utilized in the ADP processes, methods were investigated by the Health Physics and Industrial Hygiene Groups for detecting the mercury vapor present in the air. Only three commercially available instruments were found. One, manufactured by the [redacted] Co. and operating on a phototube absorption method was found unreliable and difficult to keep in repair. A second, the [redacted] Mercury Vapor Detector, Type B, which employed the principle of the color change of selenium sulfide coated paper, was found too unreliable due to its high sensitivity to temperature and atmospheric conditions. The third, the [redacted] Instantaneous Mercury Vapor Detector, was found reliable and although it is not a fully portable instrument, it has been used successfully in the Colex Plants.

The General Electric Instantaneous Vapor Detector

The [redacted] Instantaneous Vapor Detector, operates on 110 volts alternating current, weighs 35 pounds, and is equipped with a neck strap harness which, within the limitations of the power cord, makes the instrument "portable". The harness allows the operator full use of both hands to make zero adjustments, to hold the air sampling tube at any desired level (usually at breathing level), and to record the mercury vapor concentration. The air is continuously drawn in to the instrument by means of suction from a blower and passed through a chamber containing two phototubes one of which is shielded by Pyrex glass. An ultra violet mercury lamp emitting 78% of its energy at 2537 angstroms (which is absorbed by the Pyrex glass) is directed toward the phototubes. The tubes are connected in a bridge circuit. Since the air sample passes by both tubes, any substance which alters the beam of light with energy other than 2537° A., affects both sides of the bridge circuit equally. The bridge circuit is balanced with pure air just prior to use. When air containing mercury vapor passes through the unit, the mercury vapor absorbs the ultra violet light at 2537° A. and unbalances the bridge. The degree of unbalance is proportional to the mercury vapor concentration in the air. The output is read directly on a milliammeter. Each vapor detector has its own milliampere-mercury vapor concentration calibration chart from which the vapor concentration is obtained. The meter has been found accurate and sensitive over the range 0.01 to 1.5 mg/m^3.

Greater Sensitivity - When greater sensitivity was desired for the study of respirator contamination, a [redacted] Vapor Detector was modified slightly. The blower was removed and two quartz cells (500 cc volume) were placed between the phototubes and the U.V. lamp. The cells were so installed that they could be evacuated and a small volume of air admitted for measure. The meter, so modified, was used successfully in the testing of rubber and other small samples.

Portable Mercury Vapor Tester

Although the G. E. Detector is considered portable, it has two disadvantages. First, the weight of 35 pounds is somewhat excessive for carrying around process areas. The second, and major disadvantage, is the long (up to 275 ft) cord needed to supply the necessary alternating current. In addition, a Sola voltage regulator is necessary. Several attempts have been made to overcome these difficulties with the greater effort being placed on a self powered meter. The first battery powered unit designed used a photomultiplier to obtain the desired voltage for the standard General Electric supplied U. V. lamp and phototubes. That meter was tested and found unstable in the region of 0.1 mg/m^3 mercury vapor concentration. The second meter was designed with lower voltage phototubes and with no photomultiplier. This meter was not found stable enough to use.

A third, battery operated, self-contained mercury vapor detector was designed incorporating a low voltage blower. All components of this meter have been field tested and found satisfactory; several units are now in routine use.(8)

Hand Monitors

Since the use of hand "counters" or monitors had proven successful in causing personnel to be aware of possible hand contamination on projects involving radioactive chemicals it was felt advisable to adapt the principle for use with personnel whose work involved contact with mercury. Thus, an instrument was designed which would provide an indication of mercury contamination on the hands. Adequate sensitivity was provided in a range from zero to one milligram per cubic meter of air.

The instrument provided simultaneous sampling of the atmospheric environment of the instrument at two ports, plus the mercury vapor from the hand at one port. The two air samples were drawn through similar ultraviolet absorption cells where phototubes provided electrical signals inversely proportional to the mercury vapor present. The two signals were compared in a vacuum tube voltmeter circuit, and the output was displayed on a microammeter calibrated in terms of mercury contamination.

The electronics provided an alternating current excitation for the ultraviolet lamp, and a regulated direct current voltage for the phototube detectors and the voltmeter. Electrical balance adjustments for the phototubes and voltmeter, as well as a sensitivity control, were provided.

A schematic diagram (Figure 14) and a photograph (Figure 15) provide an adequate visual description.

Instruments were installed in both Colex plant lunch rooms and have provided over one year of continuously satisfactory operation.

Badge Type Vapor Detector

Considerable effort was expended in attempting to develop a personnel badge-type monitor that would detect the total vapor to which an employee was

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ABSTRACT

Toward the end of 1955 the problem of excessive mercury vapor in the air existed in the two ADP Colex Process Buildings of the Y-12 Plant.

Early in 1956 a program was launched in which the theoretical factors involved were studied; equipment improvement, surface coatings, ventilation, vapor detection apparatus and personnel protective equipment were investigated; and plant tests were performed. The clean-up, operating, and maintenance procedures, which were developed and recommended, decreased and maintained the average mercury vapor concentration well below the accepted maximum allowable concentration of 0.10 mg/m^3.

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SUMMARY

INTRODUCTION

The ADP Colex Process employed in the Y-12 Plant involves the transporting of large quantities of mercury and liquid amalgam through large numbers of pumps, pipes, and related equipment under relatively high pressure. The speed at which the two plant buildings were designed and constructed precluded close attention to devices for the prevention and/or retention of mercury leaks and spills. In a similar manner, the emphasis on ever increasing production reduced the time available for housekeeping. As a result, the plants became visibly contaminated with mercury and the mercury vapor in the air rose above the Maximum Allowable Concentration (MAC). Thus, in January of 1956 a "crash" program was instituted to take the necessary steps to reduce and maintain the mercury vapor concentration, in the Colex plants, below the MAC.

REDUCTION OF MERCURY VAPOR

The variables affecting the mercury vapor concentration were reviewed in terms of the following mass transfer equation:

$$C = \frac{KAT^{\frac{1}{2}}}{FB_f} (Y_i - Y_s)$$

where C is the concentration of mercury in the air; A is the surface area of the mercury exposed to the air; T is the absolute temperature (Rankin); F is the flow rate in ft^3/min; B_f is film thickness; Y_i is the mol fraction of mercury at the interface; Y_s is the mol fraction of mercury in the air; and K sums up the absolute constants. From this equation it is seen that the mercury vapor concentration varies directly with the exposed area (A), the square root of the absolute temperature (T), and the difference in mol fraction of mercury at the interface ($Y_i - Y_s$) while it varies inversely with the flow rate of the air (F) and the film thickness (B_f).

Review of the above equation together with a study of the plant showed that the surface area of exposed mercury was the major source of the vapor. Thus clean-up of the exposed mercury and the development of ways and means to prevent leaks and spills were given the greatest emphasis. Due to the nature of mercury and the way it tends to spatter and subdivide into extremely small particles which become embedded in the cracks, crevises, and pores of most any surface, every surface area which was subject to mercury contamination was assumed to be a potential mercury surface. To reduce the potential surface area, it was recommended that excess material and equipment be removed from the operating areas. To reduce the mercury contamination in the non-operating area, traffic control and the removal of contaminated shoes before entering were suggested.

The basic plant cleaning procedures were found to increase contamination by spattering the mercury when it was hosed or swept to a floor drain. It was recommended that the house vacuum system be substituted and an efficient nozzle for picking up mercury was designed and tested.

A carefully supervised "all out" clean-up program studied the techniques best suited for use in the Colex plants. It was found that foreign substances often had to be cleaned away before the mercury could be efficiently removed. Acetic acid was found best for removing carbonates and "Gunk" for grease. The recommended cleaning procedure involved the thorough removal of mercury by vacuum-cleaning, washing of the area with a solution of a "Tide" type detergent, and then mopping with a solution of sodium hypochlorite which formed a surface coat on the remaining mercury and suppressed the vaporization rate. Studies of the clothing worn in the operating areas revealed that "Dynel" and "Vinyon" contaminated quickly with mercury and were extremely difficult to decontaminate. Cotton clothing was recommended for use since it did not collect mercury as easily and was relatively simple to decontaminate.

All of the sources for leaks and spills were carefully reviewed. Many leaks were corrected by tightening flanges and others were prevented by changing from "Victaulic" type couplings to the "Dresser" type on mercury lines. It was found that the valves which gave the greatest leakage problems could be eliminated. Methods were recommended to reduce and retain, by catch pans, the leaks from the packing glands of the pumps. Design changes were recommended for reducing the pipe vibration which contributed to pipe line failures.

The major source of spills was found to be in equipment change outs - especially pumps. It was recommended that enclosed transport dollies be used, as well as water flush-out before the equipment was removed, and, in the case of pumps, installation of a bag enclosure over each opening as soon as the pump was disconnected.

The studies on surface coatings, for equipment and floors, which would shed and would not hide mercury, showed that, of the materials tested, a two coat application of "Pliogard" paint was best for the walls and equipment while "Onex Seal" was the most successful floor covering.

Plastic sheet materials were investigated for their permeability to mercury vapor and their physical properties to withstand plant conditions. A laminate of 1 mil "Mylar" - 4 mil polyethylene was recommended for use in wrapping equipment with rough surfaces, for making enclosed funnel type bags to catch mercury from persistent leaks, and for elastic top bags used to seal the openings in pumps removed from the process for repair.

The effects of temperature and ventilation confirmed the predictions of the mass transfer equation. From a given source, the mercury vapor content in the air rises as the temperature increases. The greater the flow of air, the lower the mercury vapor concentration. The higher the air velocity on the mercury surface, the greater the amount of vaporization.

Studies to find a compound to suppress the mercury vapor revealed that a water solution of sodium hypochlorite, when applied to the mercury surface, reacts with the mercury to form compounds of mercury on the surface which do not, themselves, give off mercury vapor, and which prevent further vaporization of the mercury itself.

DETECTION

The only reliable mercury vapor detector commercially available was found to be the General Electric Instantaneous Mercury Vapor Detector. A completely portable meter and a hand monitor were designed for plant use. Some work was performed to find a badge type, total exposure, mercury detector. A practical system for this has not yet been found.

PERSONNEL PROTECTION

Respirators were studied for effectiveness, life expectancy, comfort to wearer, ease of disassembly, and ease of decontamination. A specification for a respirator was written. The Mines Safety Appliances Co. "Gasfoe" respiratory equipped with a "Mersorb" chemical cartridge was found to be acceptable.

RESULTS AND CONCLUSIONS

Basically the objectives of the program were met. The overall average mercury vapor contamination of the Colex Plant buildings was reduced to less than the MAC. However, the vapor concentration was not immediately reduced in every area below the MAC. Thus, continuing efforts are being made, using the information and techniques gained in this program, to maintain all areas below the MAC.

To reduce and maintain the mercury vapor in a plant handling large quantities of mercury good housekeeping must be stressed; the operating areas must not contain excess materials; the contaminated areas must be thoroughly cleaned; a vapor suppressing agent should be applied after cleaning; all floor, wall, and equipment surfaces should be made smooth by the use of proper paints or surface coatings; equipment change outs should be executed with little or no spillage; contaminated equipment should be transported in enclosed containers; and leaks which cannot be prevented should be caught and contained in suitable enclosures.

For mercury vapor detection, the G. E. meter should be utilized and, to stimulate better hygiene, the use of hand monitors should be encouraged.

For protection of personnel from high concentrations of mercury vapor, a MSA "Gasfoe" respirator equipped with a "Mersorb" cartridge should be used.

INTRODUCTION

The ADP isotope separation process employs a liquid amalgam as one of the contacting agents.[1] [2] Early in the Elex Pilot Plant studies, the potential hazard of mercury was studied and steps were taken to maintain the vapor contamination at a low level both in the pilot plants and in the Elex Production Plant. Since the Elex process[1] involved closed trays with the amalgam flow by gravity through a minimum of piping and pumps under relatively low pressures, leaks and spills were kept at a minimum and very little air contamination was encountered.

The Colex process,[2] however, involves extremely large volumes of both mercury and amalgam flowing at high velocities and pressures through numerous pumps, pipes, and the attendant flanges, valves, connectors, seals, etc. Inevitable leaks occur and large spills have been common as a result of the high frequency of equipment change-out necessary. Thus, a potential source of mercury is established for vaporization into the air. This was first realized in the pilot plants where spills and leaks resulting from the frequent equipment change outs (due both to failure and experimental studies) were common. During the pilot plant studies, however, the high frequency of equipment failure in the two Colex production plants was not completely anticipated. The urgency for speed in the design of the plants did not permit time for the engineering of special features to handle leaks and spills. The urgency and need for production in the early stages of start-up of the Colex plants, likewise, left little time for spotless housekeeping and attention to the mercury vapor contamination. Thus, by early January, 1956, the air contamination of the Colex Plant buildings indicated that an all out effort should be exerted to (a) reduce the mercury vapor contamination in the Colex buildings, and (b) determine reasonable operating procedures and techniques to allow normal operation of the process while maintaining the mercury vapor concentration in the air below the currently accepted MAC (Maximum Allowable Concentration) of 0.1 mg/m^3.[3] The necessity to act quickly at that time was most urgent in view of the fact that, if better control of the mercury contamination could not be maintained, the warmer weather in the spring and summer could be expected to increase the mercury vapor concentration and cause a potentially serious health hazard.

In order to accomplish the above goals, a program was undertaken in which the theoretical factors involved were studied; experimental tests were performed both in the laboratory and in the plant; the knowledge gained over the preceding four years, in the ADP program, was reviewed; and practical clean-up, operating, and maintenance procedures were devised. This report is concerned with that program.

REDUCTION OF MERCURY VAPOR CONCENTRATION

MASS TRANSFER EQUATION

The first consideration in reducing the concentration of a contaminating vapor, in the air, is to establish and, if possible, eliminate the source. As was stated in the Introduction, the source of mercury vapor in the Y-12 Colex Plants is the exposed liquid mercury resulting from leaks and spills. Since, as in this case, it is not always possible or economically feasible to remove the source completely, it is necessary to understand the mechanism whereby the source produces the vapor. It can then be determined whether (a) it is practical to reduce the vapor concentration to a sufficiently low level by controlling the physical variables of the vaporization mechanism, such as temperature, air flow, etc., or (b) to what extent it is necessary to expend effort both in reducing the source to a reasonable minimum and in controlling the physical variables as well. As will be seen from the following discussion of an applicable mass transfer equation, the surface area of mercury exposed is the largest contributing factor to its evaporation. Thus, it was indicated that the greatest effort should be expended in reducing the amount of exposed liquid mercury and to eliminate as completely as possible the conditions which permitted the escape of liquid mercury from the process. Each of the other variables, however, has an effect, and wherever applicable, control of these variables has been used to aid in the reduction of the vapor.

An applicable mass transfer equation for the mercury-mercury vapor system is:

$$N = \frac{DP\,(Y_i - Y_s)}{RTB_f} \qquad \text{(Equation 1)}$$

Where N = Moles diffusing/hr (ft^2)

D = Diffusivity coefficient

P = Pressure in atmospheres

R = Gas constant

T = Temperature (^{o} Rankine)

B_f = Film thickness

Y_s = Mol fraction of mercury in air

Y_i = Mol fraction of mercury at interface

The diffusivity coefficient (D) may be defined by an empirical equation which shows it to be a function of the molecular weights of the mercury and air, molecular volume of the mercury and air, temperature to the 3/2 power,

the pressure, and a constant. For this discussion, the absolute values are not important and the constants that apply to mercury and air may be grouped and defined as K'.

Therefore: $$D = K' \frac{T}{P}^{3/2} \qquad \text{(Equation 2)}$$

Also, from definition it may be shown that

$$N = \frac{W}{A} \qquad \text{(Equation 3)}$$

Where: W = Mols diffusing/hour

A = Surface area of mercury exposed to air

And $$C = W/F \qquad \text{(Equation 4)}$$

Where C = Concentration of mercury in the air

F = Flow rate of air in cubic feet/hour

Therefore, if these terms are substituted into the original equation a relationship can be shown that defines the concentration of mercury in the air, ie:

$$C = \frac{KAT^{1/2}(Y_i - Y_s)}{FB_f} \qquad \text{(Equation 5)}$$

The concentration is shown to vary directly with the exposed area (A) the square root of the absolute temperature (T), and the difference in mol fractions of mercury at the interface and in the air ($Y_i - Y_s$) while it varies inversely with the flow rate of air (F), and the film thickness (B_f).

DECONTAMINATION OF SURFACE AREA

Potential Surface Area

The physical properties of mercury made it difficult to define the surface area exposed to air at any given location. Mercury in the plant was found to vary in "particle" size from large puddles to droplets invisible to the unaided eye. Obviously, the maximum area exposed from any given quantity of mercury occurred when that quantity had been finely sub-divided. Experience in handling mercury previously had shown that leaks and spills which fell onto the floor or equipment invariably sub-divided and scattered over a large area when the larger drops spattered on the surface. The degree of sub-division was found to be dependent upon the distance the mercury had traveled before it hit the surface. Rough surfaces in the operating area also assisted in sub-dividing the mercury into small droplets and made coalescense into large puddles impossible.

The flat surfaces presented by the floors, and the fact that the floors represented the maximum distance that any amount of mercury would travel before

coming to rest, suggested that the floors contained the greatest potential mercury surface and were, therefore, the prime source of the air contamination.

It cannot be over emphasized that the surface of mercury exposed is a direct result of the degree of housekeeping that can be maintained in any area which is subject to contamination by mercury.

Plant Conditions - A close examination of the housekeeping in the plant indicated, in general, that the cleaning was as thorough as might be expected in any other industrial plant. Although no quantitative measurement of the surface of mercury exposed could be made in any given area, visible mercury was a common sight in the plant. It was further established that any area, with evidence of visible mercury, had a much larger quantity of mercury not visible to the unaided eye.

It was therefore assumed that the potential mercury surface area, in a given location, was any exposed surface subject to mercury contamination.

Building and Equipment Clean-Up

To reduce potential surface area it was recommended that a check be made in all operating areas and any equipment or material which was not absolutely necessary be removed from the area. Such material included excess piping, brooms, brushes, rags, mops, boxes, drums, and anything made of wood. It was further recommended that any drums necessary to the process be sealed and valve handles (especially the chain operated type), unless absolutely necessary for daily routine use, be removed.

Non-Operating Areas - It was also found that the transfer of mercury on clothing, shoes, and equipment caused lunchrooms, offices, control rooms and other such non-operating areas to become contaminated. It was suggested that close control over contaminated foot wear might be effected by the use of overshoes in the contaminated areas with their removal before entering a "clean" area.

A second proposal was to install shoe wash stations between contaminated operating areas and "clean" non-operating areas. Such a devise was designed, built, and furnished to the Operations Department. This devise consisted of a platform with a sunken metal box which was filled with brushes located in various positions. The box contained a suitable rubber cleaning solution (Appendix A-8) and was designed to clean each shoe separately and efficiently. A photograph of the shoe wash station may be seen in Figure 1. The devise was not used, since the clean-up program soon reached the stage where the transport of mercury to the control rooms and lunchrooms became negligible.

Recommendations for control of the non-operating areas may be found in Appendix A-1.

Vacuum Cleaning System - It was observed that the methods employed for removal of the visible mercury were inefficient and, in many cases, were the cause of further air contamination. Two common practices were the sweeping and water hosing of large pools of mercury toward the floor drains. Both

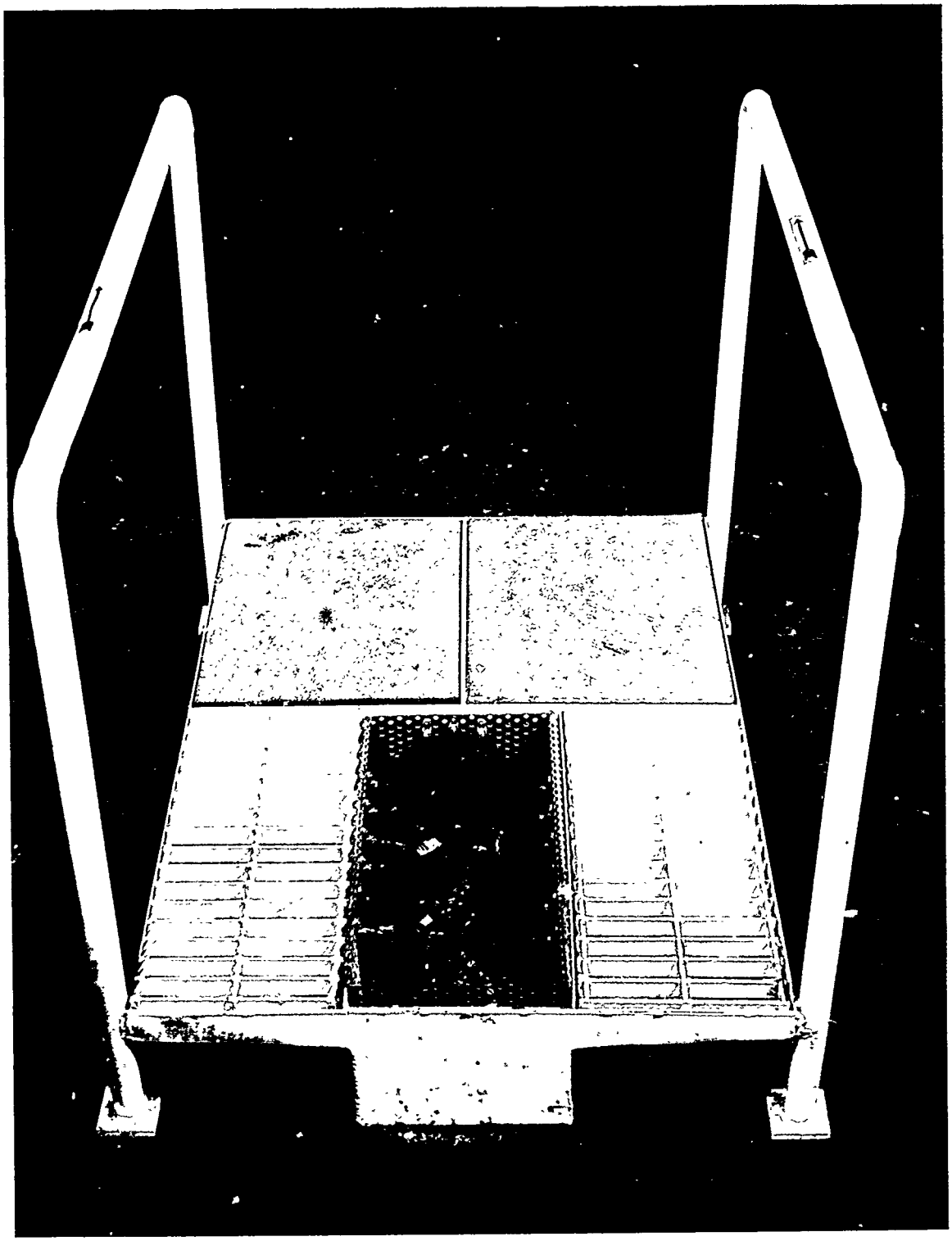


Figure 1. SHOE WASH STATION

resulted in scattering and further distribution of the mercury in the form of smaller particles. Investigations showed that the most efficient method of removal was by vacuum cleaning equipment. It was recommended that the house vacuum system, which was just being installed, be used where ever applicable and that all sweeping and water hosing of mercury be immediately discontinued.

A study was made of vacuum nozzle characteristics in conjunction with the building vacuum system. It was found that at low nozzle air velocities, of 6,000 feet per minute, the mercury droplets tended to coalesce into large globules which remained suspended in the handle of the nozzle whereas, at higher velocities, 12,000 to 16,000 fpm, the mercury broke rapidly into droplets which traveled with the air stream.(4) Since commercial nozzles could not be located which would furnish the needed velocity and also be convenient to use, fourteen different nozzles and handles were designed, fabricated, and tested. The best nozzle (as shown in Figure 2) and handle combination was recommended. The Operations group had a supply of these fabricated and placed in use.

Experimental Clean-Up Program - An experimental clean-up program in a portion of the Colex plant was instituted to eliminate, if possible, all exposed mercury. The West Cascade Area of the 9201-5 building, which represented the major problems regarding mercury contamination, was selected. A group of window and wall washers, working around-the-clock on rotating shifts, were assigned to thoroughly clean the entire area including walls, floors, pipe work, and equipment.

Technical personnel from the Cascade Development Department co-ordinated the program on each shift. The area was cleaned in its entirety - from the ceiling of the top level to the floor of the ground level. It was often found necessary to clean other materials from the surface in order to clean off the mercury. Carbonate formations were removed with a dilute solution of acetic acid. Grease was removed with a non-flammable, water soluble commercial compound called "Gunk"*. In general, the agitation, during the cleaning of an area, produced a higher-than-average air contamination during the actual cleaning. Except in certain areas of extremely poor ventilation, the contamination dropped below the MAC the day after the cleaning was finished in any given area.

As a result of this cleaning, sufficient information was obtained to recommend a "clean-up" procedure (See Appendix A-11). In addition, close observation of the operations revealed that certain routine jobs, such as pump change-outs, habitually caused contamination of the air in the vicinity. The more serious of these jobs were listed in a memo (See Appendix A-10) so that increased emphasis might be exerted thereon.

Although considerable emphasis had been placed on the handling of mercury, resulting from leaks and spills, since the use of mercury first started in the early days of the ADP program, it required a continuing effort to impress those intimately associated with the problem with the hazards involved and the importance of good housekeeping. The only available measurement of the mercury vapor was by the use of the General Electric Mercury Vapor Detectors used in the routine checks by the Health Physics Group. (See Detection of

*A glossary of all trade names and manufacturers appears in Appendix E.

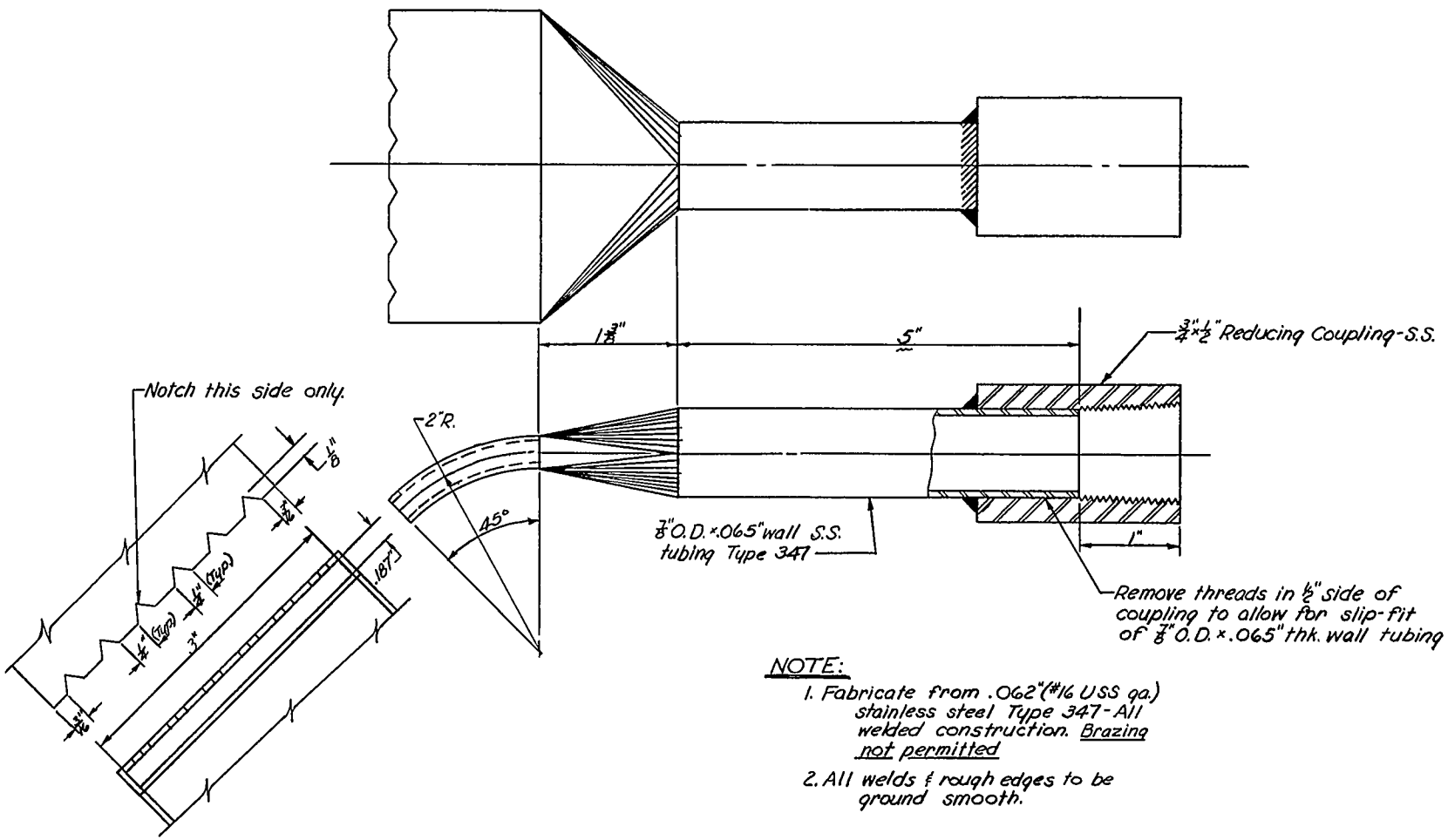


Figure 2. HOUSE VACUUM SYSTEM PICK-UP NOZZLE

Mercury Vapor Section). The data from these checks were available to supervision only. Since constant contact with the mercury tended to create a false sense of security in the worker, it was recommended to supervision that they continually emphasize the importance of housekeeping to the operating personnel. It was further suggested that good personal hygiene be practiced and that food and tobacco be kept out of the operating areas (See Appendix A-3).

Clothing

Synthetics vs Cotton - Clothing worn in the operating area was found to be highly contaminated and very susceptible to the retention of mercury droplets in the interstitial spaces of the cloth. Two types of company-issued work clothes, "Dynel" and "Vinyon", both synthetics, were being worn in the operating areas. These two synthetics have a loose rope-like weave with a high gloss surface. Examination of cloth samples, which had been exposed to mercury, with the aid of a microscope revealed that mercury particles stuck on the glossy fibers in such a manner as to make cleaning difficult. Normal laundry procedures did not remove the mercury - and, even more alarming, was the fact, that in the laundry operation, the contaminated uniforms were contaminating the uniforms from other areas (where mercury was not in use) and were thus supplying a source of mercury contamination for all plant areas. The only adequate cleaning method found for these two synthetic materials was washing in strong nitric acid solutions or strong sodium hypochlorite solutions. It would be difficult, however, to equip a laundry with the special equipment needed for handling such concentrated solutions.

It was found that cotton material did not contaminate as quickly because the mercury did not cling to the fibers in the same manner as it did to the synthetic fibers. In addition, and for the same reason, the cotton was found easier to decontaminate. A vigorous scrubbing with a soap solution removed all traces of mercury from cotton fabrics. Thus standard laundry techniques could be applied.

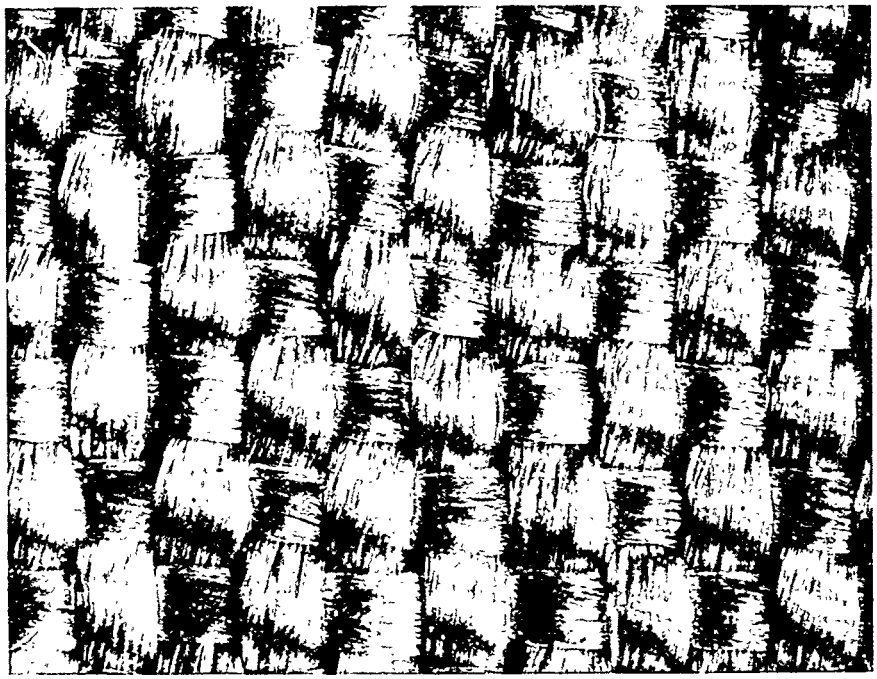
Photographs, taken with 20X magnification, of contaminated and uncontaminated "Dynel", "Vinyon", and cotton may be seen in Figures 3, 4, and 5. The results of the various tests performed on fabrics may be seen in Appendix B-1.

As a result of these findings, it was recommended that only cotton work clothes be worn in the Colex operating areas. In addition, the design of the work clothes should incorporate a minimum of seams and pockets that act as traps for mercury.

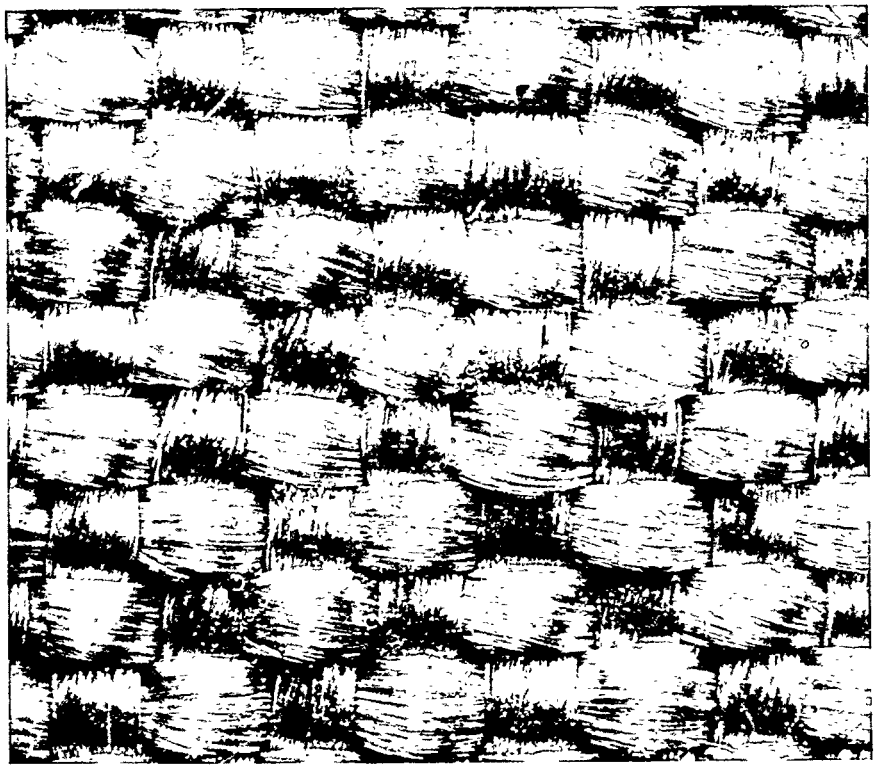
PREVENTION OF SURFACE CONTAMINATION

Leaks

Source - One of the major sources of the exposed mercury in the Colex Plants was found to be from leaks. Investigation showed these leaks to be mainly from pipe flanges, couplings, valves, and pumps. Further studies revealed that the mercury entrainment in the aqueous process solutions was sufficient

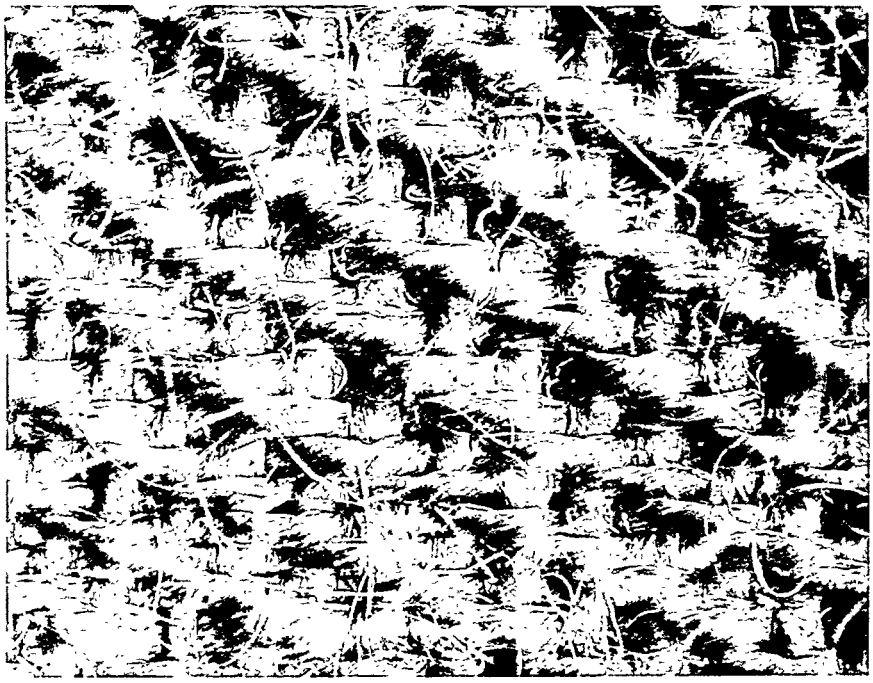


(a) Uncontaminated 20X Magnification



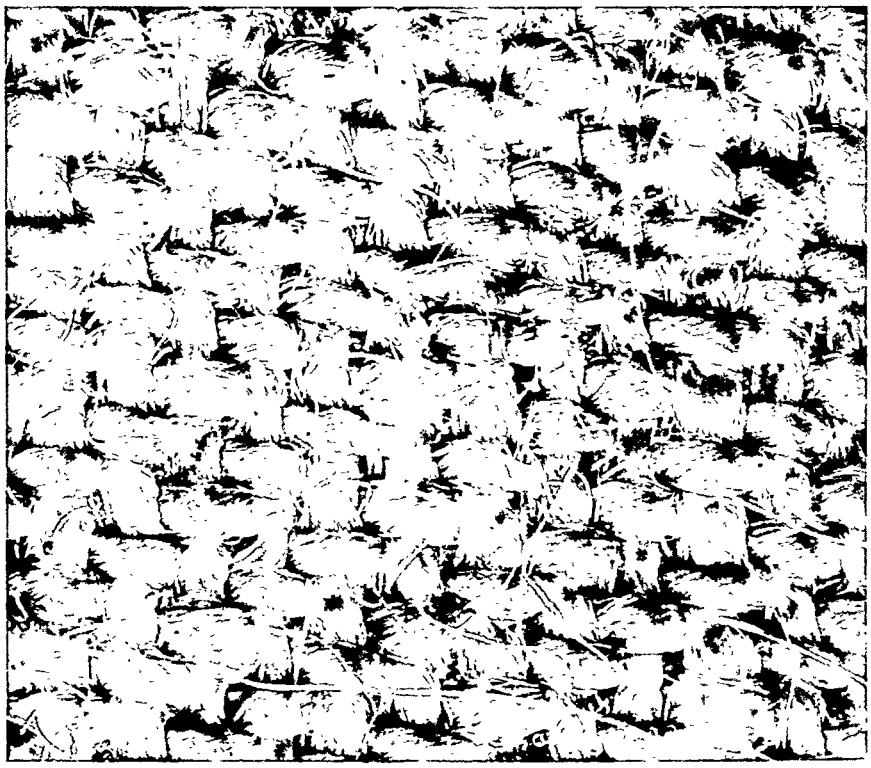
(b) Contaminated With Mercury 20X Magnification

Figure 3. COMPARISON OF DYNEL FABRICS



(a) Uncontaminated

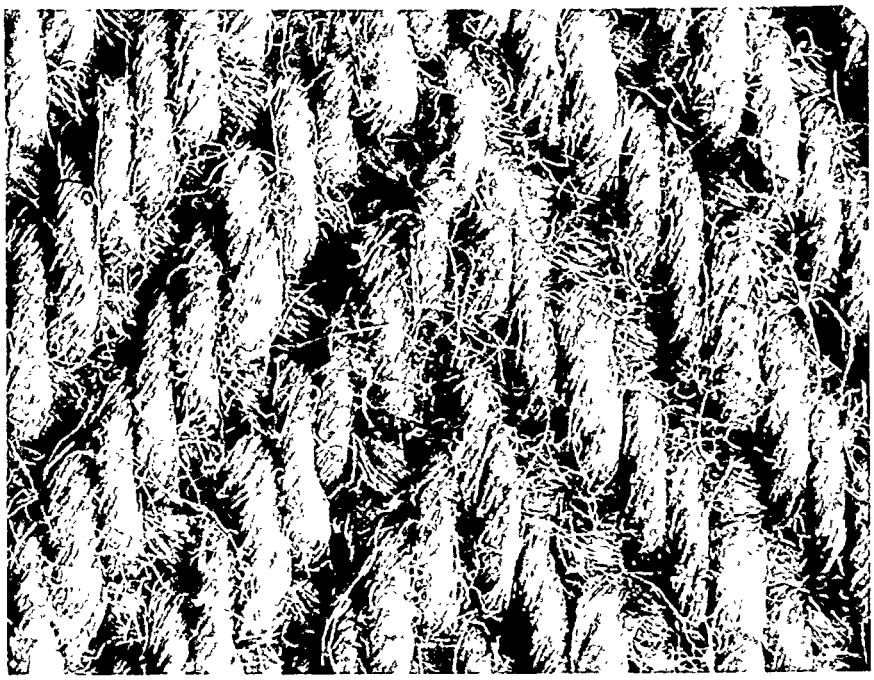
20X Magnification



(b) Contaminated With Mercury

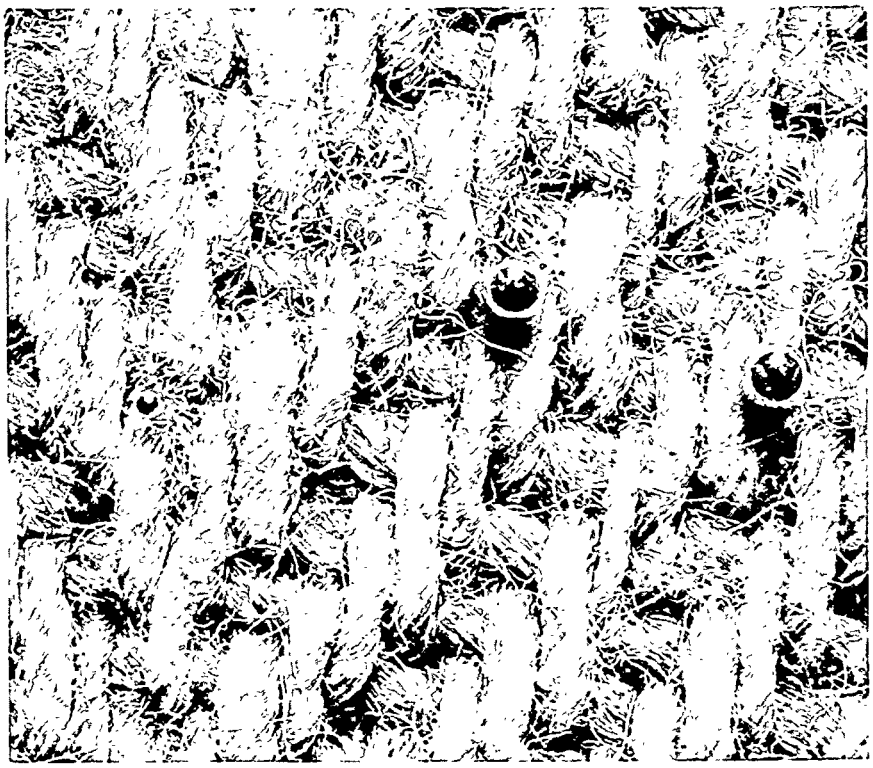
20X Magnification

Figure 4. COMPARISON OF VINYON FABRICS



20X Magnification

(a) Uncontaminated



20X Magnification

(b) Contaminated With Mercury

Figure 5. COMPARISON OF COTTON FABRICS

to produce serious mercury vapor contamination from relatively small quantities of exposed aqueous solution. It was assumed that this was due to the finely divided particle size of the mercury which, in turn, resulted in a large exposed surface area. Thus, the prevention of aqueous leaks assumed the same importance as mercury leaks.

Flanges - The first step taken by the Operations Department was to assign all available pipefitters to the job of repairing the leaks with special emphasis on the flanges. In conjunction with this step, the Development Group instituted an experimental program to determine the recurrance rate of leaks. Two tags were placed at the site of each leak. When the leak was repaired, one tag was removed and turned in for recording. If a leak developed at the same spot again, the second tag (of a different color than the first) was turned in for tabulation. Over a period of five months, no significant recurrance of leaks was noted.

A second objective of the above experimental study was the intention to investigate the flange gasket materials. The standard gasket material used in the Colex Plants was pressed sheet asbestos except in a few low pressure lines where rubber was substituted. This phase of the investigation was abandoned due to the permanent correction of the leaks by repairing and tightening.

As a result of these studies, it was recommended that flange gaskets not be re-used (Appendix A-2).

Couplings - From manufacturers literature and cost comparisons, it had appeared, during the pilot plant period, that "Victaulic" couplings were a better connection for certain amalgam lines than flanges. In addition, the expansion which could be tolerated with the "Victaulic" fittings was sufficient to permit the use of these fittings in place of expansion joints. Satisfactory results were obtained, with no leakage, when two such fittings were tested in the Pilot Plant. Thus, the second Colex Plant to be built, Alpha-4, was designed to incorporate the Victaulic couplings wherever expansion or flexibility was needed. This type of fitting, however, started leaking after three weeks of plant operation. The leak was of a slow dribbling nature. The gaskets supplied in the assembly were made of "Hycar". Test gaskets of natural rubber and neoprene were obtained and tested. In each case, a tight seal was maintained only for about three weeks. Again the same type leak, which had been noted with the Hycar gaskets, appeared.

Tests were then made with "Dresser" couplings and no leaks occurred even in cases of poor alignment. The "Dresser" couplings were competitive in cost with the "Victaulic" fittings and the allowable expansion was considerably more. Another definite advantage of the "Dresser" type coupling was that it could be tightened after installation whereas the "Victaulic" fittings could not.

As a result of these studies the "Dresser" couplings were recommended and installed. No leakage has been observed from these couplings.

Valve Packings - The problem of the extensive leaking of the valve packings required two approaches. The first, (discussed in a subsequent section,

"Surface Enclosures"), was to find ways of collecting and/or containing the leakage. The second, on which the greater long range emphasis was first placed, was to establish corrective methods to prevent the leaks. It was postulated that the valve packings were damaged when the valves were operated. To overcome this, a packing gland was designed which utilized a cam movement to release the pressure on the packing before the valve was operated. This design was never tested due to the decision to remove from service the "Cameron" 3-way, six-inch, plug valves which were the worst offenders as to packing leakage. These valves had been mounted in a horizontal position and, with vibration in the line, undue stress and wear occurred on the packing, resulting in leakage around the stem.

Pumps - Large quantities of mercury were contained in the grease leakage from the packing gland area of the amalgam ("Moyno") pumps. By supplying a small stream of demineralized water to the packing gland instead of grease, lubrication was provided and the mercury leakage was considerably reduced.

Another large source of mercury contamination was in the aqueous leakage between the heads and cylinders of the Alpha-5 type aqueous ("Kinney") pumps. The original joint between the head and the casing was a metal to metal seal with a cement used between the two surfaces. No suitable cement could be found which would guarantee a good seal against the aqueous process solution. A design using an "O" ring seal was developed and proved successful. An "O" ring groove was cut into the pump cylinder and a 1/4 inch rubber "O" ring was installed between the cylinder and the heads.

This change of design was recommended and the Operations Department had all of the Alpha-5 type pumps converted to incorporate the design. No significant leakage has been observed from the heads of the converted pumps.

A second problem of leakage with the Alpha-5 type aqueous pumps involved the drip collector pans. These pans could not be cleaned in position and required the services of maintenance personnel for removal. As a result, the drip pans were not cleaned frequently. Efforts were made to reduce the packing leak (which emptied into these pans) by keeping a closer check on the tightness of the packing. Although this helped somewhat, the pans were redesigned as discussed in a subsequent section "Surface Enclosures".

Vibration - An engineering study of pipe vibration was made in an attempt to reduce and eliminate piping failures. The pipe on the discharge of the Kinney positive displacement aqueous pumps was the major offender. As a result, recommendations were made to install surge tanks on the discharge of the aqueous pumps; install "Dresser" couplings between the aqueous pumps and the discharge header line; remove, as much as possible, [redacted]; install "Dresser" couplings at [redacted] valve assemblies; and brace all pipe lines more adequately than provided by the original design. Such extensive alterations took considerable time to execute. However, the aqueous line failure rate became inconsequential when all of the changes were completed. J.D.Sith

Spills

Equipment Change-out - As was previously stated, certain operations habitually deposited mercury onto the floors and equipment. The most notorious of these

was the replacement of failed amalgam and aqueous pumps. Considerable spillage resulted when the flanges were disconnected and, when the pumps were lifted from position, the residual process solutions spilled onto the surrounding equipment and floor.

A suggested approach for catching the mercury spillage, during the pump change-outs, was to install permanent catch pans, at each piece of equipment, and pipe these to a chemical salvage drain. Study indicated, however, that the additional surface area provided by the pan would provide more contamination (due to the potential mercury surface exposed) than would be gained by the collection of the spillage. Further studies resulted in the design of portable catch pans for use at the suction and discharge ports of each of the major type pumps. These pans appeared practical in tests and their use was recommended to the Operations Department.

Two methods were proposed for preventing spillage from the pump while it was being lifted from position, transported to the repair area, and stored prior to repair. The first of these was to machine tight-fitting plugs to fit the suction and discharge openings. Due to the rough surface of these openings, this method proved unsuccessful. A second method, discussed in more detail in the subsequent section "Surface Enclosures" was the use of a plastic bag with an elastic top which would completely seal around the discharge and suction flanges. This method proved successful and was recommended.

In order to reduce the mercury remaining in the amalgam pumps, a method of water purging the pump before removal was developed and recommended. Details of this innovation combined with a complete recommended pump change out procedure may be found in Appendix A-4a.

It was observed that considerable aqueous leakage was experienced when the stators of the 9201-4 type aqueous ("Moyno") pumps were replaced while the pump was in position. It was recommended (See Appendix A-6) that field change outs of stators be discontinued. It was further recommended that drain valves be installed on the 9201-5 type aqueous pumps (See Appendix A-5).

Clean-up - The clean-up of mercury spills resulting from equipment changes were handled routinely but with a tendency to be left until the replacement was complete or, in many cases, until other operational work was not pressing. It was recommended that mercury clean-up, using the house vacuum system wherever feasible, be made immediately after a spill and, in the case of pump change outs, definite responsibilities were fixed for all phases of the clean-up (See Appendix A-4a).

Equipment Storage Areas - Inspection of the areas where the aqueous and amalgam pumps were stored prior to repair indicated the need for dismantling and cleaning procedures for failed equipment. Such a procedure was prepared and was furnished to the Operations Department (See Appendix A-9).

SURFACE COATINGS

Floors

Prime Vapor Source - Although for some period of time the floors had been considered to be a prime source of mercury contamination, no quantitative

measurements had been made to substantiate this belief. Tests were designed whereby the mercury vapor contamination in the air over a large floor area would be measured and then remeasured after the floor had been "covered" in such a way as to prevent the mercury vapors from rising. Two methods of masking the vapor were considered. The first method was to cover the floor area with several inches of continuously flowing water. It had previously been determined in grossly contaminated areas that running water was effective in reducing the mercury vapor concentration. The second method was to cover the floor with a strong solution of the commercial mercury vapor suppressor compound "HgX". This compound, in water solution, also had previously been found to be a highly effective decontaminating agent as long as the solution was not allowed to evaporate to dryness. Unfortunately the running water tests were inconclusive due to the difficulty in controlling the flow of water over a large area because of channeling and formation of stagnant pools. Laboratory tests have shown that whereas flowing water is an apparent barrier for mercury vapor, quiescent water is not. The diffusion rate of mercury vapor into air from a liquid mercury source is decreased but not stopped when the source is covered with water. The diffusion of the mercury vapor through the water is proportional to the concentration of vapor in the water. Thus, if fresh water flows continually over the mercury source, the mercury vapor concentration of the water remains low and the vapor diffusing into the air is virtually stopped.

Results of the tests using "HgX" as the masking agent established that the contaminated floors in the Colex Plants were responsible for 30 to 50 percent of the mercury vapor concentration at breathing level.

Floor Condition - There were two major factors contributing to the difficulty of cleaning the floors. First, the concrete had been acid etched in large areas. Second, in those areas where the floors had been painted, the paint was in very poor condition. Consequently, the resulting irregularities formed small traps from which it was difficult to remove the mercury. When the floors were examined with a 20X portable microscope, particles of mercury, which were invisible to the unaided eye, were detected throughout the operating areas in the crevices of the concrete. Even after careful cleaning, the microscope revealed large quantities of finely divided mercury still embedded in the crevices. The situation was most severe in areas where the concrete floor had never been painted.

Paints - An investigation of concrete paints showed that none of those tested could withstand the Colex Plant conditions for any long period of time. Test areas in the plant were painted with [redacted] and [redacted] paints. In each case the floors were properly acid etched and thoroughly cleaned before the application of the paint. Primers, which were recommended by the paint manufacturers, were used in cases where needed. Some of the painted areas were given sufficient time for drying whereas others were opened to plant traffic while the painted areas were still tacky. After several months, all of the paints except "Glid-iron" showed signs of peeling from the concrete or were badly scuffed by plant traffic. It was noted, however, that the painted areas were less contaminated than unpainted areas and were easier to clean.

The [redacted] paint, on short term tests, looked promising. Long term testing, however, showed that it was not resistant to the sodium hypochlorite cleaning solution used in the plant. In addition, there were three other draw backs: it was expensive; it required considerable labor costs for the extensive cleaning and preparation of the floor before it was painted; and it required special, as well as time consuming, techniques for application.

Several other paints, not specifically designed as concrete paints, were tested on a much smaller scale and they too showed the same tendencies as the concrete paints. The resulting surface was for a time easily decontaminated but the paints had poor resistance to plant traffic and chemicals.

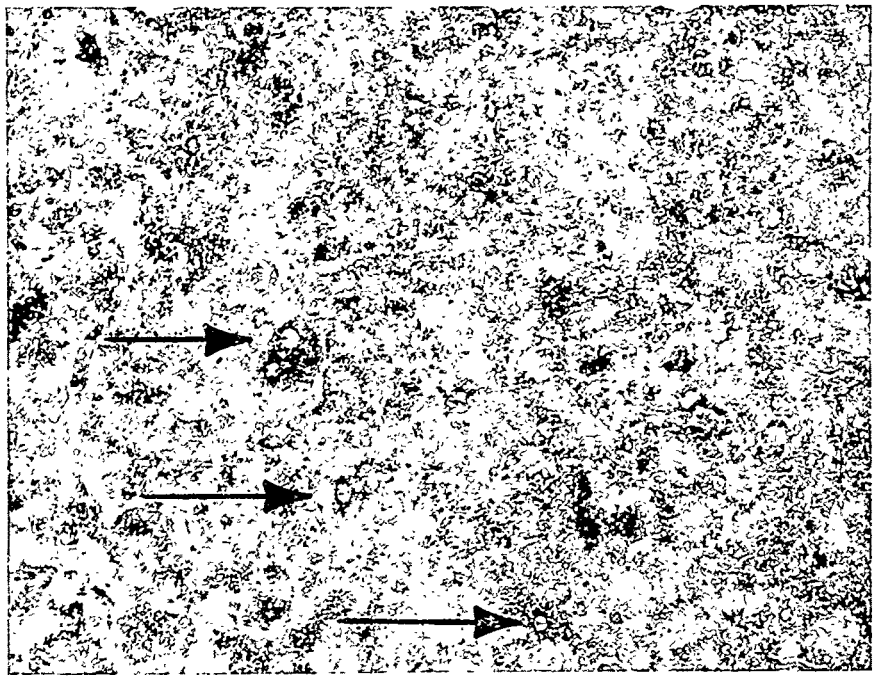
Sealers - It was found that the concrete floor areas which had a very smooth finish, or which had an unbroken painted surface, were easily cleaned of mercury droplets and were a much lower source of air contamination than concrete floor areas which had been acid etched or had an otherwise rough surface. Therefore, in an effort to obtain smooth surface floors, and since no suitable paint had been found, floor sealers and floor waxes were tested.

Several floor sealers were tested in plant areas. After allowing sufficient drying time for each sealer, the film was examined for its adhesive properties and then subjected not only to caustic but also to the sodium hypochlorite cleaning solution. Re-examination of the films indicated that almost all of the floor sealers tested were attacked by the caustic, the sodium hypochlorite solution, or both. After allowing plant traffic to pass over the test areas for several days, the film was again examined for adhesive properties.

Of the floor sealers tested, [redacted] appeared to be the best. The tests showed this sealer to be attacked slightly by both caustic or sodium hypochlorite solution. The rate of attack, however, was very slow. The compound formed after attack was usually embedded into the pores of the concrete and thereby provided further protection by decreasing the porosity of the material under test. Several applications of the sealing compound were necessary before a sufficient film was built up to prevent the sealer from breaking away from the floor after exposure to the above mentioned solutions. In areas which had been severely acid etched, several applications were necessary to fill the pores of the concrete even when no saponification occurred. Several large areas were tested using [redacted], and the areas were easily cleaned after being recontaminated by mercury. It was found that [redacted] was not a permanent seal when exposed to the repeated attacks of caustic solutions. Areas which were sealed with "Onex Seal" had to be resealed from time to time depending on the amount of protection provided by the residual film. This was determined by a microscopic examination of the floor. Such checks were made at random points throughout the areas.

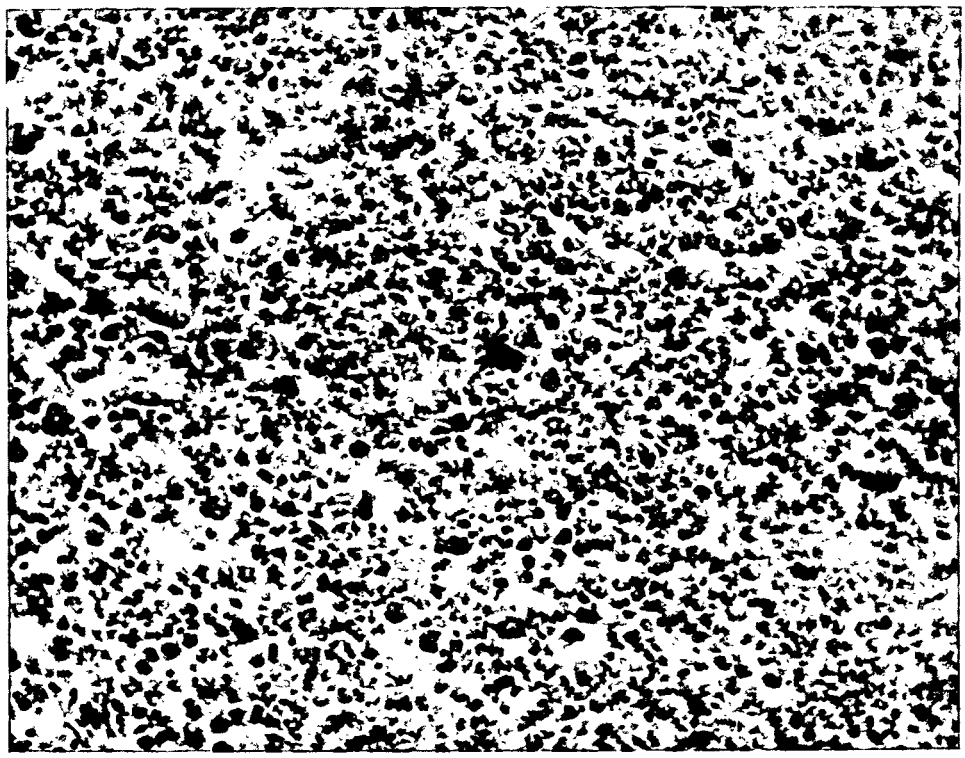
Photographs at 5X magnification of unsealed and sealed floor surfaces may be seen in Figures 6 and 7. The mercury vapor contamination, at breathing level, above the "treated" floors in Figures 6 and 7 was 0.04 mg/m^3.

Other Sealing Compounds - A lithium oleate sealing compound, formulated directly on the floor, yielded attractive results at first. The compound was made by first mopping onto a porous floor a 50-50 mixture of Oleic acid and



5X Magnification

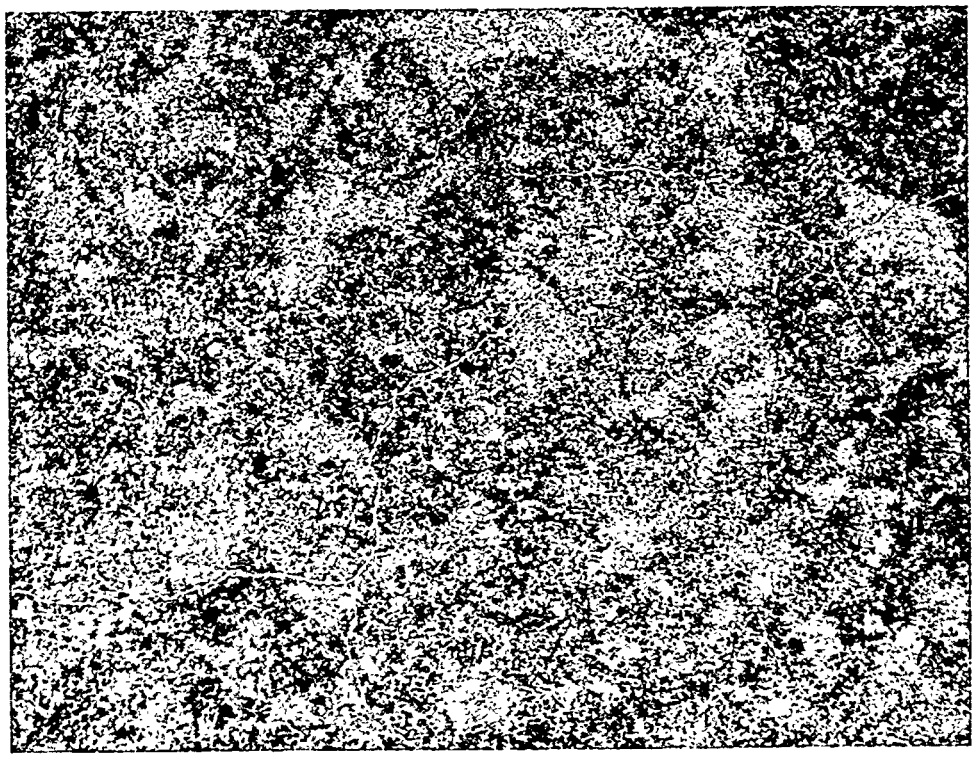
(a) No Treatment After Cleaning. (Arrows point out typical Mercury droplets).



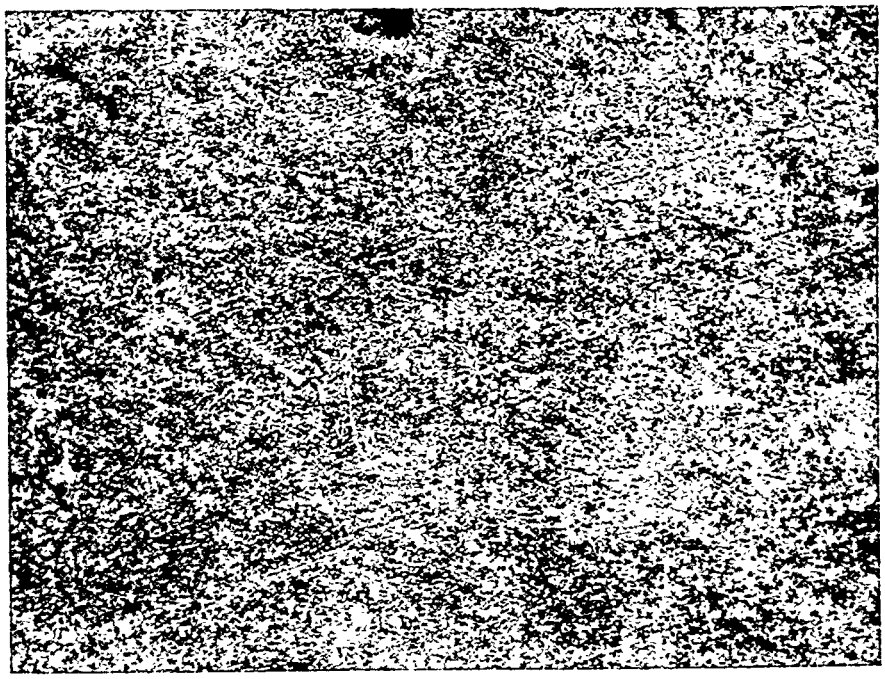
5X Magnification

(b) Treated With "CLOROX" and "ONEX SEAL" After Cleaning. (No Mercury droplets visible)

Figure 6. COMPARISON OF ACID-ETCHED CONCRETE FLOOR SURFACES



(a) No Treatment After Cleaning



(b) Treated With "CLOROX" and "ONEX SEAL" After Cleaning

Figure 7. COMPARISON OF SMOOTH CONCRETE FLOOR SURFACES

isopropyl alcohol. (The alcohol served as a vehicle to aid the oleic acid to penetrate into the pores of the concrete.) After the solution had penetrated the concrete, the area was mopped with a 1.0 normal solution of lithium hydroxide which immediately reacted with the acid to form lithium oleate. An area treated in this manner yielded complete resistance to caustic but was slightly attacked by repeated water washing as the lithium oleate is slightly soluble in water. This type of sealer, however, has the disadvantage of leaving an unattractive white surface which cannot be removed. Examination of the seal revealed that all of the pores of the concrete were sealed and the floor was easily cleaned after recontamination. The unattractiveness of the floor plus the short wearing life due to repeated water washings prevented further use of this sealer.

[redacted], a sealer consisting of a suspended solution of polyethylene, was tested. This solution, however, had the disadvantage of reacting immediately with sodium hypochlorite unless the film had been properly dried. In addition, this seal had a tendency to peel away from the floor in places where the original floor surface was extremely smooth. Unlike [redacted] it did not have to be buffed into the floor, since it had good penetrating ability. [redacted] was tested in a large area and was found to afford less protection than [redacted] Inspection of the test site revealed several smooth areas which were free of the [redacted] after a life of three days. It was further noted, that a one coat application was insufficient for acid etched floors. In fact, some areas were not completely sealed after several applications. The air contamination, however, was no greater over the [redacted] test area than it was over the [redacted] test area. In addition, the test area was not affected by caustic spills but the film did not withstand plant traffic for as long a period as did [redacted]

Waxes - All of the waxes tested showed no resistance to caustic solutions and saponified immediately even though the proper drying time (as recommended by the manufacturer) was carefully observed. It was found that a wax applied over a sealer lessened the life of the sealer because the wax penetrated the seal and, after saponification occurred, the wax and sealer broke away from the floor.

The detailed results of the tests performed on all floor sealers and waxes may be found in Appendix B-3.

Recommendations - Based on the results of the tests performed, [redacted] was recommended for use on the concrete floors of the Colex Plants.

Walls and Equipment

The equipment and walls of the Colex Plants had been painted with a variety of paints most of which did not resist caustic. Thus, the metal equipment in many areas, which was subjected to frequent caustic spills and splashes, had been completely stripped of paint in less than a year of operation. In addition to the lack of caustic resisting paint, some equipment had been painted without proper cleaning preparation thus weakening the bonding of the paint. Rough unpainted wall and equipment surfaces as well as broken spots in the paint on such surfaces provided potential traps for mercury droplets. A program was initiated to establish the most acceptable caustic resistant paint suitable for both walls and equipment.

The first and most important requirement was to find a paint with good bonding qualities when applied to metal and, secondly, one which could be applied with reasonable ease. Since it soon became evident that the primer coat was as important as the paint itself, a critical examination of various primers was included in the program. As the study of paints was pursued, it was observed both from the original paint and from the test paints, that paints with a glossy finish possessed strong adhesive properties toward mercury droplets making it difficult to clean mercury from their surface. The paints which exhibited the lowest adhesive properties for mercury particles were those which had a flat surface with a pastel color. A general note can be made here that in all the decontamination studies made, this same surface characteristic was observed. Glossy or shiny surfaces tended to retain mercury particles whereas flat (but of course smooth) surfaces shed the mercury and allowed easier cleaning or decontamination.

Primers - In the search for a primer coating, , a material classified as a paint, was found to possess the best qualities. This paint, a mixture of styrene and butadiene, exhibited not only excellent adhesive properties on most metallic surfaces but also extremely good resistance to caustic spills and splashes. It is, however, attacked by many organic compounds. Tests were made using both on metallic surfaces which had been properly cleaned and on others which had no preparation. In all cases the showed complete resistance to caustic and good adhesion except on a few of the "uncleaned" surfaces which were badly corroded.

Of the materials actually classified as "primers", cost. , was found to be the best but it did not equal the overall qualities o just discussed. In all cases the test surfaces were thoroughly cleaned before applying this primer coat. It was found that when applied properly, the ticles. Ther had the same adhesive properties as se of this but was not as caustic resistant. In one test, after contact with caustic, the primer could be pealed from the metal surface.

Paints - The properties exhibited by facturer i indicated, at first, that it would be an excellent paint as well as a primer. The paint as originally tested, however, had a glossy finish which, as mentioned above provided adhesive properties for mercury particles. The manufacturer submitted, for testing, a sample of nts were recommen, a flat finish paint which could be used over the any as six coat ap. Test areas were painted using the ng a Regular" as the primer and er than the cost as the paint. The combination had good adhesive properties, excellent resistance to caustic, and the ability to "shed" mercury. An inspection made seven months after the above combination had been painted on the walls and equipment of several areas, showed the paint in good condition and no corrosion of the metal was found.

Other Paints - Two other brands of paints showed promise at first. Tests involving ntamination paint indicated better adhesive qualities could be obtained if that mercury was was used instead of the recommended the dark primer. However, some difficulty was encountered with the former combination since the solvent in to hide the had a tendency to dissolve and peal off the tested co film if the proper care were not exercised in the application. Although the resulting surface, when d into the was properly applied, had excellent resistance to caustic solutions and a low affinity for mercury, it

was found that the full brush technique of application, needed to assure the best possible protection, would increase, by about 50%, the cost of painting an area as compared to the combination cost.

The combination of primer and paint was found to resist caustic solutions and to have a low affinity for mercury particles. There were three basic drawbacks to the use of this combination. First, an extremely careful cleaning procedure had to be employed before painting to insure protection. Second, it was found that the paint would peel from the surface if the film was broken. Third, the spraying of as recommended by the manufacturer is impractical in working areas since this paint contains certain volatile solvents which cause nausea in many people.

Other paints were recommended by the manufacturers. Some of these required as many as six coat applications. Since the cost of applying a paint is usually much greater than the cost of the paint itself, such a paint, requiring six times the labor would cost six times the cost of a one coat paint. Therefore, no other products were investigated.

The results of all paints tested may be found in Appendix B-2.

Paint Color - A study was made to determine what color would best reveal mercury contamination under the plant type lighting. The concensus of twenty people was that mercury was the most obvious on the dark reds and the dark greens. Paints bordering on white, such as gray, light browns, light greens, etc., had a tendency to hide the mercury droplets. In some cases the colors tested completely masked the mercury. Mercury resting on the dark green and dark red showed no tendency to blend into the background.

Recommendations - As a result of the paint testing program, the combination using a light green primer coat of " and dark green final paint of was recommended for use in the Colex Plant buildings as outlined in a letter from G. B. Lockhart to W. E. Heckert.(5)

SURFACE ENCLOSURES

Transport Containers

Pump Dollies - To facilitate the removal of contaminated equipment from the process area, special transport dollies were designed which completely enclosed the equipment being removed. These dollies were of "tub" type construction to prevent mercury spillage. Since the containers were made airtight by the use of covers, air contact with the contaminated equipment was prevented. This, in turn, provided a second advantage in reducing mercury vapor contamination.

Three such dollies were designed: one for the 9201-4 type amalgam and aqueous pumps, one for the 9201-5 type amalgam pump, and one for the 9201-5 type aqueous pump. One of each of these dollies was made and tested by the maintenance personnel. The bulkiness, weight and difficulty of loading and unloading these

dollies made them somewhat impractical. This was especially true after three other innovations were established. These were: (a) the external surfaces of the pumps were routinely kept cleaner and thus little or no mercury would spill from the surface; (b) plastic bags (to be discussed later) were designed with elastic tops to fit over the open flanges of the pumps to catch any spills from within the pump and (c) packing-gland covers, as discussed in the next section, were designed and installed.

Equipment Dollies - Also for the use of the Maintenance group, an enclosed scrap dolly was designed that would carry contaminated equipment such as valves, expansion joints, and small pumps from the operating area. These also were air-tight, drip-proof, vessels. Several such dollies were fabricated and were found practical.

Equipment Enclosures

Pump Enclosures - A design was suggested and one model fabricated for the total enclosure of the amalgam pumps in the 9201-4 building. Each enclosure was to be equipped with an exhaust to carry the mercury vapors out of the building. Studies disclosed that such enclosures were not only expensive but failed to solve the problem since a potential source of contamination was created by the additional surface area.

Packing Area Enclosures - A design was made and recommended for the total enclosure of the packing area of the 9201-5 type aqueous (Kinney) pump. The design accomplished two purposes: first, it prevented excess air movement around the packing area, thereby reducing air contamination; and, second, provided a simple means of salvaging process leakage around the packing area. This design was accepted, installed, and found satisfactory. Only one disadvantage was found. The enclosures did reduce accessibility to the packing area and thus prevented early detection of leaks.

A removable packing area seal which could be easily opened for examination or maintenance of the packing was designed and recommended for enclosing the packing area of the 9201-4 amalgam pumps. The seal totally enclosed the packing area and required no modification of the pump. These seals were installed throughout the 9201-4 building and were found to aid in reducing the amount of mercury exposed to the air.

An enclosed packing area was designed as an integral part of the body casting for the Building 9201-5 replacement amalgam pump which was in the development stage during the period of time in which the air contamination studies were getting underway. A hinged cover with a fastener allowed easy access to the packing area and a drain hole with a pipe fitting provided a simple method of continuous draining of any leakage to a salvage system.

J. D. Sirk

Floor Drain Covers - In order to reduce the air contamination originating from the mercury vapor ladened gases arising from the floor drains, a design change was recommended for the drain covers. A cover was designed with very little open area consisting of a few round holes to replace a "grill type" cover with considerable open area. The design was accepted and the new covers were installed with a resulting reduction in the potential mercury source.

Plastic Covers for Valves and Flanges - A study was made to determine the best method for containing the mercury leakage which could not be prevented from certain valve packings and flanges. Early attempts to catch such leaks utilized crude open bucket type containers. These, naturally, provided an excellent source of mercury vapor (Appendix A-7). The most practical approach appeared to be the use of plastic containers to fit closely around the valves or flanges. In addition, such containers could be equipped with drain nozzles or valves to permit either direct connection to a salvage system or allow periodic draining. A thorough investigation into the making of molded plastic containers revealed that, due to the complexity and number of designs necessary, the mold costs would be prohibitive for the small quantities of each design needed.

The use of plastic sheet sealed into a bag-type funnel was studied next. A portable electric sealing unit of sufficient capacity to seal or "weld" the "bag - funnels" together could not be procured. It was found, however, that the pliable plastic sheets could be easily taped into suitable shapes. Although several satisfactory designs of hard plastic fittings were fabricated and tested, it was found that metal pipe fittings installed in the "bag - funnels" by means of gaskets were satisfactory. Since the simplified "bag - funnels" were found to be practical (and were immediately accepted in the plant as a standard means of covering difficult to repair leaks) the only remaining phase of the investigation, was to determine which type of plastic material would be most suitable for plant service. The testing of various plastic materials for use in the funnel type bags was carried out in conjunction with the study of plastic coverings and the results are discussed in detail in the following paragraph.

Plastic Coverings - In addition to the use of plastic sheet material for mercury drip collectors, it was found that the plastic sheet, when utilized to cover rough or porous surfaces, provided an easy to clean surface and thereby reduced the potential source of mercury vapor. However, to make this use of plastic, it was necessary to find material which would meet the following requirements: (a) low permeability to mercury vapor; (b) resistant to attack by air, mercury, amalgam, water and caustic solutions; (c) resistant to puncture; (d) tear resistant after puncture; (e) flexible; (f) partially transparent to permit observation of leaks; (g) readily sealed, and (h) reasonable in cost.

Screening tests on a large variety of wrapping materials to check their permeability to mercury vapor were conducted as described in Appendix B-8. Of the plastics tested it was found that the most impermeable materials were Saran, "Mylar", fluorothene, "Teflon", and cellophane. Fluorothene and "Teflon" were expensive, opaque, and were not sufficiently flexible. Cellophane was not resistant to alkali, age hardened, did not heat seal, and had little strength. "Saran" and "Mylar" both appeared to be excellent barriers to mercury vapor, although neither was sufficiently tough or tear resistant. Accordingly, laminates of these barrier materials with tough plastic films such as "Vinylite" or polyethylene were investigated. The following four manufacturers' samples were tested: (a) [redacted], 0.5 mil Mylar laminated with 1 mil Saran; (b) [redacted] C.C.C. Inc., 1 mil "Mylar" laminated with 3 mil polyethylene; (c) [redacted], 2 mil Saran laminated with 4 mil vinyl; and (d) [redacted] 1 mil "Mylar" laminated with 4 mil polyethylene.

None of these laminated materials showed any significant permeability to mercury vapor in the screening test. Tests for resistance to puncture and tear indicated the laminate of 1 mil "Mylar" - 4 mil polyethylene was the best material of the group and it was recommended for plant use.

TEMPERATURE AND VENTILATION

Temperature

The effect of the ambient temperature on the mercury vapor concentration was investigated. Although heating facilities were available in the entire Colex Plant area, cooling facilities were available only in the control rooms and some office areas. Since the source of ventilating air was from the outside, the minimum temperature available in the operating areas was, therefore, the outside temperature. Thus, a fluctuation of 70 to 80 degrees (Fahrenheit) between summer and winter was possible in the available air. Test areas were chosen and the temperatures were adjusted from the outside winter temperature to temperatures exceeding 90° F. Various temperature cycles were run and the vapor concentrations measured. As was predicted by Equation 5, the mercury vapor concentration was found to vary proportionally with the square root of the absolute temperature. The observed data was compared with saturation concentration of mercury in air calculated from partial pressure data (Figure 8) and the curves were found to be of similar shape.

This effect of increased vaporization of mercury as temperature is increased was further verified (Figure 9) in controlled laboratory experiments by Wardzell and Jacobs[6] who were investigating the effect of air velocity on mercury vaporization at various temperatures. In addition, they found that the mercury vaporization rate was increased when the mercury source temperature was raised above the ambient temperature.

It was, therefore, recommended that operating area temperatures be maintained as low as practical. Further recommendations were that (a) where feasible, hot vessels should be insulated to reduce the temperature of the surrounding area and (b) all cutting and welding operations (which involve temperatures

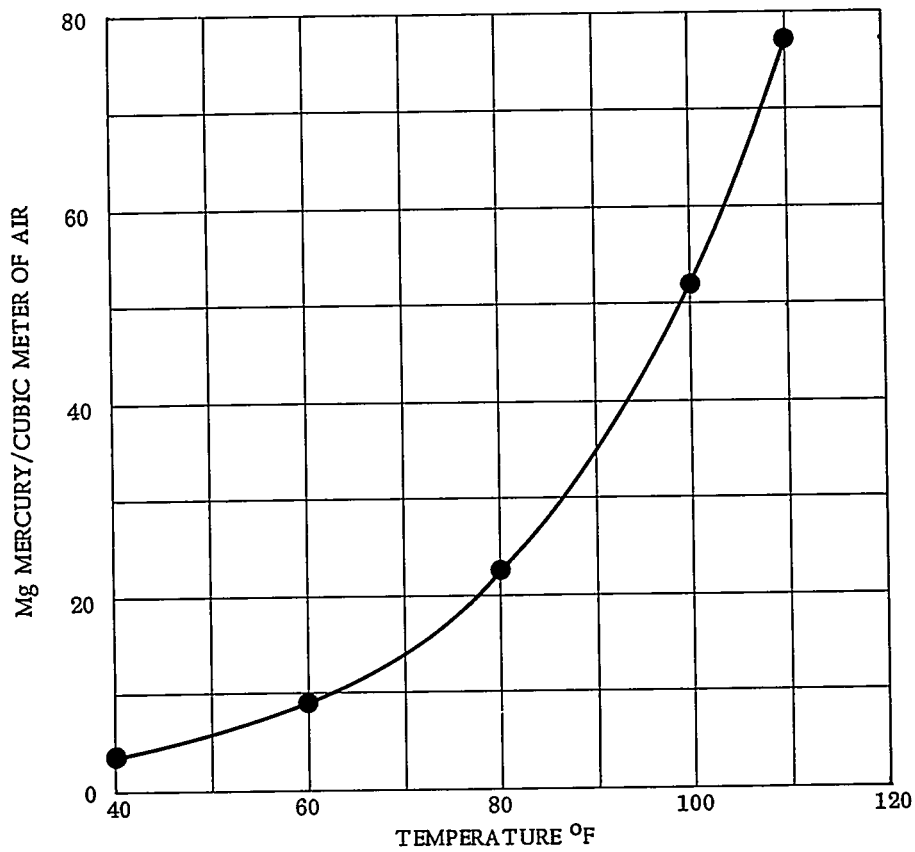


Figure 8. SATURATION CONCENTRATION OF MERCURY IN AIR AT VARIOUS TEMPERATURES

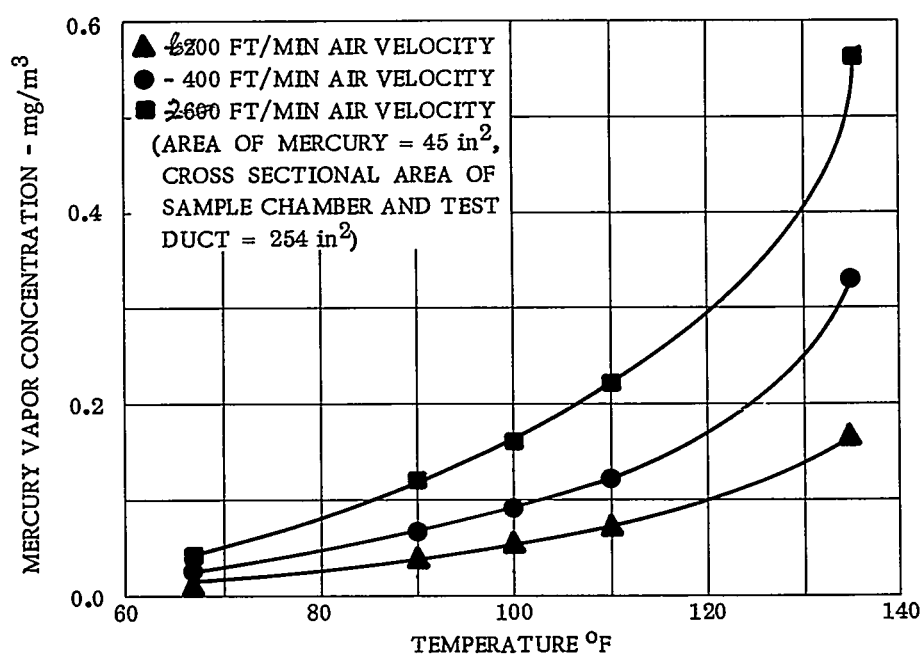


Figure 9. THE EFFECT OF TEMPERATURE ON THE VAPORIZATION OF MERCURY AT VARIOUS AIR VELOCITIES

well above the boiling point of mercury) should be performed with good ventilation and with the personnel involved properly protected by acceptable respirators containing "Mersorb" cartridges or by fresh-air masks.

Ventilation

Air Flow - Studies were performed to ascertain the effect of the air flow rate on the concentration of mercury vapor in the plant air. The flow rate throughout the operating areas was checked by the simple procedure of observing the amount of flutter imparted to thin strips of suspended facial tissue.

The results were correlated with the mercury vapor concentration. As was previously indicated by Equation 5, the mercury vapor concentration was found to vary inversely with the flow rate of the air. In areas receiving little or no air flow, the mercury vapor concentration was consistently above the MAC. Several of the areas with no air flow were chosen for special air flow tests. The air in those areas was set in motion by regulated ventilation and it was proven that it was possible to reduce and maintain any area below the MAC by a sufficient flow of clean air regardless of the quantity of mercury vaporized in that area.

As a result of these studies, recommendations were made to the operating departments to increase the air flow in specific areas and to make an effort to avoid stagnant air in any area. In those areas where the air flow was increased, the average vapor contamination was decreased.

Air Velocity - In addition to these plant studies, controlled laboratory tests by Wardzell and Jacobs(6) defined more quantitatively the effect of air velocity on mercury vaporization. A portion of their findings may be seen in Figure 10. Their apparatus (shown diagrammatically in Figure 11) consisted of two chambers with a controlled source of clean air. The vapor source, consisting of a weighed quantity of mercury, was placed in one chamber and the vapor detection sampling tube in the other. The mercury source was gently agitated in all tests to prevent the formation of a continuous oxide film on the surface.

As may be seen from their results, increasing the air velocity past a point did not decrease the vapor concentration in the exit air. Thus it was indicated that surface velocity increased the quantity of mercury vaporized. Such had been predicted from Equation 5 which stated that the vapor concentration varied directly with the difference in mol fraction (Y_i - Y_s) in the mercury vapor at the interface. The air velocity had, then, increased the mol fraction at the interface by reducing the mol fraction in the air (Y_s) and so provided more vapor to be swept away. Thus it was evident that the velocity of air at the surface of mercury should ideally be reduced to a minimum and that such control was dependent upon the type of ventilation.

It was therefore recommended that ventilation of the operating areas should be by diffused air with care taken to prevent any stream of high velocity air from being directed toward floors or equipment which were potential vapor sources.

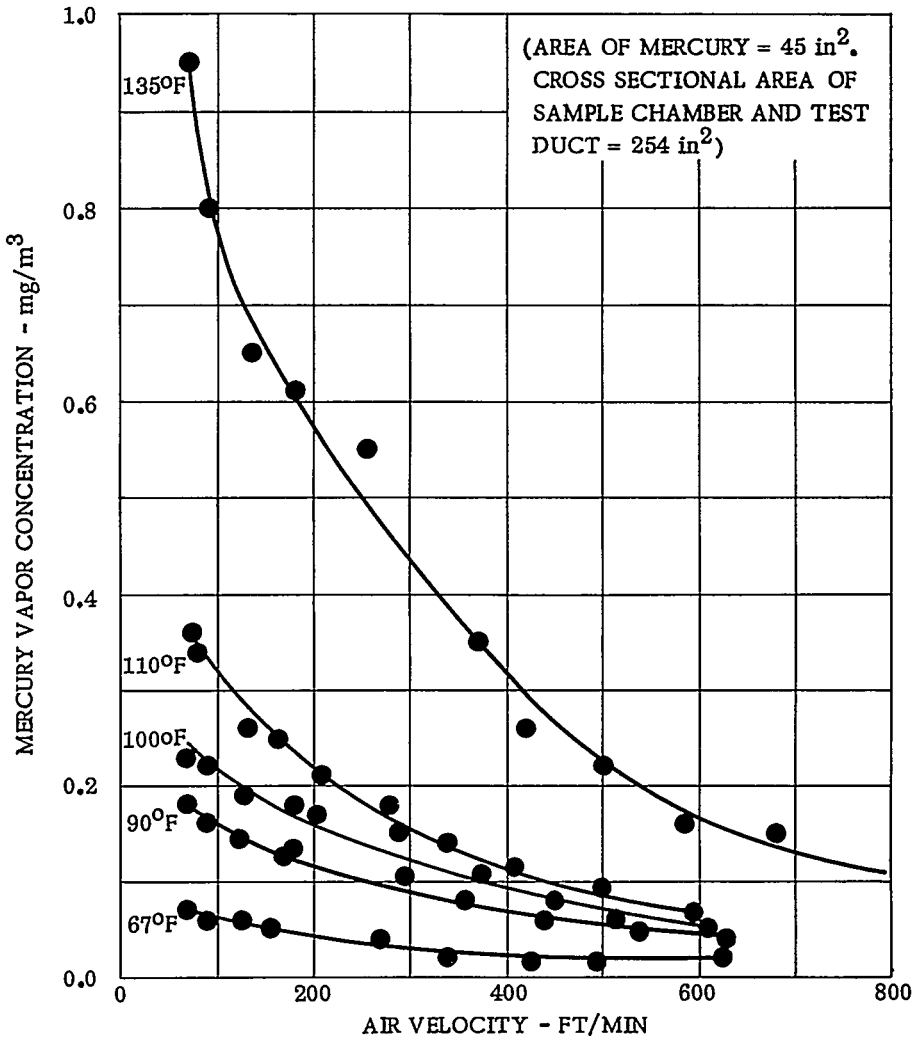


Figure 10. THE EFFECT OF AIR VELOCITY ON MERCURY VAPOR IN AIR

Humidity

On days of high humidity it was noted that the mercury vapor concentration increased over the normal value for a given area. A laboratory test was performed to determine the effect of water vapor on the vaporization of mercury. This test involved first the passing of dry air, at the rate of 10 liters per minute, over a pool of fresh clean mercury in a 500 ml cell.

The exit air was checked with a mercury vapor detector and was found to contain 2 mg/m^3 of mercury. After twenty-four hours a visible oxide film had formed on the mercury surface and the exit gas mercury concentration had decreased to 0.38 mg/m^3. The incoming air was then saturated with water vapors and within twenty-five minutes the mercury vapor content of the exit air had increased to 1.1 mg/m^3. The results of this test may be seen in Table I and Figure 12.

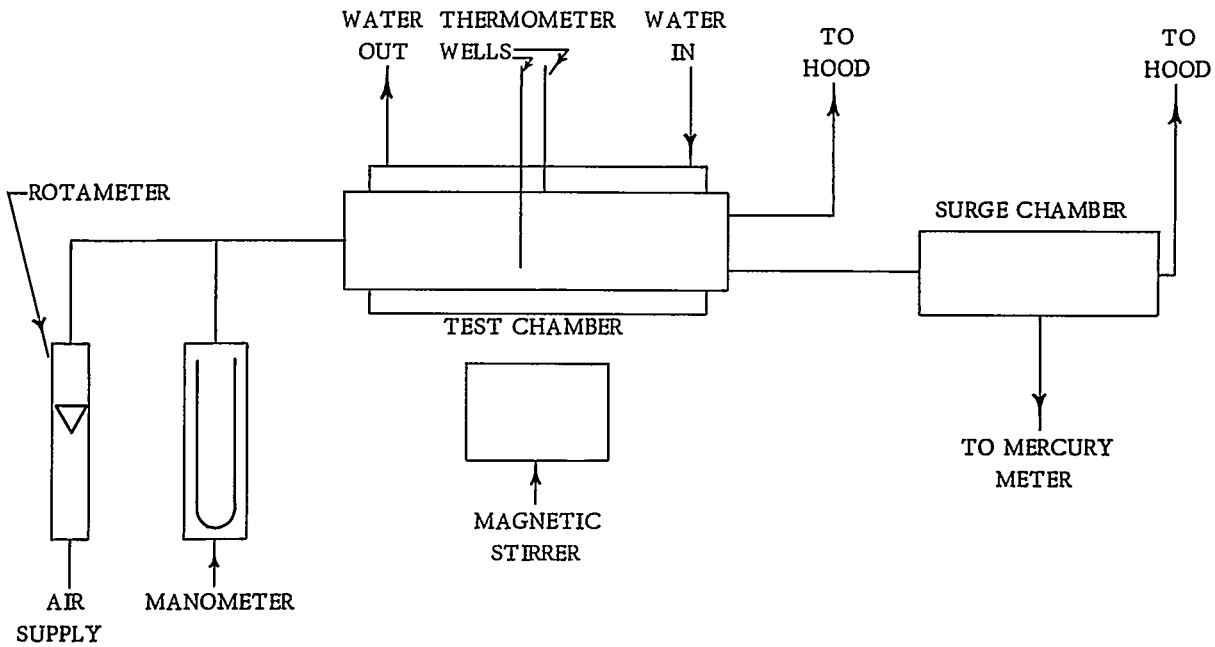


Figure 11. APPARATUS USED BY WARDZELL AND JACOBS TO MEASURE MERCURY VAPORIZATION

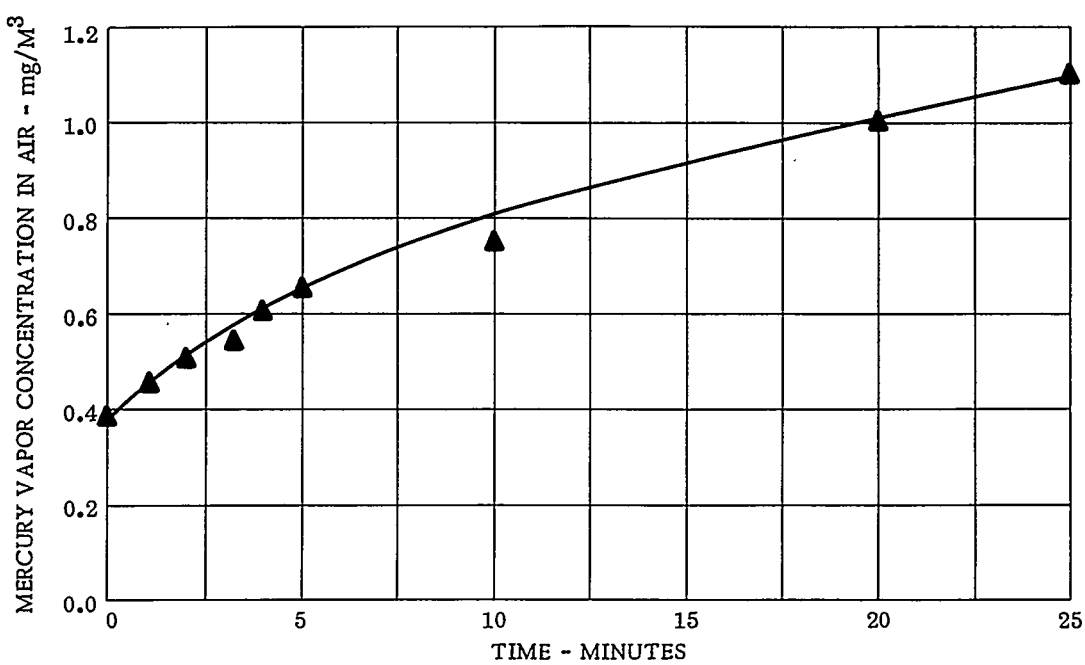


Figure 12. EFFECT OF HUMIDITY ON MERCURY VAPOR CONCENTRATION

TABLE I

EFFECT OF WATER SATURATED AIR ON THE VAPORIZATION OF MERCURY

Time (Minutes)	Mercury Vapor Concentration (mg/m^3)
0	0.38
1	0.45
2	0.50
3	0.54
4	0.60
5	0.65
10	0.75
20	1.00
25	1.10

The decrease in the mercury vapor content of the air appeared to be the result of the protective oxide coating formed on the mercury. And, in turn, the increase in the mercury vapor when the water saturated air was used, was assumed to be caused by the water vapor reacting with, and removing, the oxide film.

SURFACE TREATMENT OF MERCURY

Surface Film

It was observed in Equation 5, which was previously presented, that the mercury vapor diffusing rate would be reduced if the film thickness was increased. Thus studies were performed to find an effective method of altering the surface of the exposed mercury to increase the equivalent "film thickness" by forming an additional surface film, an insoluble compound, or some other type of covering.

Surface Treatment

Water - As previously discussed in the section of this report devoted to floors, covering exposed mercury with a layer of running water was somewhat effective. This was found to be impractical for plant use due to the formation of still pools and the poor working conditions furnished by wet floors.

"Hg X" - Some degree of decontamination had been experienced in the past with the use of "Hg X", a commercial compound, for the suppression of mercury vapor. It was assumed that the chemicals in this compound reacted with the surface of the liquid mercury to form a surface film which prevented the formation of the vapor. Laboratory tests conducted on "Hg X" proved that in a water solution it was highly effective in reducing air contamination. After evaporation of the water, the residual salt gave no protection. Further indications were that, even in the water solution, the effectiveness of "Hg X" began to decrease after 48 hours and it became necessary to add fresh "Hg X".

Because of the partial success of the "Hg X" compound, a search was made for chemicals which would react with the mercury surface to form a vapor suppressive film. Many such chemicals were found and tested. Most of them were impractical to use in the plant (see Appendix B-4). One of the most promising of the group was a 20% solution of ferric chloride(7). This solution was found to be extremely corrosive to most metals. A small plant test was conducted in an area which had a high vapor contamination and an extremely rough floor. The ferric chloride solution was mopped on the floor and allowed to air dry. The results showed poor stability of the mercuric chloride formed and, as might be expected, serious corrosion of exposed metal surfaces in the immediate area. This solution, therefore, could not be recommended.

Special Vapor Suppressor - Further studies produced a mixture of several chemicals, referred to as "SVS" (special vapor suppressor), which, under laboratory tests, produced a vapor suppressing film over mercury particles. "SVS" consisted of 0.01% Thio-b-napthol, 0.2% "Elvanol 52-22" 0.1% "Nacconal NR", 0.5% glycerine and water. The Thio-b-napthol and the "Nacconal" provided suitable wetting agent properties when exposed to caustic solutions. The film was formed by the "Elvanol", a polyvinyl alcohol, and was made pliable by the glycerine. The mixture was made by first adding the "Elvanol" to the water and heating slowly with agitation until clear. To this, the "Nacconal" and glycerine were added. The Thio-b-napthol was first dissolved in lithium hydroxide solution (sodium hydroxide cannot be substituted) and then added to the first solution. The use of inexpensive materials resulted in a low cost mixture.

The application of SVS consisted of covering the mercury contaminated surface with the solution by simply mopping it on. It produced a highly impermeable film against mercury vapors and remained so until the film was broken. It exhibited good stability unless the film was broken or was dissolved in water. The film, although applied in a water solution, was not destroyed by either water or caustic if the water from the resulting solution was allowed to evaporate undisturbed. Plant tests, however, were erractic; there were some instances of increased vapor concentration. Inspection of the floors revealed that in many cases the film had formed only on the smooth concrete. Concrete which was very porous allowed the solution to enter the pores and no continuous film was formed. The instances of increased air contamination were apparently due to the oxidized film, which formed on the mercury surface, being washed off, thereby leaving a clean, extremely active, surface. Some of the tests were invalidated because in preparing the solution the Thio-b-napthol was dissolved in sodium hydroxide which forms an insoluble product with the "Elvanol" preventing the formation of the film.

The plant tests established that "SVS" did not possess the stability necessary for continuous use in combating the problem of mercury vapor contamination.

Sodium Hypochlorite - During a visit to a commercial caustic plant where large amounts of mercury were being used and where the housekeeping was no better than in the Colex Plants before the clean-up studies, it was noted that the mercury vapor concentration was consistently below the MAC. Also noted was a persistant odor of chlorine in all areas where exposed mercury was observed. On the hypothesis that chlorine had some effect in surpressing the vapor,

solutions of "Clorox", which is basically a water solution of sodium hypochlorite, was mopped onto the floors in several contaminated areas. A startling decrease in vapor concentration was noted.

Areas in the plant were treated with 1.1%, 2.1%, 4.2%, and 8.5% solutions of sodium hypochlorite. (Concentrations are calculated on basis of weight percent; commercial solutions, as received, are commonly 8.5%.) Although in all cases the air contamination was reduced, the best and longest protection occurred from the use of an 8.5% concentration. Any of the above concentrations was found to convert the surface of the exposed mercury to mercuric chloride, mercurous chloride or mercuric oxide, depending on the acid or base condition of the floor at the time of application. The resulting products of the reaction yielded very little if any mercury vapor. The only major disadvantage to the 8.5% solution was that, if it was splashed on the employees cotton work clothes, it rapidly attacked the cloth. A second and minor difficulty was found when the solution was applied in areas where the ventilation was extremely poor; the chlorine gas from the decomposition of the sodium hypochlorite contaminated the air greater than the MAC of chlorine (0.1 ppm) for short periods of time. Although the original testing was made with "Clorox", it was found that a suitable solution of sodium hypochlorite could be made inexpensively from the by-products of another process in Y-12.

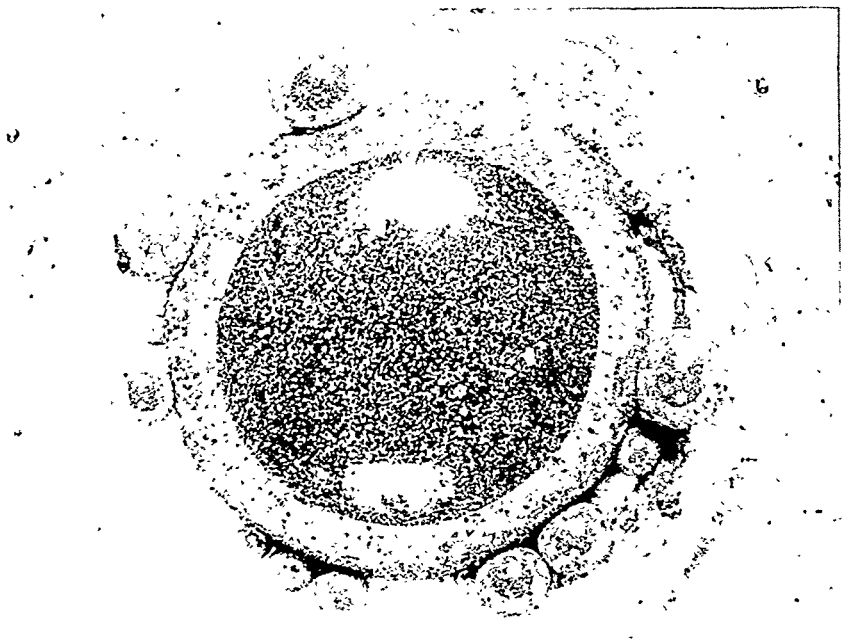
For the best results in the use of sodium hypochlorite solution for a vapor suppressor, it was found that the area should be cleaned carefully before application of the solution. The recommended procedure was essentially as follows: (1) wash the area with a 5% solution of Acetic Acid in water to remove carbonates; (2) scrub the area thoroughly with a water solution of a suitable detergent of the "Tide" type (Experience showed that detergents were better than soap solutions due to the tendency of the latter to saponify in contact with the caustic from the process.); (3) rinse with water to remove the excess acid and other contaminants; (4) allow the area to air dry for at least 20 minutes; and (5) mop the area with the sodium hypochlorite solution.

Examination of a floor which was very porous, treated in the above manner, with the aid of 20X magnification showed mercury particles, covered with a protective film, in the pores. The size of the droplets varied from 0.1 mm to 0.2 mm and as many as thirty could be found per square inch of floor area. The air contamination in some such areas was lowered from 0.15 mg/m^3 to 0.04 mg/m^3 by the cleaning and hypochlorite treatment.

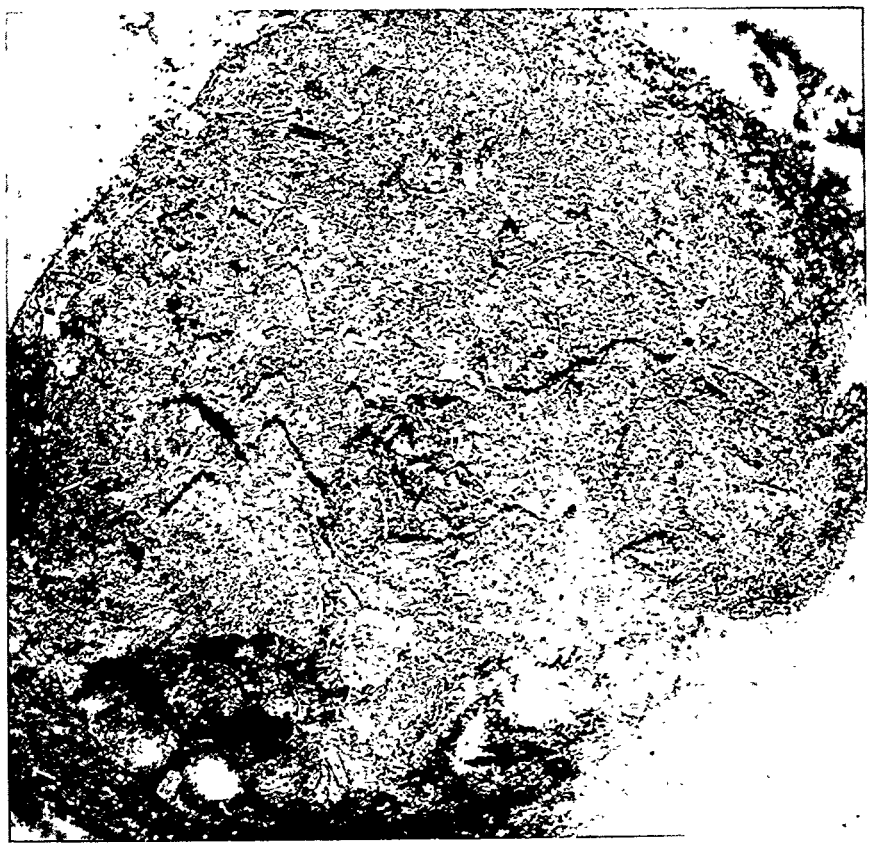
It was found, of course, that the floors could be easily recontaminated by leaks and spills. In such cases it was necessary to repeat the above procedure.

The above procedure involving the careful cleaning of floors and application of sodium hypochlorite solution was recommended to the operations personnel. It was used routinely with excellent results during the clean-up period. Once the buildings were under good housekeeping control, it was found unnecessary to use the sodium hypochlorite routinely and was used only as an emergency measure in contaminated areas.

Photographs taken at 20X magnifications showing untreated mercury and mercury after treatment with "Clorox" (or sodium hypochlorite) may be seen in Figure 13.

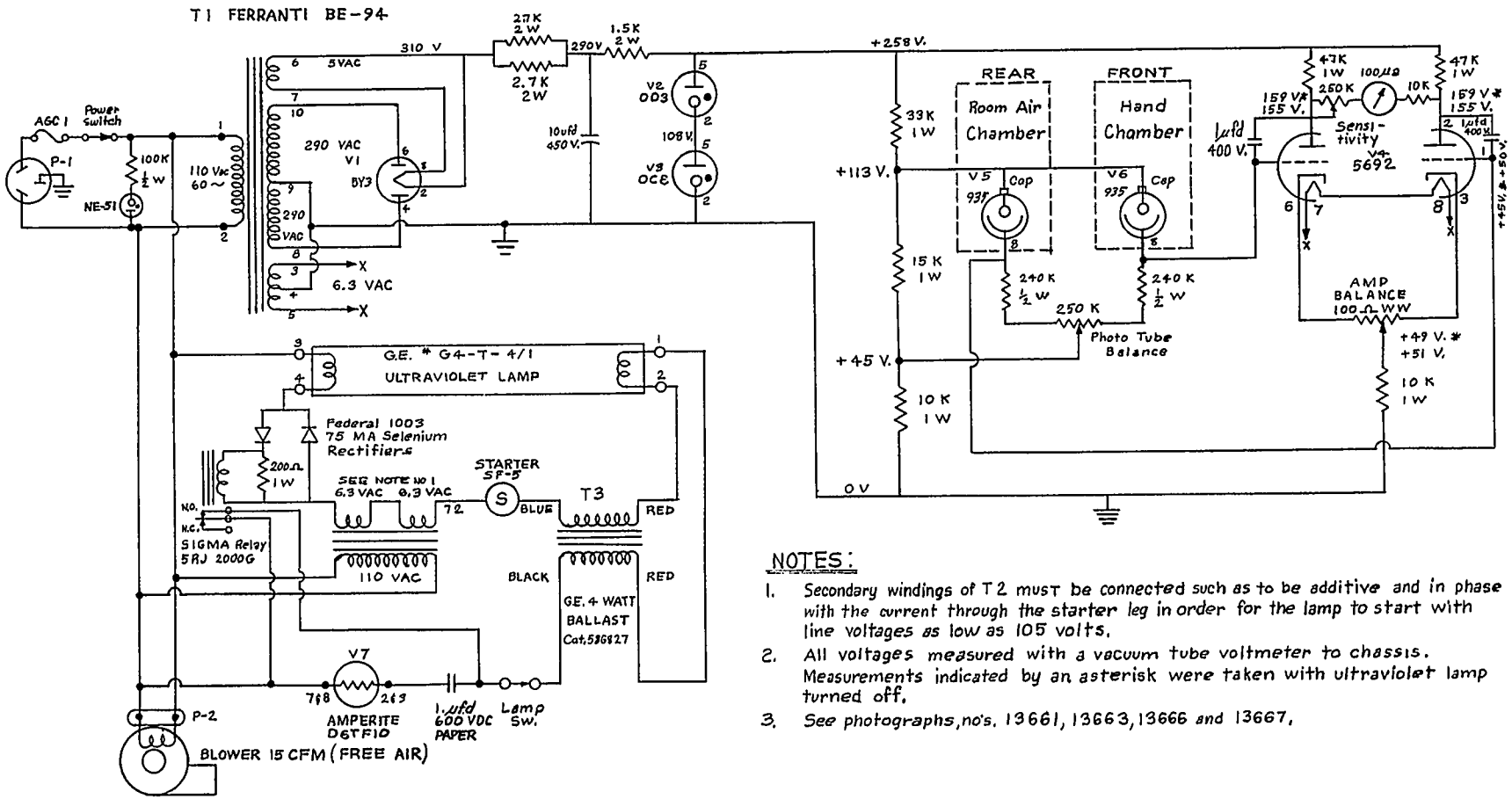


(a) After exposure to air for 24 hrs. 20X Magnification



(b) After treatment with "CLOROX" 20X Magnification

Figure 13. COMPARISON OF MERCURY SURFACES



NOTES:

1. Secondary windings of T2 must be connected such as to be additive and in phase with the current through the starter leg in order for the lamp to start with line voltages as low as 105 volts.
2. All voltages measured with a vacuum tube voltmeter to chassis. Measurements indicated by an asterisk were taken with ultraviolet lamp turned off.
3. See photographs, no's. 13661, 13663, 13666 and 13667.

Figure 14. HAND SOLVENT VAPOR DETECTOR MODEL #1 SCHEMATIC DIAGRAM

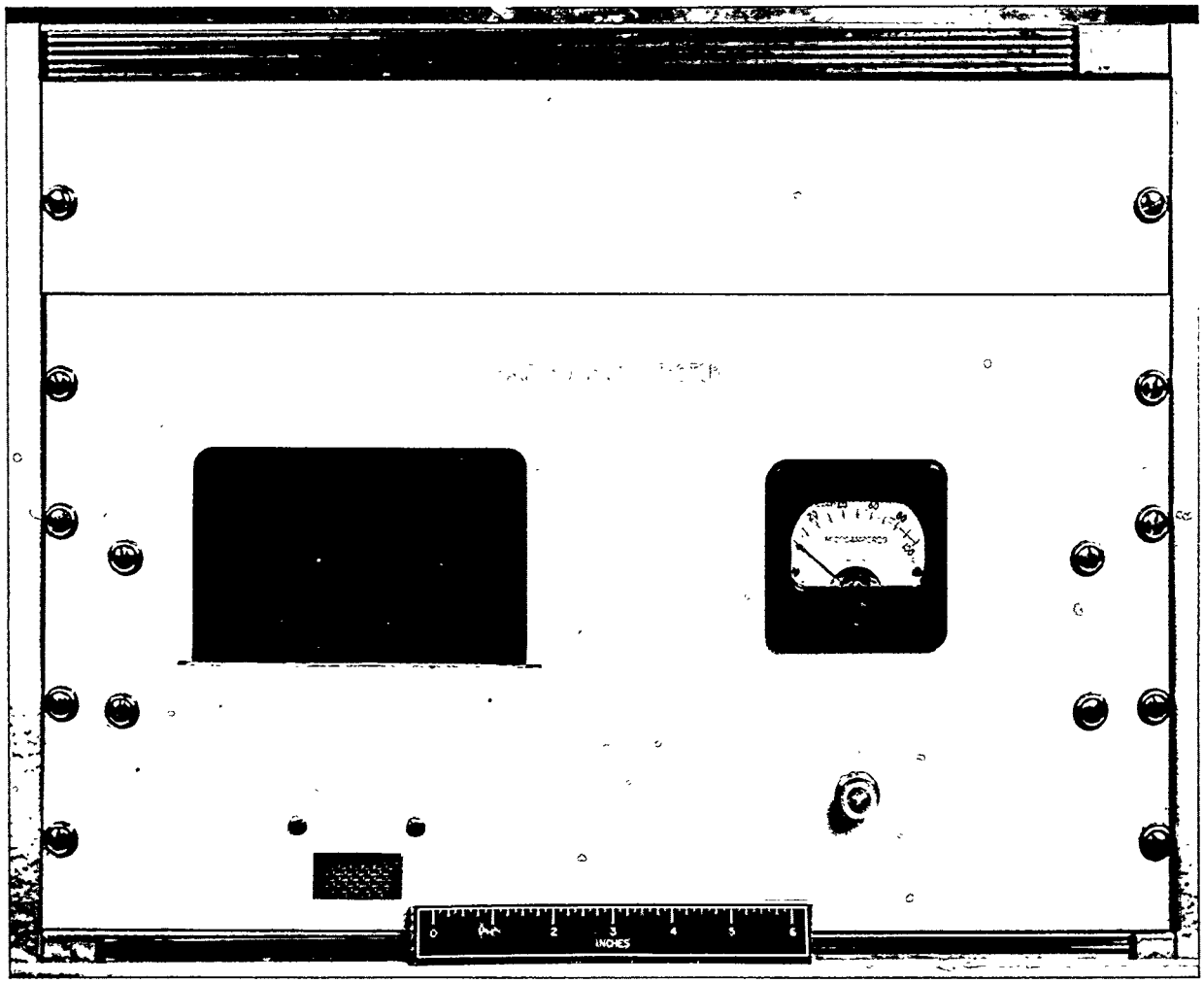


Figure 15. HAND MONITOR FOR MERCURY CONTAMINATION

exposed. It was felt that the palladium chloride-mercury reaction on filter paper would supply the basis for a simple and inexpensive badge. In this reaction, palladium chloride is reduced to the black metallic state in the presence of mercury at room temperature. The degree of darkening was found to be proportional to the mercury vapor concentration in the range studied.

The analytical technique proposed for such a badge was to first place the exposed filter paper in an ammonia atmosphere to complex and decolorize the unreduced palladium ions; the filter paper was then washed with water to remove the complexed ions; the amount of reduced palladium was determined by densitometry; and the accumulated exposure was determined through use of a calibration curve.

The first badge tested was machined from polyethylene and acrylic plastics and the parts were threaded. This machined design was considered too expensive to mass produce. A second design utilized the slip-fit type badge.

Difficulty was encountered in obtaining a seal around the port opening. After some study it was concluded that the slip-fit type badge could not be made sufficiently tight through machining techniques. Although the field tests of palladium chloride badge showed the practicability of its principles, it was felt that considerably more work, both in the laboratory and in field testing would be necessary to make it workable.

PROTECTION OF PERSONNEL

RESPIRATORS

From the beginning of the ADP program there were always certain specific operations or areas in which the mercury vapor concentration, to which personnel were exposed, was sufficiently high to dictate the wearing of protective respiratory equipment. In the original investigations for a cartridge suitable for protection against mercury vapor, only two commercially available products could be found. One was a cannister for use in a heavy duty combat type gas mask and the other, a "Mersorb" cartridge manufactured by The Mines Safety Appliance Co. (MSA) for use in their light weight, face type, respirator. Since the light weight type respirator was available, the heavier, more awkward, and less comfortable combat mask was not considered. The MSA respirator with the "Mersorb" cartridge was accepted for use in all operations where heavy concentrations of mercury vapor were encountered. At that time no specific tests were performed to determine the effective life of the cartridges.

It was felt advisable during the mercury control program, covered by this report, to make a further investigation concerning respirators suitable for protection against mercury vapors. Three phases of the problem were studied. The first phase was to ascertain whether the "Mersorb" cartridge possessed sufficient capacity for good protection or whether further investigations should be made for a better type cartridge. The second phase consisted of the evaluation of the MSA respirator along with other commercially available respirators to determine whether another design might be more suitable for use in the Colex operations. The third and final phase of this investigation was concerned with finding the most efficient methods for decontaminating the respirators from mercury. Much of the work on these three phases was performed concurrently and thus the discussion is divided by subject rather than by chronological sequence.

Cartridge Capacity

In the laboratory tests, to determine the life expectancy of the "Mersorb" cartridge, an air stream of 100 liters per minute (roughly five times the respiratory rate of an adult walking three miles per hour) was passed through the test cartridges. A second air stream, saturated with mercury vapor, was blended into the main stream before it impinged on the cartridge. The second stream was regulated to control the mercury vapor concentration, entering the cartridge, at 1.5 mg/m^3 of air. This was, of course, fifteen times greater

than MAC. Two cartridges were tested in this manner. The air stream to the first was maintained at less than 50% relative humidity and the second at an average of 50%. The exit air was checked for the mercury vapor concentration with the [redacted] Instantaneous Mercury Vapor Detector Meter described elsewhere in this report.

In the first test, the cartridge absorbed all the mercury vapor from the air passing through for the first ninety hours. At that time the exit air contained 0.03 mg/m^3 of mercury. The leakage remained in the range of 0.03 to 0.05 mg/m^3 until 121 hours. At that time it was discovered that a composite sample was not being received. Therefore, the sampling port was relocated to give representative sampling of the effluent stream and the indicated leakage rose to 0.12 mg/m^3. Since this was greater than MAC the test was terminated.

The second test was made under conditions similar to those employed in the first except the incoming air stream was humidified by bubbling through water. A slight leakage began after sixty hours and the rate slowly increased to 0.03 mg/m^3 by 130 hours. The cartridge was accidently soaked with water twice during the next forty hours and the leakage dropped to 0.01 mg/m^3. By 260 hours the leakage had increased to 0.06 mg/m^3 and to 0.10 mg/m^3 at 310 hours at which time the test was terminated.

The results of these tests indicated that the "Mersorb" cartridges were more than adequate for use in Colex operating areas even under adverse conditions. Thus it was recommended that, regardless of what type respirator might be chosen, the use of MSA "Mersorb" cartridges be continued.

Evaluation of Respirators

Several different types of respirators, produced by various manufacturers, were obtained and examined in regard to comfort for the wearer, ease of disassembly, and ease of decontamination from mercury. The classification of the respirators with respect to comfort was made with considerable reservation since the degree of comfort of any given respirator was found to vary with different individuals. The ease of disassembly and re-assembly operations was checked in view of the need for frequent decontamination and also for replacement of component parts which might be accidently damaged. The ease of cleaning the respirators for decontamination from mercury was investigated using the cleaning solutions discussed in a subsequent section. With respect to cleaning, it was found that the geometry of the parts and the materials of construction were the governing factors.

[redacted] - The most comfortable respirator checked was the [redacted]. It was designed to fit under the chin rather than across the chin. This respirator was found to be difficult to decontaminate and extremely difficult to dissassemble completely.

[redacted] - Although the [redacted] respirator was found to be moderately comfortable, some difficulty was experienced in making it fit air-tight around the nose. It was reasonably easy to disassemble and decontaminate.

fortable but difficult to disassemble for cleaning. Since mercury particles adhered to it more readily than to any other respirator tested, it was very

- The respirator was found to be the most uncomfortable of those tested. It was so constructed as to exert tremendous pressure on the nose and was practically impossible to make air-tight. It was, however, disassembled without difficulty.

- The respirator produced by the American Optical Company was found to rank with the Sellstrom with respect to comfort and disassembly. It was also relatively easy to decontaminate.

- Two types of MSA respirators were tested. The first, the which had been in general plant use, was found comfortable but difficult to disassemble for cleaning. Since mercury particles adhered to it more readily than to any other respirator tested, it was very difficult to decontaminate.

The second respirator was a newer model, the , made of anodized aluminum. Whereas this respirator was rated as only "Fair" in respect to comfort, it was simple to disassemble and could be decontaminated as easily as any respirator tested.

Table II is a brief summary of the respirators tested.

TABLE II

COMPARISON OF VARIOUS RESPIRATORS

Manufacturer & Type	Ease of Decontamination	Ease of Disassembly	Comfort
	Fair	Simple	Fair
	Fair	Simple	Poor
	Difficult	Difficult	Good
	Good	Simple	Fair
	Fair	Simple	Fair
	Difficult	Difficult	Best

One additional test was performed in the evaluation of the respirators. Since it had been observed that certain types of cartridges hindered the normal breathing of some individuals, the pressure drop across various cartridges was determined over a range of air flows to find what type of cartridges offered the lowest resistance to breathing. The Cartridge contained in both types of the respirators were found to be as good or better in this respect as the other brands tested. The details of this test and the results are in Appendix B-7.

As a result of these tests and studies, a specification was established for respirators to be used for protection from mercury vapor (See Appendix C). It was further recommended that the respirators equipped with cartridges be used in the Colex operations if the manufacturer would make certain minor modifications in order to meet the specifications. These modifications were made and the " respirators with the " cartridges were accepted for the Colex plant use.

Decontamination of Respirators

Since the respirator masks were carried into and worn in contaminated areas, they soon became contaminated themselves. An investigation was made to find the most efficient method for cleaning and decontaminating used respirators. This program was executed in conjunction with the respirator evaluation program and so several different respirators were tested by each procedure. After each cleaning attempt, the respirators were checked for mercury vapor using a special test chamber and a specially altered vapor detection meter as described in Appendix B-6.

"Calgonite" and Water - The first cleaning method tested involved the simple brushing of the respirator using a water solution of "Calgonite". This was extremely ineffective due mainly to the geometry of the respirators. Although the mercury was readily dislodged from the smooth exposed surfaces, it could not be completely removed from the crevices.

Nitric Acid - A second test employed brushing off the exposed mercury and immersing the respirator in 8% nitric acid-water solution for twenty minutes. This method was also ineffective since the mercury was only slightly soluble in nitric acid. More concentrated nitric acid would be harmful to the rubber compounds of the respirators.

Rubber and Plastic Compounds - It became obvious early in the course of these studies that mercury had a tendency to adhere more readily to some types of rubber and plastic than to others. Several rubber and plastic samples were obtained and the tendency of the mercury to cling to the various materials was noted. This tendency to cling to the surface of some rubbers appeared to be related to the amount of filler in the rubber.

Following these studies, seven different solutions were tested for their ability to remove the mercury from the rubber and plastic surfaces. The "Calgonite"-water solution was tested and found effective on the plastics tested and rather ineffective on the rubber compounds.

It was suggested that the use of a high molecular weight amine might be effective in removing the mercury droplets from the rubber surface, since it had previously been reported that these compounds had a tendency to emulsify mercury. Several different combinations of high molecular weight amines in solution were tested and showed some promise on the rubber and plastic samples under test.

In addition several other solutions were tested. The results of all the tests on the rubber and plastic compounds are listed in Appendix B-5.

Amines for Respirator Cleaning - Although solutions of high molecular weight amines were fairly successful in decontaminating the rubber test samples, they proved quite ineffective in cleaning the respirators which utilized different types of rubber than used in the above tests. The tendency of most of these amines to be toxic also made their use unattractive.

Nitrous Acid - According to McAlpine and Soule(9), a solution of mercury in nitric acid should be readily affected in cold dilute solutions if a small

quantity of nitrous acid is present. Thus, such a solution was tested on the contaminated respirators. Fair to moderate results were obtained.

Sodium Bicarbonate - Green Soap - A Russian article[10] recommended the use of a water solution of 2.5% sodium bicarbonate and 2.5% tincture of green soap as an effective method for removing mercury from clothing. This simple solution was tested and found to be the most efficient of all those tested. An effective variation of this solution was made by substituting 2.5% NaOH for the Na_2CO_3. Although this was equally as good, it was found to be too strongly basic for convenient use.

Details of the test conditions and the results obtained may be seen in Appendix B-6.

Recommendations - As a result of these tests, the use of the 2.5% tincture of green soap - 2.5% sodium bicarbonate solution was recommended for use in decontaminating the respirators. The cleaning procedure and the other knowledge gained in the respirator testing program were combined as a memorandum "Use and Decontamination of Mercury Vapor Respirators" (See Appendix D).

RESULTS AND CONCLUSIONS

The major objective of the "Clean-up" program was achieved. The average mercury vapor concentration of both Colex buildings was reduced from a point well above the MAC of 0.1 mg/m^3 to safely below it by March 1956, a period of two months. The 9201-4 building average dropped to below 0.05 mg/m^3 in April, and has remained below this point for over a year. The 9201-5 building average remained below the MAC for the remainder of 1956 and dropped below 0.05 mg/m^3 in January 1957. (Perry, 1957)

Since the vapor concentration of the majority of areas has been low, once those areas were decontaminated and properly maintained, the "average mercury vapor" concentration of the Colex plant at times gives an optimistic impression. It has not always been possible to reduce the mercury vapor concentrations below MAC in all areas. A clearer indication of the progress may be observed in Figures 16 and 17 which were prepared by the Industrial Hygiene Group. These graphs show the percentages of the mercury vapor samples falling into various concentration ranges. The data indicate that a continuing effort must be exerted to maintain a low mercury vapor concentration.

In the process of finding methods and procedures for reducing the mercury vapor concentration below the MAC in the Colex Plant, certain basic factors governing the control of mercury contamination were established. Such factors included alteration of the equipment so as to prevent mercury leaks; methods of containing the leakage which could not be prevented; procedures for removing equipment to minimize spillage; protective coatings for equipment, walls, and floors; the proper control of ventilation and air flow; and the most efficient methods of cleaning. Such factors are discussed with specific recommendations in the following paragraphs.

It was found that areas which were contaminated with mercury should be thoroughly cleaned. The most effective cleaning procedure involved several steps as follows: Wash with 5% acetic acid to clean away carbonates; wash with "Gunk" solution to clean away grease; vacuum clean area to clean away as much mercury as possible; scrub well with a water solution of a "Tide" type detergent; and mop area with a water solution of sodium hypochlorite. The floor of the area should then be coated with "Onex Seal".

It was found necessary to keep all areas free of excess equipment and material in order to reduce potential surface area for contamination.

It was established that "Dynel" and "Vinyon" materials due to their ability to hold mercury and their inability to be easily decontaminated, should not be used for clothing in the operating areas. Instead, cotton which does not contaminate as easily and which is easily decontaminated by routine laundry washing should be used. The work clothes should have a minimum of seams and pockets which act as traps for mercury. The clothing should be washed frequently.

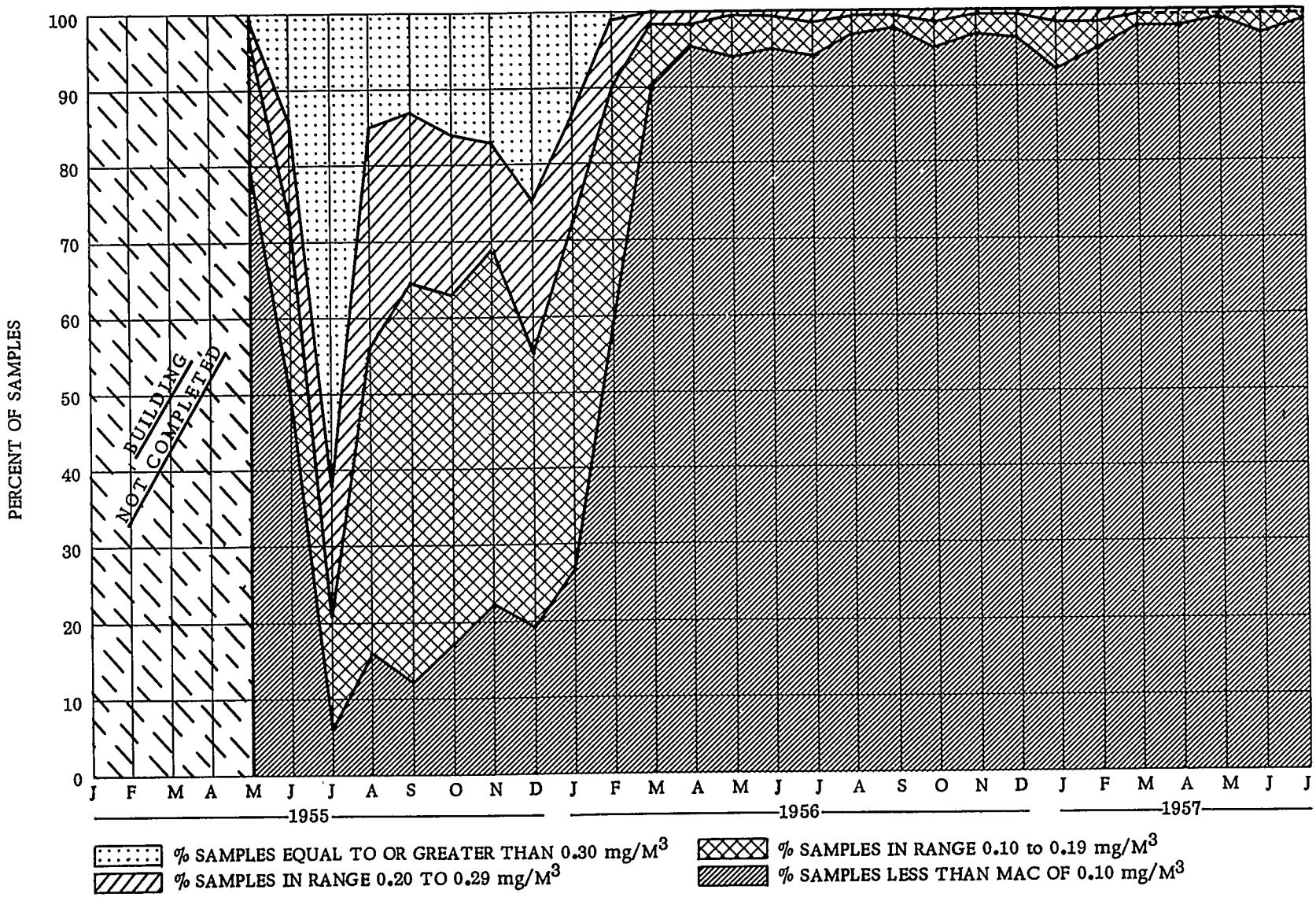


Figure 16. MERCURY VAPOR CONCENTRATION

SAMPLE DISTRIBUTION BY CONCENTRATION - BUILDING 9201-4

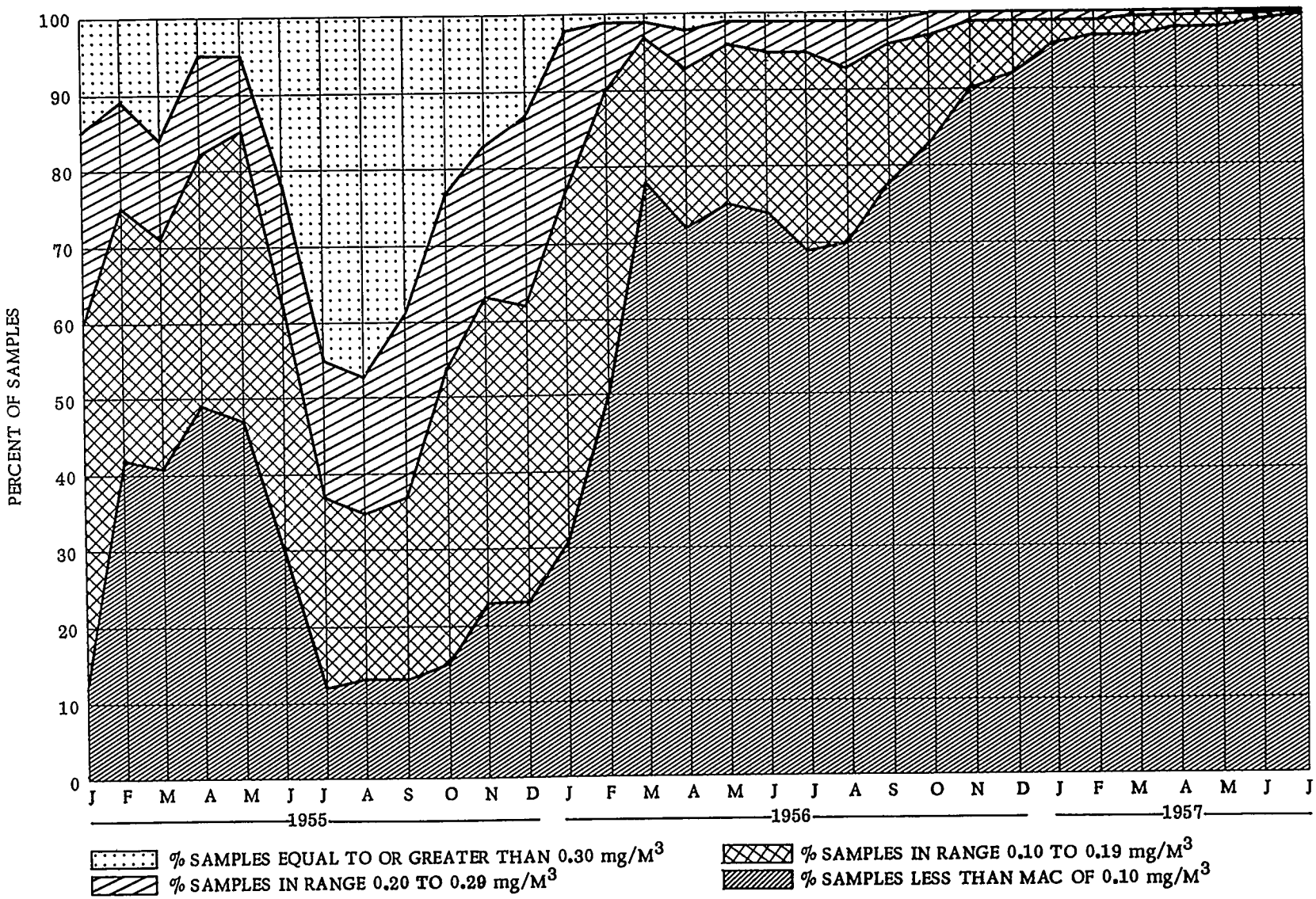


Figure 17. MERCURY VAPOR CONCENTRATION

SAMPLE DISTRIBUTION BY CONCENTRATION - BUILDING 9201-5

Since the major source of the exposed mercury was found to be leaks, every effort should be made to eliminate them. In the Colex process it was found that exposed raffinate solution, due to entrainment of finely divided mercury, contributed heavily to the mercury vapor contamination. Thus raffinate leaks and spills should be treated the same as mercury leaks and spills. All equipment should be carefully checked for leaks. Those leaks which cannot be corrected, such as around the seals and packing glands of pumps, should be enclosed by protective coverings which allow easy access to the equipment and simple drainage of the leaking solution to salvage facilities. Valves and flanges which show persistent leaks should be wrapped in plastic. Recommended for such use, due to its non-permeability to mercury vapor, is the laminate of one mil "Mylar" and four mil polyethylene.

Every precaution should be taken to avoid spills. Since the replacement of pumps was found to be the greatest source of mercury spillage, the following procedure should be followed. The pump should be thoroughly flushed with water before it is completely disconnected; as soon as it is disconnected, all openings should be sealed with elastic top plastic bags; and any spills resulting from the operation should be cleaned immediately.

It was further established that all walls and equipment should be covered with a paint resistant to the process solutions with a smooth but dull finish and of a dark green (or dark red) color. The best paint combination, of those tested, was "regular Pliogard" as a primer and dark green "Pliogard A1180" as the finish coat. The dull finish tends to repel mercury droplets whereas a glossy surface tends to hold mercury. Mercury can be seen best against a dark color.

No suitable concrete paint for the floors was found and testing should be continued in that line. Until such time as a suitable paint is found, the pores of the concrete floors should be filled with a suitable sealer. Of the compounds tested, "Onex Seal" was found to offer the best protection.

Since it was found that temperature increases the vaporization rate of mercury, all vessels which are normally at high temperatures should be insulated. The studies of ventilation established that there should be no stagnant air. Instead, there should be considerable flow of well diffused air with care exercised to prevent any air stream from being directed toward the floor or equipment surfaces since increased air velocity on the surface increases the vaporization rate.

It was established that once the visible mercury was removed from an area, the vapor, resulting from the invisible finely divided particles, could be suppressed by the application of a solution of sodium hypochlorite. This material reacts with the mercury surface to form compounds which form a protective surface film barrier preventing the mercury from vaporizing.

Since contamination of the hands, when working with mercury, is unavoidable, the use of the hand monitor should be emphasized to personnel. In addition, due to the toxicity of mercury compared to its innocuous appearance, it is the duty of supervision, in the operations and maintenance departments concerned, to keep personnel reminded of proper personnel hygiene especially in regards to eating and smoking.

When working in areas in which the mercury vapor concentration is above the MAC, personnel should wear proper respirators. The respirator which was found most suited for use in the Colex Plant operations was the Mines Safety Appliances Company "Gasfoe" respirator equipped with a "Mersorb" cartridge. The most effective decontamination procedure for these respirators when they need cleaning was found to be a water solution containing 2.5% each of sodium bicarbonate and tincture of green soap. The "Mersorb" cartridges offer good protection over long periods of time.

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APPENDIX

APPENDIX A

DECONTAMINATION MEMOS NOS. 1 THROUGH 11

Number	Date	Subject
1	1-19-56	Rubber Overshoes
2	1-19-56	Flange Gaskets
3	1-20-56	Use of Tobacco
4-a	2-7-56	Revised Amalgam and Raffinate Pump Replacement Procedures
5	1-20-56	Kinney Pump Drain Valve
6	1-20-56	Field Replacement of Alpha-4 Raffinate Pump Stators
7	1-24-56	Leak Collection Buckets
8	2-8-56	Cleaning of Rubber Shoes and Overshoes
9	2-13-56	Dismantling Recommendations for Amalgam and Raffinate Pumps
10	2-13-56	Recommended Use of Mersorb Respirators
11	2-29-56	Recommended Housekeeping Procedure

Decontamination Memo No. 1
Rubber Overshoes

Contamination of lunch rooms, offices, and the central control rooms, with mercury, has increasingly become a problem. Obviously, the source of this contamination is the operating areas; and the movement of mercury into uncontaminated areas is being effected by personnel movement.

It is therefore recommended that rubber overshoes be worn in all operational and maintenance areas. Upon leaving those areas and entering either the office areas, lunch rooms, or the central control rooms, the overshoes should be removed and deposited in a rack where they may be picked up when re-entering operational or shop areas. All overshoes should be deposited at the rack when anyone leaves the building. Overshoes should not be carried to the change house. This should apply to both the Alpha-4 and Alpha-5 plants.

It should be noted that certain difficulties in administering this recommendation are inherent. In Alpha-5, the office area and CCR are reached by passing through maintenance or operating areas. In Alpha-4, the CCR is located in a similar location. Enclosed corridors may be necessary to effect a satisfactory arrangement along with a number of stations having clean and dirty overshoe racks which are adequately serviced from the point of view of contamination and housekeeping. Outside facilities that generally have mercury in the process, such as evaporators, need fencing so that these areas cannot be entrances that by-pass overshoe stations. Some problems concerning the use of the overshoe stations by all the outside contractor's personnel will need to be solved.

Decontamination Memo No. 2
Flange Gaskets

Mercury contamination in the operating areas is increased by leaks in pipe flanges. It is recommended that a general rule be established to prohibit the re-use of gaskets. This is a general requirement on all pump changeouts, and it should be followed at any time it is necessary to break flanges in amalgam, mercury, or aqueous piping for any reason.

Decontamination Memo No. 3
Use of Tobacco

It is generally recognized that no food, cigarettes, tobacco, or other materials that may come in contact with the mouth, should be used in the operating areas. It is recommended that a further step be taken immediately to stop all personnel from carrying this type of material on their person while in the operating areas. In most cases, cigarettes and tobacco are carried by operators and maintenance men in coveralls throughout the area in which they happen to work. Handling of these materials by dirty hands or gloves, mercury splatter that is caught in pockets, and material dropped on contaminated surfaces, contribute toward making a serious mercury hazard when use is made of these contaminated articles.

Storage of food and cigarettes, or tobacco, should be in uncontaminated areas only. These areas are defined as office areas, lunch rooms, and central control rooms. A close check of storage facilities should be made periodically to insure the cleanliness of the materials left in storage and of the storage area itself.

Decontamination Memo No 4-a
Supersedes Decontamination Memo
No. 4 - Revised Amalgam and
Raffinate Pump Replacement
Procedures

Several recent amalgam pump replacements have been made using most of the following revised procedure. The results have been so gratifying, from the standpoint of reduced mercury spillage, that this procedure is recommended for adoption as soon as all the necessary piping is either revised or added in both Alpha-4 and Alpha-5.

Amalgam Pumps - Alpha-4 and Alpha-5

1. Remove power supply from drive motor and lock circuit breaker.

2. Close pump suction and discharge valves and the suction vent valve.

3. Attach hoses by means of Chicago couplings to the suction and discharge sample valves, and drain all possible amalgam to the nearest chemical drain-making certain that the hoses are inserted into the mouth of the drain.

4. Uncouple pump and drive, while pump is draining.

5. Attach a process water hose to the Chicago coupling on the suction vent line and open valve nearest this Chicago coupling.

6. Close discharge drain valve and flush water through suction bell of pump to the suction drain line.

7. When the drain hose discharges clear water, close the suction drain valve, open the discharge drain valve, and flush through the pump to the discharge drain line.

8. When the discharge drain hose flows clear water, shut off process water and close the valve at the Chicago coupling in the suction vent line.

9. Replace the discharge drain hose with the process water hose.

10. Open the suction and discharge drain valves and flush the pump with process water from the discharge drain valve through the pump and to the suction drain line until clear water is flowing through the suction drain hose.

    NOTE: If water will not flow through the pumping end, then flush only the suction end and adhere to the remainder of this procedure as closely as possible.

11. Close the suction and discharge drain valves and remove all water and drain hose from the pump.

12. Connect a house vacuum hose to the suction drain valve, open the vacuum valve, open the suction drain valve and then open the discharge drain valve.

13. Pull vacuum through the pump for approximately three (3) minutes--then close the valves.

14. Move vacuum hose to the discharge drain valve, open vacuum valve, open discharge drain valve, and then open suction drain valve. Pull vacuum through the pump for approximately three (3) minutes.

15. Move vacuum hose to the Chicago coupling on the suction vent valve and open the vacuum valve and the valve at the Chicago coupling on the suction vent line.

16. Remove the bolts from the suction and discharge flanges of the pump and disconnect the pump from the base. The operator should employ a plastic bucket or a drip pan partially filled with water to collect any process fluid spills which may occur. Pull vacuum through the pump for three or four minutes. Then disconnect the vacuum.

17. Carefully lift the pump from its base so that the suction and discharge flanges are just clear.

18. Install sheet plastic covers over the suction and discharge flanges and the packing gland area.

19. Move transport dolly as close to the pump position as practical and place the pump carefully on the dolly. Never allow the pump to swing on the hoist, since this increases the probability of mercury spillage onto the floor.

20. The maintenance men will clean the transport dolly spill pan before the pump and dolly leave the operating area.

21. Install the replacement pump and remain until the breaker is unlocked and the pump proves to be in good operating condition.

22. Never, under any circumstances, should old gaskets be reused.

23. Transfer the replaced pump and its dolly to the pump repair area. Thoroughly clean the pump and dolly.

24. The pump should be cleaned again before starting repair. As disassembly progresses, any mercury encountered should be disposed of in water filled pans to be emptied into chemical drains.

25. Transfer the repaired pump and a new set of gaskets to the repaired pump storage area. Any visible mercury should be cleaned from pump and dolly before maintenance personnel leave the storage area.

Raffinate Pumps - Alpha-4

1. Remove power supply from drive motor and lock circuit breaker.

2. Close pump suction and discharge valves.

3. Attach hose by means of Chicago couplings to the suction and discharge sample valves, and drain all possible raffinate to a chemical recovery dolly or to a plastic bucket.

4. Uncouple pump and drive while pump is draining.

5. Attach a process water hose to the suction sample valve.

6. Backwash the pump for approximately three (3) minutes.

7. Remove water supply. Close suction and discharge sample valves after the water has drained from the pump.

8. Connect a house vacuum hose to the suction sample valve. Open vacuum valve and remove bolts from flanges on discharge end of pump.

9. Allow approximately two (2) minutes of vacuum flow through pump.

10. Follow the procedure for amalgam pumps from step 17 through step 25, inclusive.

In executing this procedure, any valve setting, hose changing, and the retrieving of any spills resulting from the pump changeout, should be a chemical operator's responsibility. The operator should take every possible precaution to insure minimum mercury spillage by the use of plastic buckets or drip pans partially filled with water.

It is also important that a maintenance mechanic place a small container under the relief port in the pump bearing housing to collect any grease which vents through the relief port. This mechanic should return after approximately one (1) hour has elapsed to clean this area under the pump of any grease or oil. Replace the relief plug. All excess grease or oil should be cleaned from the equipment whenever the equipment is lubricated.

It is vital that drain hose and process water hose used in the above procedures be kept separately identified. It would be unwise to use one in place of the other.

Kinney pump replacement is currently being investigated, and a procedure will be written at such time as it is determined what method is the most practical.

Decontamination Memo No. 5
Kinney Pump Drain Valve

At the present time there is a large number of Kinney pumps in Alpha-5 without drain valves. On replacing one of these pumps the first step is to open the discharge flange and allow the raffinate to drain to the floor.

Since raffinate spills are the source of a great deal of mercury contamination, these drain valves should be provided as soon as possible.

Decontamination Memo No. 6
Field Replacement of Alpha-4
Raffinate Pump Stators

Recent observations reveal that much avoidable spillage of mercury-laden aqueous is being incurred during field replacement of stators on Alpha-4 aqueous pumps.

On the basis of this, and the fact that very little time, if any, is saved by this method, it is recommended that these aqueous pumps be replaced as units.

Decontamination Memo No. 7
Leak Collection Buckets

In many instances it has been noted that the small plastic buckets, which are used to collect process leakage from plastic-wrapped valves, flanges, and couplings, contain little or no water. There are two (2) reasons for partially filling these buckets with water. First, the water acts as a shock absorber to prevent mercury droplets from spattering. Second, the water inhibits, to a large extent, mercury vaporization. It is of prime importance, therefore, that these buckets be partially filled with water at all times.

Due to the above reasons, it is recommended that a routine inspection be made of these buckets at least once every twenty-four hours. This inspection should include washing off any visible contamination as well as making certain there are sufficient buckets and the buckets have at least an inch of water in the bottom.

Small plastic bottles are being used in place of the plastic buckets in some cases. These experimental bottles have not been used long enough to determine their feasibility, but observations are being made.

Decontamination Memo No. 8
Cleaning of Rubber Shoes and Overshoes

Tests have shown that a satisfactory cleaning of mercury from rubber footgear can be accomplished by brushing with a 0.5% solution of "Calgonite" in water. This detergent does not react with mercury, but a mechanical removal is effected.

Since rubber footwear is now being used in Alpha-4 and Alpha-5 in conjunction with the use of an aqueous solution of "HgX" on some floors, it is recommended that such foot wear be more thoroughly decontaminated before persons enter offices and lunchrooms. Shallow trays of steel or Boltaron should be fitted with a removable steel grid having brushes attached thereto, some with the

bristles upward and some so attached that the welt of the shoe may be brushed. Bristles should be moderately stiff, one to one and one-half inches long, and preferably of nylon. The 0.5% solution of "Calgonite" should extend sufficiently above the brushes that excessive splashing is eliminated. A rinse tray, containing water, should also be provided.

A routine schedule should be established for cleaning of all pans and replacement of solutions.

Decontamination Memo No. 9
Dismantling Recommendations
for Amalgam and Raffinate Pumps

Recent inspections of amalgam and raffinate pumps in storage areas of Alpha-4 and Alpha-5 indicate a need for more meticulous removal of mercury from these pumps during repair operations.

It is recommended that whenever an amalgam or raffinate pump is removed from service for any reason the pump be completely dismantled before attempting repairs. As disassembly progresses any excess mercury encountered should be removed by means of a vacuum hose or by drainage into a drip pan partially filled with water.

After the pump has been completely disassembled, all parts should be thoroughly scrubbed in "Gunk" with the exception of all rubber parts. This operation will remove a great deal of mercury which normally is not disposed of during routine repair procedures. Rubber parts should be scrubbed with brushes while the parts are submerged in continuously changing water.

The use of water or air jets for cleaning mercury-laden parts should be prohibited since these methods tend to scatter droplets of solvent.

When all parts are as clean as possible, assembly and repair should proceed in the usual manner, lubricating bearings, connecting rod joints, and packing (where necessary) with the prescribed code and amount of lubricant. A very thin film of code HU oil should be used on any moving parts exposed to the atmosphere to prevent corrosion. This film should be applied with a saturated cloth and then the cloth discarded in order to prevent possible spreading of any contamination.

Decontamination Memo No. 10
Recommended Use of Mersorb Respirators

Certain operations are being performed in Alpha-4 and Alpha-5 which by nature are sources of mercury vapor release. It is recommended that all personnel performing these operations wear a respirator equipped with "Mersorb" cartridges during execution of these duties.

Included among the operations mentioned are amalgam and raffinate pump replacement, process valve or piping replacements, circuit interrupter assembly or anode replacement, and removal of absorber tray end box covers.

Outlet circuit interrupters should be removed and replaced with the accumulator box, as a unit.

Aside from these recommendations it should be re-emphasized that all personnel in the immediate area of a cutting or welding operation on contaminated equipment wear respirators.

Decontamination Memo No. 11
Recommended Housekeeping Procedure

In view of the knowledge gained in the past several years in handling mercury, together with the knowledge being acquired in the current "all-out-clean-up" program in the Alpha-5 Plant, the accompanying procedure has been written to give a general outline for housecleaning in ADP areas where mercury is used. It must be understood that the problem is still under investigation and that this procedure is only a recommendation based on present knowledge and incorporating fundamental ideas for reducing air contamination through housekeeping. Additional detailed recommendations will be made when feasible.

Of the number of variables that control air contamination, the one that can best be defined is the surface area of the exposed mercury. That is, at given conditions of air velocity, temperature, and surface condition of mercury, the contamination is a direct function of the surface area of mercury exposed. The three (3) most obvious means of reducing this critical area are by removing all non-essential surfaces on which mercury may collect, endeavoring to collect leaks and spills at the earliest possible time with the least amount of spreading, and by expending a major effort in removing visible mercury whenever possible.

I. GENERAL RULES

There should be an immediate clean-up of a given area after all mercury or aqueous spills as well as constant cleaning of equipment, piping, walls, ceiling, and floors in the spare time of operating personnel. Therefore:

Rule No. 1: No mercury, visible to the naked eye, should exist at any time outside of the process piping and equipment. This includes the small droplets (barely visible), as well as large pools.

Grease will hold small droplets of mercury, therefore:

Rule No. 2: No free grease should exist on equipment, pipe lines, floors, walls, or ceilings.

Since in the process aqueous solutions there is finely divided mercury, therefore:

Rule No. 3: Aqueous spills must be cleaned as soon as mercury spills

and no dried chemical salts, etc., should exist on equipment, piping, floors, walls, or ceilings.

Common sense dictates that an area cannot be kept clean if a source of contaminant continues to exist, therefore:

Rule No. 4: All leaks must be reported as soon as noticed and repaired as soon as possible.

The peculiar characteristics of mercury cause it to shatter into smaller and smaller droplets when dropped or struck, therefore:

Rule No. 5: Mercury must never be:

a. Swept (some amount of "squeegeeing" may be desirable on large spills in the interest of fast cleaning, but the house vacuum should be the main method of cleaning).

b. Hit with an air or water jet from a pressurized source. (Hose downs should never be used to push mercury through an area.)

c. Walked through. (A special effort should be made to step around any puddles rather than through them.)

d. Dislodged from an object and allowed to drop onto a floor or a lower object. (The extra surface exposed due to spatter is always large.)

Rule No. 6: No excess tools or equipment should be left in an operating area and any portable equipment that needs to be left in an operating area should have designated storage areas.

II. MAJOR SITUATIONS

Three (3) situations exist and general procedures for coping with these are outlined below:

A. A mercury spill from equipment changeout, broken equipment, leak, etc. Such a spill must be cleaned up immediately. The first step is to use house vacuum and then follow other steps of Procedure "A".

Procedure "A" - Clean-up After a Spill

Step No. 1: Check to see that leaks or cause of spill has been corrected so that no more mercury will flow into area.

Step No. 2: If a floor drain is convenient, use a "squeegee" and push all mercury possible into it. If a drain is not convenient, shovel or scoop up large pools of mercury into a convenient container - carry container to solvent drain and pour out mercury without spatter. Use this step ONLY if these methods are faster than house vacuum.

Step No. 3: With house vacuum system, vacuum all visible droplets of mercury from equipment, pipes, columns, walls, floors, ceilings, etc., in the surrounding areas. Use care to clean all cracks, crevices, etc.

Step No. 4: Scrape all loose grease and chemical deposits from all equipment, etc.

Step No. 5: Sponge all greasy areas of equipment, etc., with "Gunk" solution; wash off with water. Repeat until equipment is free of grease.

Step No. 6: Sponge all areas covered with chemical salt deposits with a 10% solution of acetic acid in water until free of chemical deposits.

Step No. 7: If any mercury is visible at this time (having been released from the grease or chemical deposits), use house vacuum to remove it.

Step No. 8: Wash entire area with water solution of "Tide".

Step No. 9: Rinse down entire area with water.

Step No. 10: Wash entire area with 2.5% water solution of "Chlorox" (available in stores in gallon containers and listed as chlorine bleach solution). Do not rinse. Care should be taken that this solution is not applied to iron parts since it is corrosive.

Step No. 11: Request the Health Physics Group to monitor area with portable vapor meter.

B. Mercury and deposit accumulating from slow leaks, from pump packings, etc. - General housekeeping and daily checking of equipment followed by immediate clean-up of such areas should handle these problems.

Procedure "B" - General Housekeeping

A schedule should be instituted for an inspection per shift of all equipment to locate mercury leaks as well as deposits of grease or chemical salts. Operators spare time should be spent in cleaning equipment. Whenever spills or deposits are found, they should be handled as in Procedure "A".

C. General mercury contamination in a large area

Such a situation may be prevented by carefully following good housekeeping; but if severe enough, it may become necessary that this problem be handled by an "all out" effort involving a special clean-up crew to clean methodically every inch of the area.

Procedure "C" - High Contaminated Area

Whenever a large area has been found to be highly contaminated, the steps of Procedure "A" should be carried out in a thorough methodical way on every piece of equipment, every pipe, every wall, every ceiling, every floor, etc.

APPENDIX B

TEST PROCEDURES AND RESULTS

Test No.	Subject
1	Testing of Solutions for the Decontamination of Fabrics
2	Testing of Paints for Suitability of Use in Colex Plants
3	Testing of Floor Sealers for Use in the Colex Plants
4	Testing of Various Compounds for use as Mercury Vapor Suppressors
	Part a Laboratory Tests Part b Plant Tests
5	Testing of Various Solutions for Effectiveness in Cleaning Mercury from Rubber and Plastic Compounds
6	Testing of Various Respirators for Ease of Decontamination from Mercury
7	Pressure Drop Measurements of Various Respirators
8	Testing of Various Plastic Sheet Materials for Permeability to Mercury Vapor

TEST NO. 1

TESTING OF SOLUTIONS FOR THE DECONTAMINATION OF FABRICS

Test Procedure:

1. Mercury was poured onto the sample of fabric in such a manner as to cause the mercury to spatter and break into fine droplets.

2. The material was placed in a 250 ml pyrex cell and argon was passed through the cell at 10 cfm.

3. The exit gas was analyzed for mercury vapor with a General Electric Mercury Vapor Detector.

4. The test decontamination solution was added to the cells and the fabric was agitated in the solution for one hour.

5. The fabric was removed and allowed to air dry.

6. The cell was thoroughly cleaned and dried.

7. The fabric was again placed in the cells and steps (2) and (3) repeated.

8. A microscopic examination of the fabric was made.

9. In addition, in some cases, a tensile strength test was performed.

Results: See Appendix - Table I.

APPENDIX - TABLE I

RESULTS OF TESTING VARIOUS CLEANING AGENTS

	Vinyon		Dynel		Cotton		
	Mercury Vapor Conc. - mg/m^3						
	Before Cleaning	After Cleaning	Before Cleaning	After Cleaning	Before Cleaning	After Cleaning	Remarks
"Aquet" Solution	0.60	0.60	0.60	0.60	--	--	
Copper Sulfate + HC1	0.60	0.30	0.60	0.30	--	--	
Cupric Chloride (5% Solution)	0.60	0.60	0.60	0.60	--	--	
Ferric Chloride (5% Solution)	0.60	0.40	0.60	0.40	--	--	
Hydrogen Peroxide + Acetic Acid	0.60	0.10	0.60	0.10	--	--	Examination showed only a few drops of mercury left after test.
Hydrogen Peroxide (0.5%) + Acetic Acid (50%)	0.60	0.10	0.60	0.10	--	--	
Hydrogen Peroxide (0.5%) + Acetic Acid (25%)	0.60	0.10	0.60	0.10	--	--	
Hydrogen Peroxide (0.5%) + Acetic Acid (10%)	0.60	0.10	0.60	0.10	--	--	
Hydrogen Peroxide (0.5%) + Acetic Acid (5%)	0.60	0.10	0.60	0.10	--	--	
Hydrogen Peroxide (0.3%) + Acetic Acid (2%)	0.10[1]	0.05	--	--	--	--	This conc. does not affect skin.
Hydrogen Peroxide (0.6%) + Acetic Acid (10%)	0.60	0.04	0.60	0.04	--	--	16-Hour Test
Iodic Acid	0.60	0.60	0.60	0.60	--	--	
Iodine in Methyl Alcohol Solution	0.60	0.00 to 0.60	0.60	0.00 to 0.60	--	--	Effect temporary - material discolored.
Iodine Vapor	0.60	0.30	0.60	0.30	--	--	Effect temporary - material discolored.
Lime Sulfur + Tributyl Phosphate "Tide" wash	0.60	0.10 to 0.20	0.60	0.10 to 0.60	--	--	Left pungent odor in material.
Milk Sulfur	0.60	0.20	0.60	0.20	--	--	
Nitric Acid (70%)	0.60	0.60	0.60	0.00	--	--	Material became brittle.
Nitric Acid (35%)	0.60	0.00	0.60	0.00	--	--	No apparent damage.
Nitric Acid (18%)	0.60	0.20	0.60	0.20	--	--	No apparent damage.

[1] Used a complete uniform for this test.

APPENDIX - TABLE I (Continued)

	Vinyon		Dynel		Cotton		
	Mercury Vapor Conc. - mg/m^3						
	Before Cleaning	After Cleaning	Before Cleaning	After Cleaning	Before Cleaning	After Cleaning	Remarks
Nitric Acid (7%)	0.60	0.20	0.60	0.20	--	--	No apparent damage.
Nitric Acid (3.5%)	0.60	0.40	0.60	0.40	--	--	No apparent damage.
Nitric Acid (0.7%)	0.60	0.40	0.60	0.40	--	--	No apparent damage.
Nitric Acid (3.5%) + Sodium Nitrate (5%)	0.60	0.60	0.60	0.60	--	--	
Silver Nitrate (5%)	0.60	0.10	0.60	0.10	--	--	Precipitate formed - material discolored.
Sodium Hypochlorite (1%)	0.60	0.04	0.60	0.04	0.60	0.04	Attacked Cotton.
Sodium Sulfide	0.60	0.20	0.60	0.20	--	--	Mat'l turned black.
Sodium Thio Sulfate (5%)	0.60	0.40	0.60	0.40	--	--	
"Tide" Solution	0.60	0.60	0.60	0.60	0.60	0.02	Microscopic check showed no Hg in cotton.
"Tide" Solution[2]	--	--	--	--	0.60	0.20	Microscopic check showed Hg only on grease.
Ultrasonic Vibration + HNO_3 (18%)	0.60	0.60	0.60	0.60	--	--	
Ultrasonic Vibration + HNO_3 (7%)	0.60	0.30	0.60	0.30	--	--	
Ultrasonic Vibration + "Tide" Solution	0.60	0.30	0.60	0.30	--	--	
Ultrasonic Vibration + Water	0.60	0.30	0.60	0.30	--	--	

[2] Special test of cotton stained with "Batco" grease.

TEST NO. 2

TESTING OF PAINTS FOR SUITABILITY OF USE IN COLEX PLANTS

Test Procedure:

1. The paint tests were performed on one or more of the following surfaces: Concrete, Insulation, Cast Iron, Smooth Metal, Tile Wall, or Galvanized Metal.

2. The surface was painted with the test paint and allowed to dry for 24 hours.

3. An adhesion test was then performed by cutting the paint and attempting to peel it off.

4. Solutions of caustic and sodium hypochlorite were poured over the painted surface and allowed to dry.

5. The painted surface was examined with a 20X microscope (in some cases when testing floors, traffic was allowed to pass for 24 or more hours and then the paint was examined for mercury adhesion).

6. The painted surface was contaminated by mercury and the air contamination was determined using a special test box procedure. (Uncontaminated air at a controlled rate was drawn through the special box, 4" x 4" x 4" and open only on the bottom, placed over the area to be tested and the exit stream analyzed for mercury vapor with a General Electric Mercury Vapor Detector.)

7. The area was cleaned by vacuuming and washing with water. Then it was allowed to air dry.

8. Using the above box procedure, the vapor concentration was again determined.

Results: See Appendix - Table II

APPENDIX - TABLE II

RESULTS OF PAINT TESTS

Paint Tested (Manufacturer and Type)	Primer Used for Test	Material Used for Test	Adhesion	Caustic Resistance	Ability to Shed Hg	Remarks
		Smooth Metal	F	F	-	Not Recommended.
		Concrete	F	E	G	
		Insulation	E	E	G	
		Cast Iron	E	E	G	Paint dries to a soft film.
		Smooth Metal	E	E	G	
		Galvanized Metal	E	E	G	
		Concrete	G	E	E	
		Insulation	E	E	E	
		Cast Iron	E	E	E	Vendor does not recommend brushing.
		Smooth Metal	E	E	E	
		Galvanized Metal	E	E	E	
		Insulation	G	G	F	
		Tile Wall	G	G	F	Hard thin coat will not withstand wear.
		Galvanized Metal	G	G	F	
		Concrete floor	G	G	F	
		Smooth Metal	G	E	E	
		Insulation	G	E	E	
		Concrete	F	E	E	Takes too long to dry.
		Cast Iron	G	E	E	
		Baked-on Smooth Enamel	G	E	E	

APPENDIX - TABLE II (Continued)

Paint Tested (Manufacturer and Type)	Primer Used for Test	Material Used for Test	Adhesion	Caustic Resistance	Ability to Shed Hg	Remarks
Gaco N 700	None	Concrete	F	E	E	Lacks good adhesion properties. However, a Pliogard base aids this excepting that the Gaco paint cuts the Pliogard primer if not properly applied.
	None	Insulation	E	E	E	
	None	Cast Iron	G	E	E	
	None	Smooth Metal	F	E	E	
	None	Galvanized Metal	G	E	E	
	N 100-1	Concrete	F	E	E	
	N 100-1	Insulation	E	E	E	
	N 100-1	Cast Iron	G	E	E	
	Pliogard	Concrete	F	E	E	
	Pliogard	Smooth Metal	F	E	E	
Glidden Clear Gloss Lacquer	None	Smooth Metal	F	F	P	Not recommended.
Pliogard (Regular)	None	Galvanized Metal	E	E	P	Easy to apply - gives soft finish.
		Insulation	E	E	P	
		Concrete (floor)	G	E	P	
		Cast Metal	E	E	P	
		Smooth Metal	E	E	P	
Pliogard A 1180	Reg. Pliogard	Smooth Metal	E	E	E	Recommend further testing (appears very good).
		Cast Metal	E	E	E	
		Insulation	E	E	E	
		Concrete	F	E	E	
Super Kemtone	None	Wood	G	P	-	Not recommended.
	None	Smooth Metal	P	P	-	Not recommended.
Tygon	None	Smooth Metal	F-P	E	E	Not recommended.
	None	Cast Metal	-	-	-	Not recommended.
Vitalux Acid - Resisting Masonary Primer 421	None	Smooth Metal	F	-	-	Not recommended.
	None	Concrete	F	-	-	Not recommended.
Vita-var Traffic Paint	None	Concrete	F	F-P	-	Not recommended.

Key: E-Excellent F-Fair
G-Good F-P-Fair to Poor

TEST NO. 3

TESTING OF FLOOR SEALERS FOR USE IN THE COLEX PLANTS

Test Procedure:

1. In general, the procedure for testing sealers was the same as for testing paints (Appendix B) excepting that the drying time was varied.

2. Most of the tests were performed on concrete floors and traffic tests were from 1 to 4 days.

3. Specific areas were tested to obtain the worst possible conditions.

4. Testing of those sealers which appeared superior to the others included application over the floor which had been freshly washed with a solution of sodium hypochlorite.

5. All resulting surfaces were examined with 20X microscope.

6. Mercury vapor air contamination determinations were made before and after each test.

Results: See Appendix - Table III

APPENDIX - TABLE III

RESULTS OF TEST WITH VARIOUS SEALERS

Brand Name of Sealer Tested	Type of Floor Used for Test	Adhesion	Resistance to Caustic	Resistance to Sodium Hypochlorite	Remarks
	Concrete	F	E	E	Expensive to apply (see paints).
	Concrete	G	G	G	Film soft - will not support heavy traffic.
	Concrete	F	F	F	Film soft - will not support heavy traffic.
	Concrete	(1)	F	-	Does not leave smooth surface in spots.
	Concrete	G	F	F	Film will break from floor when exposed to caustic.
	Concrete	P	E	E	Very slick when wet (see Paints). Does not have lasting protection.
	Concrete	G	G(2)	G(2)	Film breaks away from floor on long exposure to caustic. Floor must be free of "Clorox" before application.
	Concrete	G	P	P	Does not last in operating area.
	Concrete	G	F	F	Does not leave smooth surface over entire area.
	Concrete	G	P	P	Film breaks in contact with caustic.
	Concrete	G	G	-	Seals well - leaves white surface slightly water soluble.
	Concrete	G	F	-	Tends to hold mercury.
	Concrete	G	G	G	Can be applied over floor freshly treated with sodium hypochlorite, film slowly attacked by caustic.
	Concrete	G	P	P	Film breaks up in contact with caustic.
	Concrete	F	E	E	Does not last in operating area.
	Concrete	G	P	P	Does not last in operating area.
	Concrete	F	G	G	Has a tendency to crack.
	Metal Walkway	F	G	G	

(1) Reacts with Concrete.

(2) Good only when film is allowed to dry properly.

Key: E-Excellent F-Fair G-Good P-Poor

TEST NO. 4 (a)

TESTING OF VARIOUS COMPOUNDS FOR USE AS MERCURY VAPOR SUPPRESSORS

PART a - LABORATORY TESTS

Test Procedure:

1. For each test a fresh 0.5 cc sample of clean mercury was placed in the bottom of a 250 ml pyrex cell.

2. The cell was so arranged that 10 cfm of argon could be passed over the mercury surface.

3. The mercury vapor content of the exit gas was determined by use of a General Electric Mercury Vapor Detector.

4. Three drops of the test solution were introduced into the top of the cell and the exit gas was analyzed for mercury vapor.

5. The mercury was then covered with a layer (0.2 inches) of the test solution and the contaminating vapor rechecked.

6. In cases where a film was produced on the mercury surface, it was examined with a microscope.

RESULTS: See Appendix - Table IV a

APPENDIX - TABLE IV-a

RESULTS OF LABORATORY TESTS FOR HG VAPOR SUPPRESSORS

Solution Tested	Hg Vapor Before Adding Solution	Conc (mg/m^3) 3 Drops Solution	Conc (mg/m^3) 0.2" Layer Solution
Alizarin Yellow R	0.65	0.40-0.50	0.10
Alkylamine 81-R	0.65	0.55	0.04
Alkyl-aryl poly glycol ether (conc.)	0.65	0.40	0.08
Alkyl-aryl poly glycol ether (50%)	0.65	0.40	0.08
Alkyl-aryl poly-ether alcohol (20%)	0.65	0.25-0.50	0.10
Ammonium bromide	0.65	0.40	0.06
Ammonium iodide	0.65	0.40	0.06
Aquet (5%)	0.65	0.20	0.01
Brom Cresol green (0.05%)	0.65	0.50	0.08
Bromphenol blue (0.04%)	0.65	0.15-0.25	0.02
Carbowax 20M	0.65	0.55	0.07
Cetyl pyridinium chloride (0.5%)	0.65	0.65	0.08
C. M. C. (5%)	0.65	0.20-0.50	0.03
Emulphor A.O. (5%)	0.65	0.50	0.05
Emulphor ELA (5%)	0.65	0.35	0.02
2-Ethylhexyl - 3 amine propylether (2%)	0.65	0.25-0.30	0.06
Fluroscein (0.1%)	0.65	0.50	0.12
Green soap (5%)	0.65	0.22	0.02
Hyamine 10X (1%)	0.65	0.45	0.08
Hyamine 1622	0.65	0.05	0.00
Lithium Hydroxide 4N	0.65	0.55	0.05
Meta cresol purple (0.047)	0.65	0.55	0.05
Methyl green (0.1%)	0.65	0.55	0.05
Methyl orange (0.1%)	0.65	0.55	0.10
Morpholine (50%)	0.65	0.55	0.22
Nacconal NR (5%)	0.65	0.05-0.10	0.10
N-Hexyl-Carbitol (5%)	0.65	0.15-0.40	0.04
N-octyl tri methyl ammonium bromide	0.65	0.35	0.25
Nonylamine D-1	0.65	0.65	0.20
Phenolphthalein (0.1%)	0.65	0.55	0.06
Phenol red (0.1%)	0.65	0.50	0.05
Pluronics F68 (5%)	0.65	0.65	0.10
Pluronics L64 (5%)	0.65	0.52	0.22
Polyethylene ether (5%)	0.65	0.40-0.50	0.04
Sodium Hypochlorite (1.1%)	0.65	0.05	0.00
Sodium Hypochlorite (2.1%)	0.65	0.05	0.00
Sodium Hypochlorite (4.2%)	0.65	0.05	0.00
Sodium Hypochlorite (8.5%)	0.65	0.10	0.00
Sulfosalicylic acid	0.65	0.30	0.05
Tergitol 987 (5%)	0.65	0.55	0.10
Tetra ethylene pentamine stearamine (0.2%)	0.65	0.05	0.18
Thio-B-napthol (0.01%)	0.65	0.45	0.00
Thio-glycolic acid (0.2%)	0.65	0.55	0.08
Thio urea, propyl alcohol, water	0.65	0.55	0.12
Tide (5%)	0.65	0.20-0.40	0.04
Ultra Wet (5%)	0.65	0.55	0.10
Water	0.65	0.55	0.05
Wetting Agent 58-B (5%)	0.65	0.22-0.50	0.03

TEST NO. 4 (b)

TESTING OF VARIOUS COMPOUNDS FOR USE AS MERCURY VAPOR SUPPRESSORS

PART 'b - PLANT TESTS

Test Procedure:

1. A large area in one of the Colex Plants was scrubbed with a "Tide" solution (which usually increased the mercury vapor concentration because it removed surface film).

2. The test compound was mopped or sponged on to floors and equipment in the area.

3. The solution was allowed to air dry.

4. The mercury vapor contamination in the air was measured before and after the solution was applied both at floor level and at breathing level by means of a General Electric Mercury Vapor Detector.

RESULTS: See Appendix - Table IV-b

APPENDIX - TABLE IV-b

RESULTS OF PLANT TESTS ON MERCURY VAPOR SUPPRESSORS

Chemical Tested	Results
Acetic Acid (10%) + Hydrogen Peroxide (2%)	Some reaction took place with the mercury, but the air remained contaminated.
Ferric Chloride (20%)	Air contamination dropped at first, but rose slowly to original value as solution evaporated.
HgX - Solution (1/2" layer left on floor for several days)	Air contamination reduced to 0.03 mg/m^3. However, additional HgX had to be added daily.
HgX - Solution (Saturated)	Air contamination reduced only while wet.
Calcium Hypochlorite (Saturated Solution)	Air contamination not lowered an appreciable amount.
Sodium Hypochlorite (8.5% - Solution)	Air contamination reduced to 0.03 mg/m^3. Remained at 0.03 mg/m^3 until recontaminated after 64 hours.
Sodium Hypochlorite (4.2% - Solution)	Air contamination reduced to 0.03 mg/m^3. No change until recontaminated (16 hours).
Sodium Hypochlorite (2.1% Solution)	Air contamination reduced to 0.03 mg/m^3. Rose slowly to 0.10 mg/m^3 after a few hours.
Sodium Hypochlorite (1.1% Solution)	Air contamination reduced to 0.03 mg/m^3. No further information on stability.
Special Vapor Suppressor (SVS)	The air contamination was reduced in some areas and increased in others. In no case was effect permanent.

TEST NO. 5

TESTING OF VARIOUS SOLUTIONS FOR EFFECTIVENESS IN CLEANING MERCURY FROM RUBBER AND PLASTIC COMPOUNDS

Test Procedure:

1. Samples of five different types of rubber or plastic compounds were used for this test. (See Appendix - Table V-a) Sample size: Two inch square.

2. Mercury was poured onto the test samples in such a manner as to cause the mercury to splatter and break into fine droplets.

3. Each sample was washed in a water solution of "Calgonite".

4. Each sample was then examined under a microscope for mercury retention and classified. (See Appendix - Table V-a).

5. The sample specimens were recontaminated with mercury as per step (2).

6. A freshly contaminated sample was washed in each of the seven test solutions. (See Appendix - Table V-b).

7. After washing the sample was checked under a microscope.

RESULTS: See Appendix - Table V-c.

APPENDIX - TABLE V-a

RUBBER AND PLASTIC SAMPLES & THEIR CHARACTERISTICS

Sample	Tendency of Mercury to Adhere
Mosite Rubber 738	Good
Mixing Equipment Co. Rubber	Fair
Arco Rubber	Excellent
Polyvinyl Chloride (Red)	Poor
Polyvinyl Chloride (Clear)	Very Poor

APPENDIX - TABLE V-b

COMPOSITION OF SOLUTIONS TESTED

Solution I

100 ml water
1 gm "Hyamine 10X"
1 gm "Hyamine 1622"
10 gm isopropyl alcohol

Solution II

0.18 gm diphenyl thio carbozone
250 ml triethanol amine
250 ml liquid soap
0.015 gm hydroquinone

Solution III

100 ml tincture green soap
300 ml water

Solution IV

2 gm "Tergitol"
250 gm water
10 ml "Tritone"

Solution V

3 gm "Arquad 2 HT"
Dihydrogenated tallow
dimethyl ammonium chloride
150 ml butyl alcohol

Solution VI

1 gm Calgonite
250 ml water

Solution VII

Solution V diluted with water to make the amine concentration 2,000 ppm

APPENDIX - TABLE V-c

Cleansing Effect of Test Solution

Rubber or Plastic Samples	Solution Number						
	I	II	III	IV	V	VI	VII
Arco Rubber	P	P	P	P	P	P	P
Mixing Equipment Co. Rubber	G	P	VP	P	G	F	F
Mosite Rubber	G	P	VP	VP	VP	F	G
Polyvinyl Chloride (Clear)	G	P	G	G	E	VG	VG
Polyvinyl Chloride (Red)	G	P	P	F	VG	G	G

Key: E-Excellent
VG-Very good
G-Good
P-Poor
VP-Very poor

TEST NO. 6

TESTING OF VARIOUS RESPIRATORS FOR EASE OF DECONTAMINATION FROM MERCURY

Procedure:

1. The respirator to be checked was thoroughly contaminated by splashing it with mercury.

2. The respirator was then washed in one of seven cleaning solutions by gentle agitation for 20 minutes.

3. The respirator was rinsed with water and dried.

4. The respirator was placed in a long cylindrical tube and uncontaminated air was passed through the tube at a flow of 0.25 liters/minute.

5. The exit air was checked for mercury contamination by a General Electric Mercury Vapor Detector specially outfitted for high sensitivity. (See "Detection of Mercury" section of report). Qualitative comparison readings were obtained rather than absolute values.

6. After testing in the cylinder, the respirator was contaminated again and the entire procedure repeated. The final result listed for each test is the average of six complete cleaning cycles.

RESULTS: See Appendix - Table VI

APPENDIX - TABLE VI

EASE OF DECONTAMINATING VARIOUS RESPIRATORS (FROM MERCURY)

Manufacturer of Respirator	Cleanability Rating and Meter Reading				
	Soln. I	Soln. II	Soln. III	Soln. IV	Soln. V
	P-42	P-72	G-6	E-2	E-2
	P-50	F-34	G-7	E-5	--
	P-57	F-33	F-17	E-4	E-2
	P-40	F-29	E-3	E-3	E-4
	P-65	P-80	F-21	G-7	G-10

Key: P-Poor, 40 to 100 meter reading
F-Fair, 15 to 39 meter reading
G-Good, 6 to 14 meter reading
E-Excellent, 0 to 5 meter reading

Meter readings are qualitative only

Soln. I. Butyl alcohol solution, 12 gm/l 2 HT"

Soln. II. Water solution, 6 gm/l

Soln. III. Water solution, 8% nitric acid + 0.5% nitrous acid

Soln. IV. Water solution, 2.5% Na_2CO_3, 2.5% tinc. green soap

Soln. V. Water solution, 2.5% NaOH, 2.5% tinc. green soap

TEST NO. 7

PRESSURE DROP MEASUREMENTS OF VARIOUS RESPIRATORS

Test Procedures:

1. The respirator to be tested was sealed in a simple air flow system and the pressure drop across the respirator at various air flows was measured by means of a water manometer.

   RESULTS: See Appendix Table VII

APPENDIX - TABLE VII

Respirator	Pressure Drop[1] - Cm. of Water					
Air Flows in Liters/Minute	0	6	8	14	26	43
[redacted]	0	0.18	0.32	0.48	0.90	2.70
	0	2.28	0.70	1.08	1.17	2.74
	0	0.42	0.58	0.76	0.96	2.46
	0	0.20	0.38	0.86	1.64	2.82
	0	0.32	0.52	1.12	1.39	3.66
	0	0.30	0.54	0.84	1.05	3.06

[1]It is to be noted that all of the filters did not contain "Hopcalite" (a compound of charcoal and oxides of several metals); that each filter did not necessarily contain the same quantity of filtering material; and that the geometry of the filters varied.

TEST NO. 8

TESTING OF VARIOUS PLASTIC MATERIALS FOR PERMEABILITY TO MERCURY VAPORS

Test Procedure:

1. The test sample was clamped in a glass manifold (see Appendix Figure 1), which consisted a 30 inch length of 2 inch I.D. glass pipe with side arms of 1 inch I.D. pipe, by means of a standard pipe flange connector.

2. The upper segment of each side arm was covered with a 35/40 S.T. cap, inside of which glass hooks permitted the hanging of palladium chloride test papers to indicate the passage of mercury through the specimen.

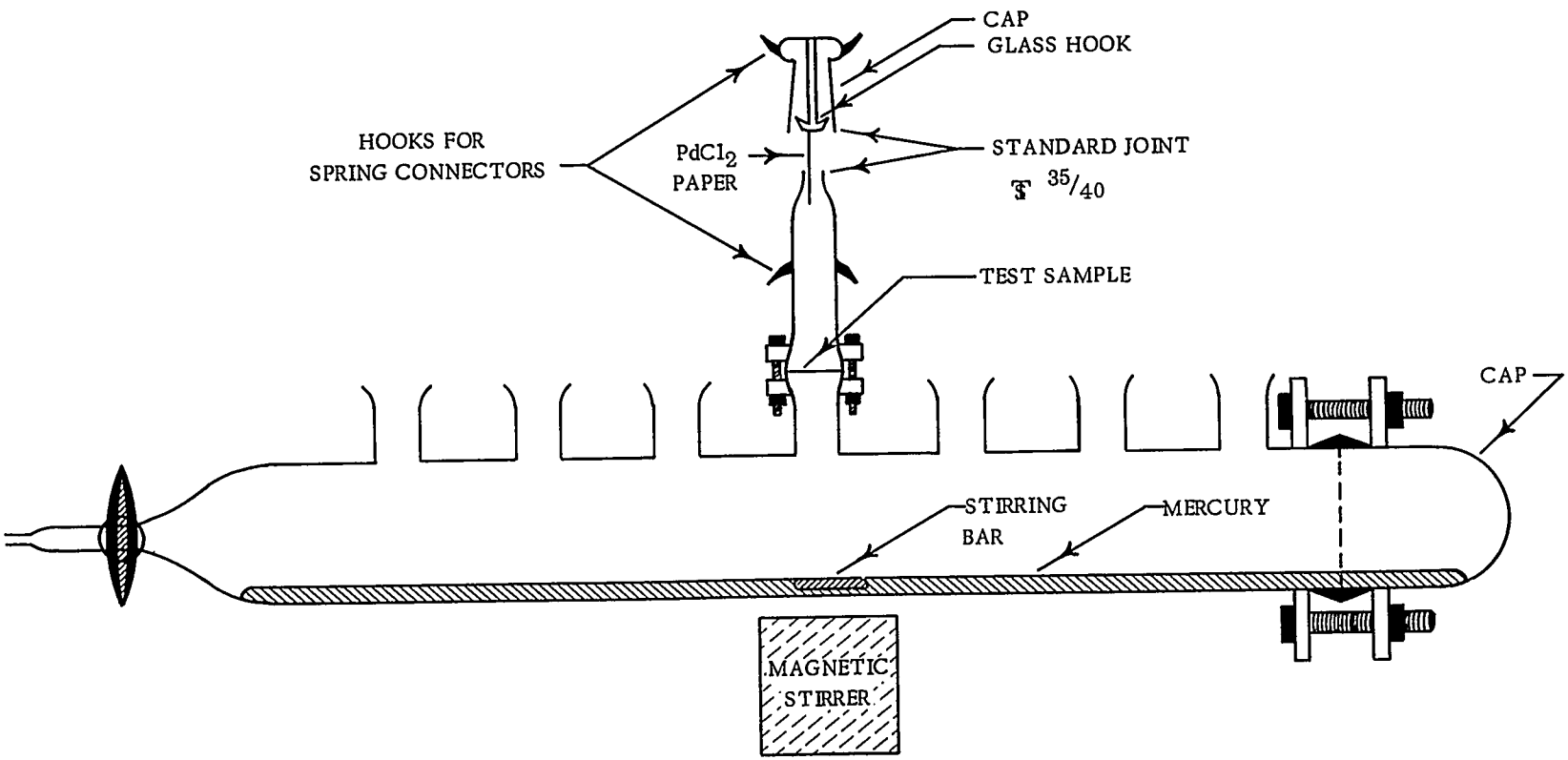
3. A mercury pool below the test specimen was agitated constantly at room temperature by means of a magnetic stirrer.

4. Daily checks were made for visual darkening of the test papers.

5. The sensitivity of $PdCl_2$ to mercury vapor was indicated by chemical analysis of exposed test papers. An unexposed paper, prepared by soaking a 5.5 cm. sheet of #50 Whatman filter paper in a 4% $PdCl_2$ solution followed by air drying, was found to contain 10 mg. of Pd. Analysis of mercury content of several such papers, after exposure for varying periods of time to air saturated with mercury vapor at room temperature, showed that detectable darkening occurred with < 0.1 mg. of total Hg and that 15 mg. of Hg was insufficient to cause total blackening.

6. Since slight darkening of the $PdCl_2$ was sometime difficult to detect with assurance, the exposed papers were developed with ammonia gas at the termination of a test. (This development destroyed the reddish-brown $PdCl_2$ color and gave a white background which permitted more precise determination of the darkening due to the mercury vapor.)

RESULTS: See Appendix Table VIII



Appendix B - Figure 1. MERCURY VAPOR PERMEABILITY TEST APPARATUS

APPENDIX - TABLE VIII

PERMEABILITY OF VARIOUS MATERIALS TO MERCURY VAPOR

Test Material	Thickness (mils)	No. of Layers	Days to Break-thru[1]	Remarks
Cellophane	1	1	46	Gift wrapping weight.
Filter Paper	Standard	1	1	Whatman #1, 40, 41, & 50.
Fluorothene	12	1	83[2]	Sample from K-25.
Kodapak	2	1	3	--
Kraft Paper	4	1	1	Ordinary wrapping.
Mylar A	2	1	69[2]	DuPont sample.
Mylar-Polyethylene (Laminate)	5	1	23[2]	1 mil mylar & 4 mil polyethylene.
Mylar-Polyethylene (Laminate)	4	1	23[2]	1 mil mylar & 3 mil polyethylene.
Polyethylene	7	1	3	Drum liner.
Polyethylene	40	1	24[2]	Cut from plastic bottle.
Rubber	4	1	1	Pure gum.
Rubber	16	1	.1	Cut from glove.
Saran	< 1	1	83[2]	Saran wrap from grocery.
Saran	1	1	69[2]	Saran wrap from grocery.
Saran	1	2	69[2]	Saran wrap from grocery.
Saran	2	1	69[2]	Special sample - Dow.
Saran	2	4	69[2]	Special sample - Dow.
Saran-Vinyl (Laminate)	6	1	23[2]	2 mil saran and 4 mil vinylite.
Teflon	6	1	83[2]	Sample from K-25.
Vinylite	8	1	3 to 6[3]	From Y-12 Stores.
Vinylite	8	2	7	From Y-12 Stores.
Vinylite	8	3	13	From Y-12 Stores.
Vinylite	20	2	14	From Y-12 Stores.
Waxed Paper	1	1	3	"Kitchen-Wrap" brand.

[1]Break-through taken as first darkening noted on $PdCl_2$ test papers.

[2]Test discontinued without detection of break-through.

[3]Four tests were made on 1 mil vinylite.

APPENDIX C

SPECIFICATION FOR RESPIRATORS FOR PROTECTION AGAINST METALLIC MERCURY VAPORS

1. Performance

Each respirator unit shall be capable of continuously removing a minimum of 99% of the metallic mercury vapor from air under the following conditions:

Mercury vapor concentration	-	1.0 mg/meter^3
Temperature	-	85° F
Relative Humidity	-	75%
Air Flow	-	15 liters per minute
Duration	-	150 hours

During such usage, the pressure drop across the element(s) shall not exceed 10.0 mm H_2O.

2. Materials of Construction

The respirator body shall be of black enameled steel or black anodized aluminum. The face piece cushion shall be of unicellular neoprene or other synthetic rubber having a low adsorptive capacity. Headbands shall be of low sulfur rubber (less than 2%) and shall be of the double strap design. Other parts may be made of metal, rubber or plastic with the following materials being acceptable:

Enameled Steel
Stainless Steel
Natural and Synthetic Rubber
Polyethylene
Polyvinyl Chloride
Cellulose Esters (excluding nitrate)

No copper, tin, lead, zinc or cadmium may be used. Brass snaps are permissible only if nickel plated to a plate thickness of 0.002" or greater.

3. Design

The respirator may be of single or twin cartridge design. It shall be of compact design so that it may be worn with eye and head coverings of any design. The gross weight shall not exceed eight (8) ounces.

Disassembly and re-assembly shall be easily accomplished without special tools so that each component may be adequately cleaned and sterilized. Crevices should be minimized. A natural draining exhalation valve shall be used.

APPENDIX D

USE AND DECONTAMINATION OF MERCURY VAPOR RESPIRATORS

A laboratory test was conducted on the "Mersorb" cartridge designed for use in the new MSA "Gasfoe" respirator. Air at about 77% relative humidity and containing approximately 1.9 mg of mercury vapor per cubic meter was passed through a cartridge at the rate of 100 liters per minute. After 192 hours, the exit concentration was up to about 0.02 mg/meter^3. This test indicates that such cartridges should be good for at least one month of normal usage, provided care is taken to keep liquid mercury from contact with the cartridge.

It is upon the basis of these results, the recommended maximum allowable concentration (MAC) and consideration for personal hygienic conditions that the following recommendations are being made after consultation with the Y-12 Industrial Hygienist, Mr. L. J. LaFrance:

A. Use of Respiratory Protective Equipment

1. Approved respiratory protective equipment for mercury vapor should be worn when it is known that the concentrations are in excess of the maximum allowable concentrations of 0.10 mg/m^3. This MAC is based on an 8-hour day - 5 days a week or for a 40-hour week.

2. Fresh air supplied respiratory protective equipment should be worn during all cutting, burning or welding operations on or around equipment that is contaminated with mercury.

3. Fresh air supplied respiratory protective equipment should be worn during repairs or alterations to process equipment such as columns, decomposers, tanks, etc., where the individual is working inside, or has his head inside, the equipment being worked upon.

4. Approved respiratory protective equipment should be worn by individuals involved in equipment change outs, such as pumps, circuit interrupters, etc., and during the maintenance of such equipment that requires an individuals' nose and mouth to be in close proximity to the equipment.

5. Approved respiratory protective equipment should be worn in all situations defined as emergencies, which involve major spills, leaks, etc., of mercury and mercury vapor.

B. Issuance and Decontamination of Respiratory Equipment

These matters may be handled in several different ways, but it is our present conclusion that the following may be more desirable than some of the alternate schemes:

1. Complete respirators should be issued to personnel on an individual basis. Each individual should then be made responsible for handling

and storing his respirator to prevent accumulation of liquid mercury, grease, dirt, etc., when not in use.

2. A new cannister should be provided for each man each month. In event of gross contamination, by liquid mercury, a new cannister should be provided immediately. This service should be provided by line supervision.

3. A bin system should be provided so that an individual may obtain a clean sterile respirator (less cannister) when he begins work on the day following his days off each week. The cannister should be retained and used with the clean face piece. He should also obtain a clean respirator at any other time his equipment becomes dirty or contaminated. Used respirators would be collected in containers and sent to a central cleaning station. This would provide for, at least, weekly cleaning of respirator bodies, facepieces and head bands.

4. All reusable respirator parts should be decontaminated and sterilized in a central station using the following procedure:

   a. Disassemble all respirator parts.

   b. Soak parts in an aqueous solution containing 2-1/2% Na_2CO_3 and either 2-1/2% soap or 0.1% Tergitol at 60° C for one hour.

   c. Scrub each respirator part in the above solution with a stiff brush to remove any foreign material.

   d. Rinse in boiling water and drain dry.

   e. Reassemble respirators (less cannister) and place each in a paper bag to maintain cleanliness.

APPENDIX E

TRADE NAMES AND MANUFACTURERS*

Amercoat (86-87) Trade mark of various paints
Amercoat Corporation
4909 Firestone Blvd.
So. Gate, Calif.

American Optical Co. Respirator
Americal Optical Co.
14 Mechanic St.
Southbridge, Mass.

Aquet - Trade mark for liquid laboratory detergent
Emil Greiner Co.
22 North Moore St.
New York, N. Y.

Arco Rubber - Source Unknown

Arquard - Trade mark for series of quaternary ammonium salts containing one or more alkyl groups ranging in chain lengths from C_8 to C_{11}.
Armour Chemical Div., Armour & Co.
1355 W. 31st Street
Chicago 9, Illinois

Bake-flex - Trade mark for varnish like floor finish
Flexrock Co.
Philadelphia, Pa.

Batco - Trade mark for series of greases
Battenfeld Grease & Oil Co.
32nd & Roanoke Road
Kansas City, Mo.

Calgonite - Trade name for an alkaline detergent composition containing "Calgon" as a principal ingredient
Calgon, Inc.
Hagan Bldg. 323 4th Ave.
Pittsburgh 30, Pa.

Cameron Plug Valve
Cameron Iron Works, Inc.
P. O. Box 1212
Houston, Texas

Carbitol - Trade mark for diethylene glycol monethyl ether
Union Carbide & Carbon Corp.
30 East 42nd St.
New York, N. Y.

Carbowax - Trade mark for polyethylene glycols and methoxypolyethylene glycols
Union Carbide and Carbon Corp.
30 East 42nd Street
New York 17, N. Y.

Cesco Respirator
Cesco Manufacturing Co.
1946 Miller St.
Homestead, Pa.

Clorox - Trade mark for a bleaching, deodorizing and disinfecting solution of sodium hypochlorite
Clorox Chemical Co.
850-60 42nd Avenue
Bakland, Calif.

Colorflex - Trade name - floor paint
Flexrock Co.
Philadelphia, Pa.

Comfo (Cushioned face piece respirator) trade mark for a cartridge type respirator
Mine Safety Appliance Co.
201 N. Braddock Avenue
Pittsburgh, Pa.

Conq-R-Dust - Trade mark for floor wax
S. C. Johnson & Son
Carnu Street
Racine, Wisconsin

Dresser Coupling
Dresser Manufacturing Div.
Dresser Industries, Inc.
313 Fisher Ave.
Bradfort, Pa.

Dynel - Proprietary name for copolymer of vinyl chloride and acrylonitrile, used as a textile fiber
Union Carbide & Carbon Corp.
30 East 42nd Street
New York 17, New York

Elvanol - Trade mark for a water soluble synthetic polyvinyl chloride
E. I. DuPont DeNemours & Co., Inc.
Wilmington 98, Delaware

Emulphor - Trade mark for a series of non ionic emulsifying agents & dispersants
General Aniline & Film Corp.
435 Hudson St.
New York 14, New York

Flintcrust - Trade mark for a concrete floor hardner
Flexrock Co.
Philadelphia, Pa.

Florseal - Trade mark for series of floor sealers
Yarnall Paint Co.
5541 Gray Avenue
Philadelphia, Pa.

Gaco - (N-700, N-100-1) - Trade mark for various paints
Gates Engineering Co.
Wilmington, Delaware

Gasfoe - Trade mark for a chemical cartridge respirator
Mine Safety Appliances Co.
230 North Braddock Ave.
Pittsburgh, Pa.

G. E. Mercury Vapor Detector
General Electric Co.
Schenectady 5, New York

Glid-iron - Trade mark for a new chemical resistant paint
The Glidden Company
1099 Madison Ave.
Cleveland, Ohio

Gunk - Trade mark for a line of alkyl phenolic amine soap base emulsifiers of vegetable origin. They are soluble in water and oils and form stable oil and water emulsions. Self emulsifying solvent concentrate.
The Curan Corp.
100 South Canal St.
Lawrence, Mass.

Hard Gloss - Trade mark - commercial floor sealer
S. C. Johnson & Son
Carnu Street
Racine, Wisconsin

HgX - Trade mark for chemical compound used to cover mercury contaminated surfaces to suppress mercury vapor
William M. Stieh & Co., Inc.
20 Vesey St.
New York, N. Y.

Hyamine - Trade mark for a series of quaternary ammonium salts supplied in both crystal and solution form
Rohm & Haas Co.
Washington Square
Philadelphia, Pa.

Hycar - Trade name for various types of synthetic rubber
B. F. Goodrich Chemical Co.
Div. of B. F. Goodrich Co.
Rose Bldg. 2060 E. 9th Street
Cleveland 15, Ohio

Kinney Pump - A gear pump used for transporting the aqueous phase in the 9201-5 building
Kinney Manufacturing Co.
Boston, Mass.

Kodapak - Trade mark for a cellulose acetate sheet material
Eastman Kodak Co.
T. R. Building
Rochester, New York

Mersorb - Trade mark for a respirator cartridge used for protection against mercury vapor
Mine Safety Appliances Co.
201 N. Braddock Ave.
Pittsburgh, Pa.

Moist Bond Enamel - Trade mark for a heavy duty enamel for floor covering

Mosite Rubber - Source unknown

Moyno Pump - A progressing cavity type pump used in the Colex Plants for transporting amalgam, also, used in the 9201-4 building for transporting the aqueous phase
Moyno Pump Division
Robbins & Myers, Inc.
Springfield, Illinois

Mylar - Trade mark for a highly durable, transparent, water repellent film of polyethylene terephthalate resin
E. I. DuPont DeNemours & Co., Inc.
Wilmington 98, Delaware

Nacconol - Trade name for a series of alkyl aryl sodium sulfonates possessing wetting, scouring, emulsifying & dispersing properties
National Aniline Div.
Allied Chemical & Dye Corp.
40 Rector St.
New York 6, New York

Onex Seal - Trade mark of a floor sealer
Hillgard Sales Co.
290 Robidoux St.
St. Joseph, Mo.

Pliogard - (A1180, Regular) - Trade mark for various paints
Saran Protective Coating Co.
Ferndale, Michigan

Pluronics - Trade mark for a series of non-ionic surface active agents prepared by the addition of ethylene oxide to polypropylene glycols
Wyandotte Chemicals Corp.
Alkali Square
Wyandotte, Michigan

Puritan Wax - Trade mark for a floor wax
Puritan Chemical Co.
926 Ashly Street N. W.
Atlanta, Ga.

Sellstrom Respirator
Sellstrom Mfg. Co.
257 Hicks Road
Palatine, Illinois

Shur Tred - Trade mark - commercial floor sealer
S. C. Johnson & Son
Carnu St.
Racine, Wisconsin

Terra New - Trade mark - commercial floor sealer
S. C. Johnson & Son
Carnu St.
Racine, Wisconsin

Teflon - Trade mark for tetrafluoroethylene resins
E. I. DuPont DeNemours & Co., Inc.
Wilmington 98, Delaware

Tergitol - Trade mark for a group of surface active agents
Union Carbide & Carbon Corp.
30 East 42nd St.
New York 17, New York

Tide - Trade mark for a soap like detergent
Proctor & Gamble Co.
Industrial Sales Dept.
T-R Gwynne Bldg.
Cincinnati, Ohio

Triton - Trade mark for a line of synthetic organic surface active dispersion agents, detergents, and emulsifiers
Rohm & Haas Co.
Washington Square
Philadelphia 5, Pa.

Tufcote - Trade mark for a heavy duty enamel recommended for use as a sealer
E. I. DuPont DeNemours & Co.
Wilmington, Delaware

[redacted]

Ultrawets - Trade name for alkyl aryl sulfonate anionic detergent or surface active materials (dodecyl benzene cyclic type)
The Atlantic Refining Co.
260 S. Broad St.
Philadelphia 1, Pa.

Victaulic Coupling
Victaulic Co. of America
50 West 50th St.
New York, New York

Vinylite - Trade mark for a series of synthetic thermoplastic resins and plastic
Union Carbide & Carbon Corp.
30 E. 42nd Street
New York 17, New York

Vinyon - Trade mark for synthetic textile fibers and thermoplastic resins used for the manufacture of textile products
Union Carbide & Carbon Corp.
30 East 42nd Street
New York 17, New York

Vyniflex - Trade mark for floor sealer
Flexrock Co.
Philadelphia, Pa.

Wilson Respirator
Wilson Products, Inc.
249 Washington St.
Reading, Pa.

* Whenever possible, the definitions appearing in this section were adapted from -

The Condensed Chemical Dictionary
5th Edition
Reinhold Publishing Corporation
New York
1956

[redacted]

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OAK RIDGE Y-12 PLANT INFORMATION CONTROL FORM

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OAK RIDGE, TENNESSEE 37830

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October 15, 1971

Code: H13
J. M. CASE FILES

Union Carbide Corporation
Nuclear Division
ATTN: Mr. J. M. Case
P. O. Box Y
Oak Ridge, Tennessee 37830

PARTICIPATION IN ENGINEERING FOUNDATION CONFERENCE

Gentlemen:

Reference is made to your letter dated October 7, 1971, concerning the above subject.

This is to advise that we concur in your proposal to have Mr. H. T. Kite attend the subject conference to present an unclassified paper on Control of Mercury Vapor. In preparing the paper, consideration should be given to questions that may arise with regard to releases of mercury to the atmosphere and methods of controlling such releases.

Please advise if we can be of further assistance to you in this matter.

Sincerely,

Russell E. Lee
for Charles A. Keller
Director
Production Division

OPW:HDH

CC: Mr. P. R. Vanstrum

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UNION CARBIDE CORPORATION
NUCLEAR DIVISION
P. O. BOX Y, OAK RIDGE, TENNESSEE 37830

October 7, 1971

U. S. Atomic Energy Commission
Post Office Box E
Oak Ridge, Tennessee 37830

Attention: Mr. C. A. Keller

Gentlemen:

The Y-12 Plant has been asked to send a representative to the January, 1972 Engineering Foundation Conference on "Mercury in the Industrial Environment". Copies of the tentative agenda and a letter from Dr. W. E. Clark, of the Oak Ridge National Laboratory, concerning this conference are attached.

The Y-12 Plant proposes to send Mr. H. T. Kite to this meeting to present information obtained by Y-12 Plant personnel on the subject of atmospheric mercury control. The majority of the information to be presented would be derived from the Confidential Report Y-1185, entitled "Control of Mercury Vapor in [Plant] Operations", by J. E. Perry and J. M. Napier (issued February 17, 1958). A paper for presentation at the conference would be prepared by Messrs. Kite and Napier utilizing only those portions of Report Y-1185 which are unclassified. No discussion of production processes would be included. Subject matter to be discussed in the paper and in the talk at the conference would be concerned with the following:

Prevention of Surface Contamination

Detection of Mercury Vapor

Protection of Personnel - Respirators and Clothing

Ventilation

Surface Coatings to Facilitate Clean Up

Vapor-Suppressing Agents

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Author(s) C. S. McMURRAY AND J. W. REDMOND

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Mary J. Frank 3/8/96
Signature Date
Y12 CO Classification Analyst

DOCUMENT REQUEST APPROVED (Division or Department)

[signature] 3/4/96
Signature Date

Signature Date

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Y-1188
Instruments

3-58 R.C. Olson
6-61 Plant Records
5-72 H. Kite
8-72 ORNL Lab Records

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PORTABLE MERCURY VAPOR DETECTOR

C. S. McMurray
J. W. Redmond

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Y-12 Plant
UNION CARBIDE NUCLEAR COMPANY
DIVISION OF UNION CARBIDE CORPORATION
Oak Ridge, Tennessee

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DIVISION OF UNION CARBIDE CORPORATION
Y-12 PLANT
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PORTABLE MERCURY VAPOR DETECTOR

C. S. McMurray
J. W. Redmond

Oak Ridge, Tennessee

Date of Preparation: January 7, 1958

(Y-1188 draft version 9-2-57)

Report Number Y-1188

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This report is distributed in accordance with the category, Instruments, as given in the "Standard Distribution Lists for Unclassified Research and Development Reports," TID-4500 (13th Ed., Suppl.), August 15, 1957.

ABSTRACT

This report describes a functional mercury vapor detector which is a portable, self-contained, survey instrument, and had a minimum range from zero to two-tenths milligram of mercury per cubic meter of air.

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SUMMARY

This instrument provides a more convenient mercury vapor survey meter than is commercially available. Operation is not hampered by external power requirements. It may be easily carried and operated by one person. The use of this meter has reduced survey cost by approximately sixty per cent.

INTRODUCTION

The equipment employed at this installation to determine mercury vapor concentrations has been a commercial instrument. Significant delay and inconvenience were experienced due to the external power requirements. Long extension cords were employed to minimize the number of warm-up periods after power interruption, but these were cumbersome, and consequently the surveys required two persons to operate one instrument. Since no improved commercial instruments were available, design of a self-contained portable mercury vapor detector was pursued (see Figure 1).

The ultraviolet absorption measuring technique was accepted as the only practical detection principle. Provisions for high sensitivity, stability, and sampling method presented the greatest design challenges.

Tests were not fruitful with photomultipliers as ultraviolet radiation detectors because of stability requirements and power demands; consequently, the more conventional phototubes were selected. The sampling problem was resolved with a specially designed direct current centrifugal blower. The design incorporates special techniques for minimizing the effects of external electromagnetic fields.

A self-contained instrument evolved which has replaced the commercial models in all survey work. It is battery-operated, weighs eighteen pounds, and occupies three-tenths of a cubic foot. A minimum range of two-tenths milligram of mercury per cubic meter of air has been attained.

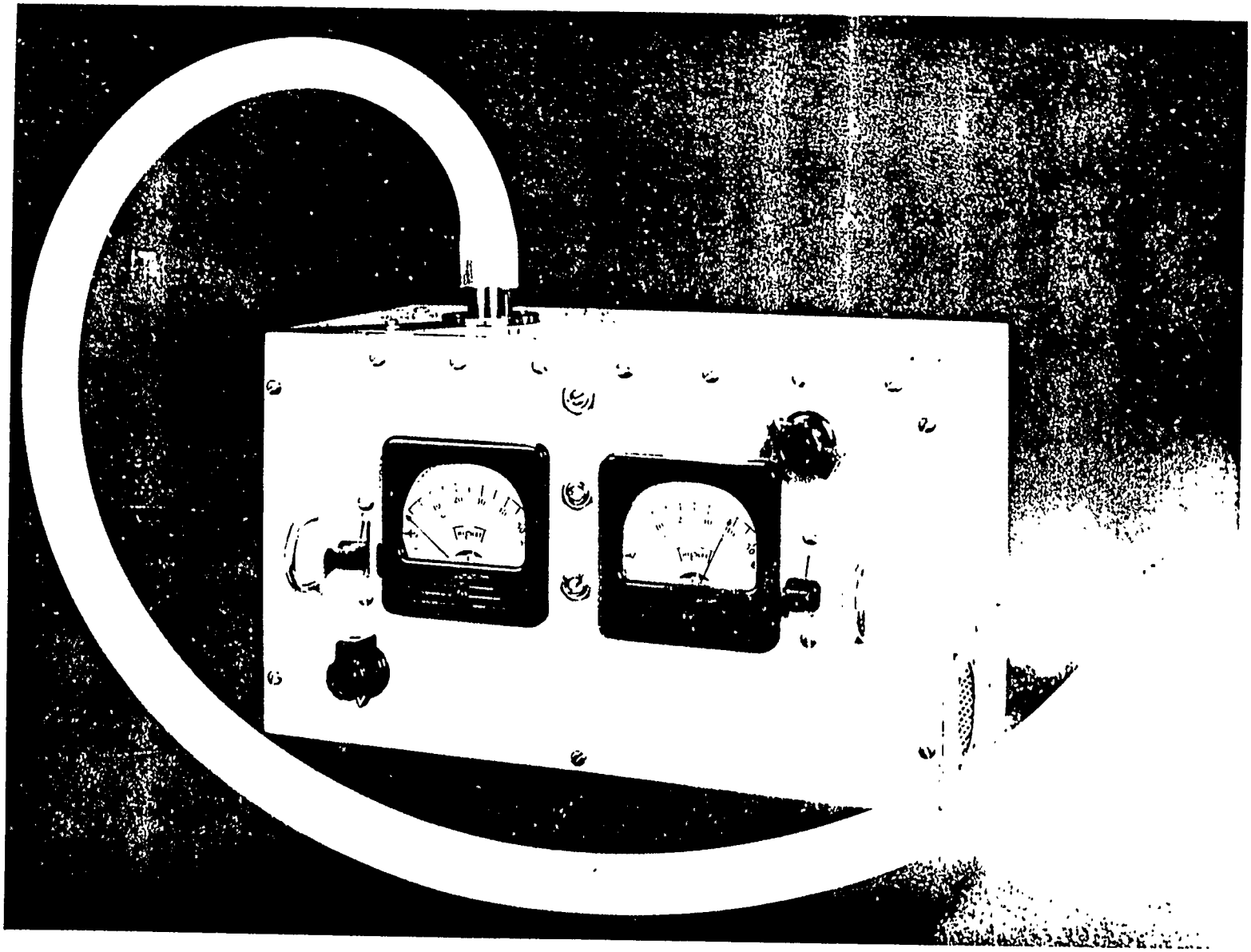


FIGURE 1. PORTABLE MERCURY VAPOR DETECTOR

ULTRAVIOLET ABSORPTION CELL

Mercury vapor concentrations are usually measured with an ultraviolet absorption cell, since mercury has a predominant spectral resonance at a wavelength of 2536.5 angstroms. When mercury vapor is passed between a light source of 2536.5 angstroms (a mercury discharge lamp) and an ultraviolet sensitive phototube, a portion of the ultraviolet light is absorbed, decreasing the light intensity reaching the phototube. Therefore, the output of the ultraviolet sensitive phototube is dependent upon the concentration of mercury vapor present in the cell.

The detection system utilizes two phototubes as shown in Figure 2. One Type 934 is used as a reference which responds only to light in the visible spectrum, and the other is a Type 935 which responds to light in both the visible and ultraviolet regions. The latter is referred to as the signal phototube.

With no mercury vapor present in the absorption cell, the output voltages of the reference and signal phototubes are balanced such that their voltage difference is zero. Introduction of mercury vapor into the system decreases the ultraviolet radiation reaching the signal phototube, thereby causing a reduction in output voltage. Since the reference phototube is unaffected by the presence of mercury vapor, its output voltage remains the same. The difference in voltage developed between the two phototubes is therefore a function of mercury vapor concentration. A subminiature vacuum tube voltmeter is used to measure and display this voltage difference. A mercury vapor generator is used to calibrate the instrument.

ULTRAVIOLET LIGHT SOURCE

A mercury discharge lamp is employed as the source of ultraviolet radiation, since 80% of the radiant energy is at the desired wavelength of 2536.5 angstroms. The majority of the remaining radiation is in the low end of the visible spectrum. A major problem encountered was the selection of a low power consumption lamp. Several types were tested, using a battery and vibrator type power sources. The latter method was rejected due to instability.

A Type B-H6 lamp was the most suitable, since excitation could be obtained with a minimum current drain. An operating current of 0.75 milliampere provided an adequate light intensity. The main difficulty encountered in operation of the lamp at this subnormal current is the effect of temperature on the intensity, and a slight change in the ratio of ultraviolet to visible emission. This effect was reduced by sealing the lamp within a quartz tube which utilizes the trapped air as a thermal insulating medium. Although this increased the instrument warm-up time, it reduced the zero shift due to changes in ambient temperature.

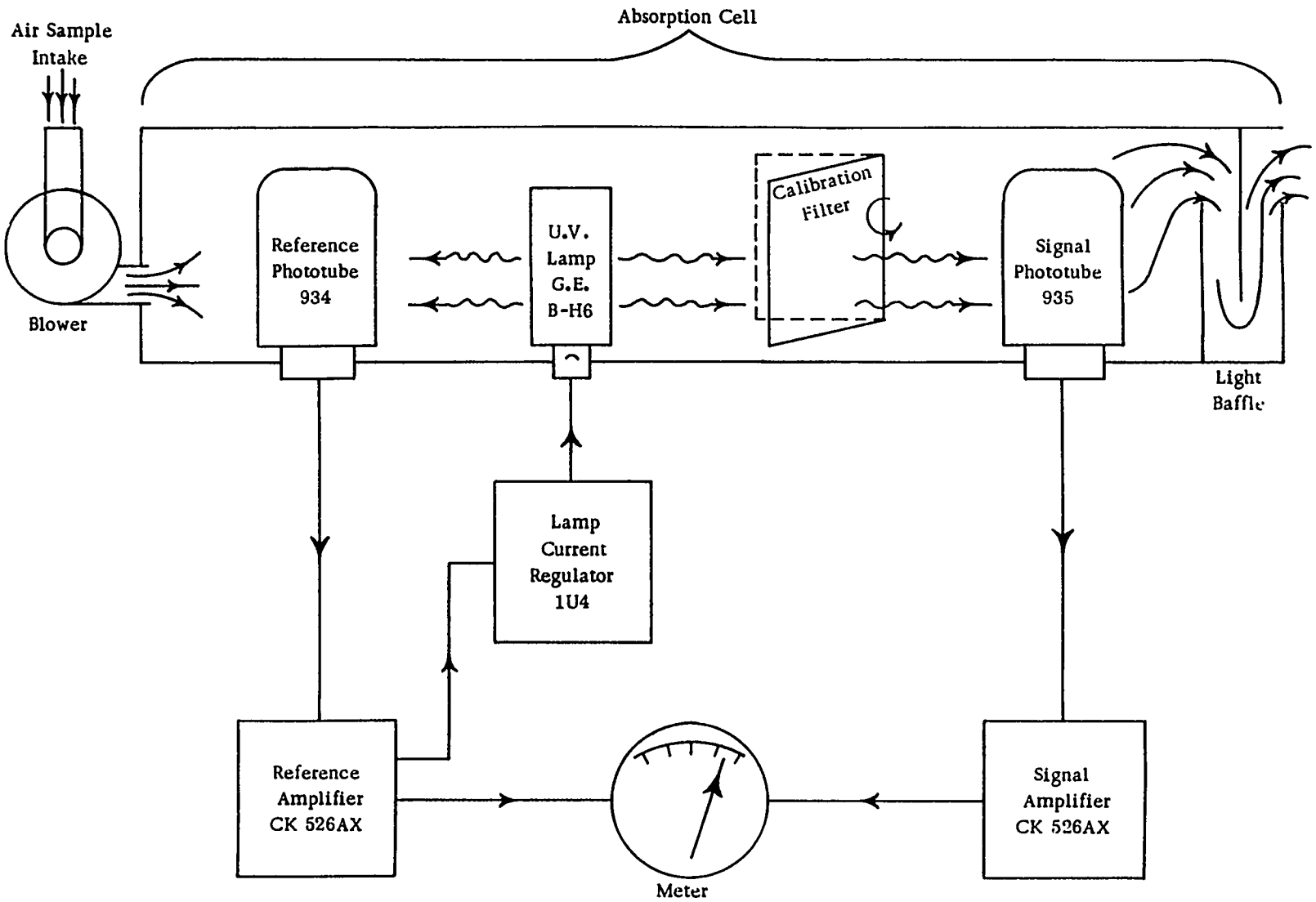


FIGURE 2. PORTABLE MERCURY VAPOR DETECTOR FUNCTION DIAGRAM

A minimum potential of 925 volts is required to excite the lamp, and is supplied by four 300-volt dry cells. The voltage across the lamp decreases to 215 volts after ignition. The remainder of the supply voltage is dissipated through current limiting resistors, and a series lamp current regulator. The latter (tube Type 1U4) is controlled by the output voltage of the reference amplifier, and provides stabilization of the lamp intensity (see Figures 2 and 3).

DIFFERENTIAL METERING CIRCUIT

The metering circuit employs two Type CK526AX subminiature tubes to amplify the outputs of the reference and signal phototubes. Both amplifier tubes are housed in a magnetic shield. Sufficient power is developed to operate a 20 microampere meter which indicates the difference between the two phototube signals. Calibration of the instrument is accomplished by adjusting the meter sensitivity.

The CK526AX amplifier tubes were selected from five types tested. These are superior from the standpoint of low filament and plate power requirements, ability to withstand mechanical shock without shift in response, and long time stability. With most subminiature tubes, the transconductance varies 40 to 50%. The tubes must be matched within 10% for satisfactory operation, since the amplifiers are used in a balanced arrangement. A slight mismatch can be compensated for by adjustment of the amplifier balance potentiometer in the plate circuit (see Figure 3).

SAMPLE BLOWER

Air to be measured for mercury vapor content is introduced into a three foot section of 3/4 inch ID neoprene tubing attached to the instrument. A low-power, battery-operated centrifugal blower transports the sample through the absorption cell at the rate of one half cubic foot per minute. Sampling time is five seconds; flushing time is ten seconds. A six-volt dry cell is used to operate the blower, which draws one quarter ampere of current. The blower is operated only during sampling.

BATTERY MONITOR

A front panel meter indicates battery condition during operation. It also provides a measure of current through the ultraviolet lamp. Battery operating cost is approximately twenty-four cents per hour. Information pertaining to the battery pack is provided in Table I.

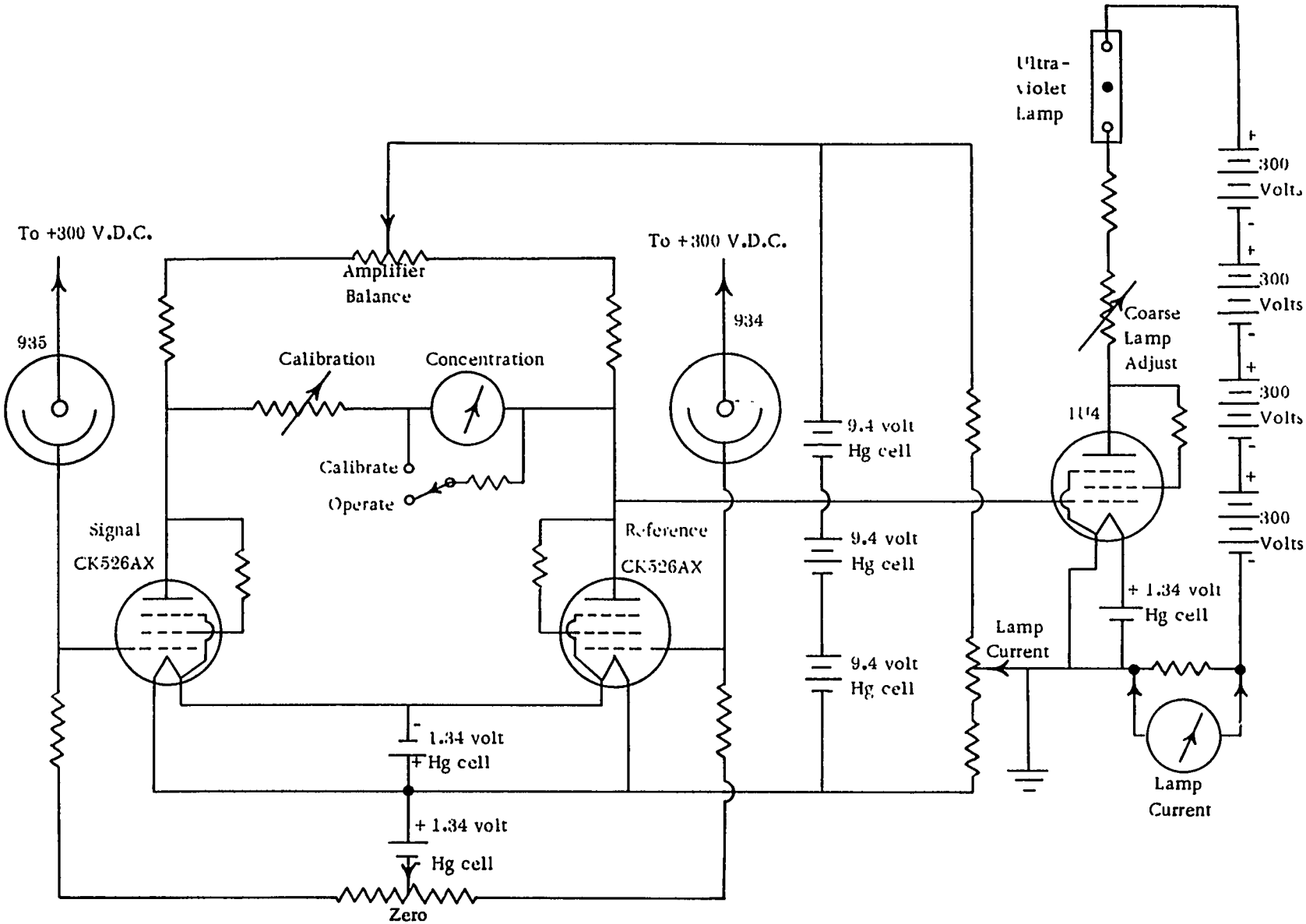


FIGURE 3. PORTABLE MERCURY VAPOR DETECTOR SIMPLIFIED SCHEMATIC DIAGRAM

TABLE I

BATTERY INFORMATION

Type	Quantity	Life (hrs)		Approximate Cost
1.3 Volt Mercury Cell	5	125		$ 2.80
9.4 Volt Mercury Cell	3	125		4.17
300 Volt Dry Cell	4	125		20.24
6 Volt Dry Cell	1	24[1]		0.56
			TOTAL	$27.77

[1]This battery is used intermittently to power blower motor.

CALIBRATION

The instrument is calibrated with a mercury vapor generator. A typical response curve is shown in Figure 4.

Field calibration is obtained by checking the instrument at two points on the response curve. The instrument is adjusted for zero response with no mercury vapor present. (If the atmosphere is not free of mercury vapor a Hopcalite filter is attached to the sample hose.) The second point, full scale, is provided by employing the absorption characteristic of pyrex glass. A filter of this sort is inserted between lamp and signal detector to produce an output equivalent to 3.5 milligrams of mercury per cubic meter of air. The meter is shunted simultaneously with the insertion of the filter so that a direct correlation with operating sensitivity is provided.

SUMMARY OF FIELD OPERATION

The portable mercury vapor detector has been in daily service for six months, each having over 500 hours of operation. Only one malfunction has occurred, i.e., redistribution of mercury droplets in the mercury lamp.

A warm-up period of twenty minutes is required to minimize drift. After this period, the drift is less than one and a half meter divisions per hour. The instrument requires minor zero adjustment with shift in ambient temperature, however field calibration adjustments are made in less than two minutes.

Instrument reproducibility at any mercury vapor concentration is one meter division (2% of full scale).

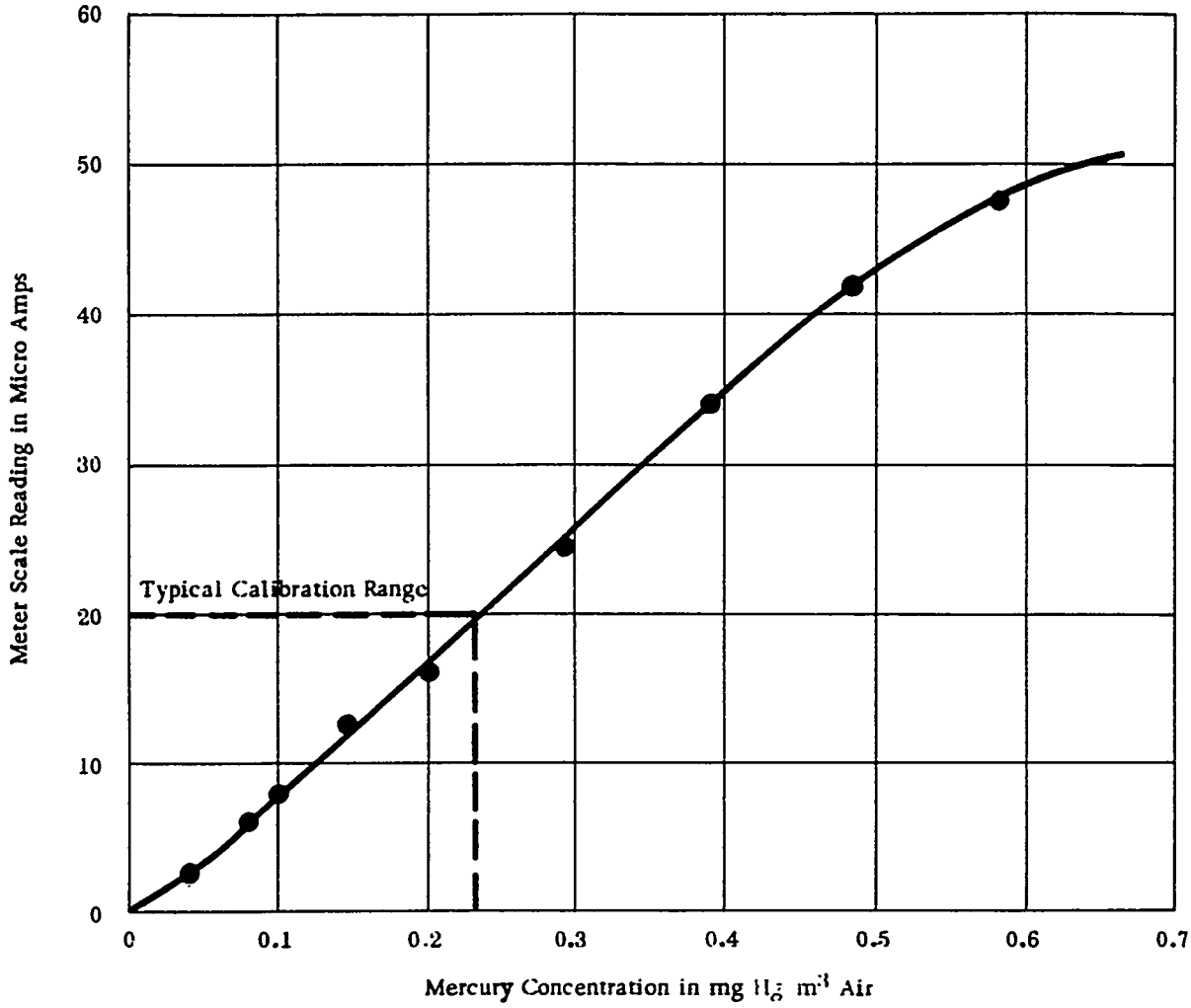


FIGURE 4. PORTABLE MERCURY VAPOR DETECTOR RESPONSE CURVE

APPENDIX A

OPERATING PROCEDURE

OPERATING PROCEDURE

1. Turn the instrument power on and check batteries by rotating meter selector switch through each position. Meter indication above the red line indicates a serviceable battery condition. The blower battery condition can be checked only with the blower switch turned on. The lamp current is adjusted after a twenty minute warm-up period.

2. Set the calibrate-operate control to the OPERATE position and turn the BLOWER on.

3. Set the meter selector switch to the LAMP position and adjust the LAMP CURRENT control such that the meter indicator is at the red line. If sufficient lamp current cannot be obtained by adjustment of the front panel LAMP CURRENT control, increase the lamp current by clockwise rotation of the COARSE LAMP CURRENT control located in the battery compartment. Insufficient lamp current with the coarse adjustment fully clockwise indicates the need for lamp battery replacement.

4. Adjust the ZERO control to zero the VAPOR meter. This must be done in a mercury vapor free atmosphere. Use a Hopcalite filter over the end of the sample hose if necessary.

5. Set the calibrate-operate control to the CALIBRATE position and adjust the CALIBRATE control for a full scale reading on the VAPOR meter.

6. Set the calibrate-operate control to OPERATE and recheck the zero as in Step 4, and readjust if necessary.

7. Set the calibrate-operate control to OPERATE. The instrument is ready for operation. The blower should be turned off when not needed, in order to conserve its battery.

APPENDIX B

MAINTENANCE

MAINTENANCE INFORMATION

SECTION I - CIRCUIT FUNCTIONS

1. General Information - Mercury has the property of absorbing ultraviolet radiation; the concentration of mercury vapor determines the amount of absorption. The portable mercury vapor detector utilizes an ultraviolet lamp and phototubes with their associated amplifiers as the means of measuring this absorption. The instrument is checked and calibrated in the field by artificially introducing absorption with a pyrex filter.

   Provisions for monitoring the lamp current and pertinent battery supply voltages are included. Air to be sampled is moved through the instrument by means of a battery operated blower.

2. Ultraviolet Lamp Circuit - A B-H6 mercury lamp is the source of ultraviolet radiation (80% ultraviolet - 20% visible). The lamp intensity is controlled by a reference phototube (Type 934) and a 1U4 series current regulator. A potentiometer in series with the lamp is incorporated as a coarse lamp current control. A fine adjustment of the current is accomplished by adjustment of the signal level to the 1U4 regulator.

3. Phototube and Amplifier Circuits - Two phototubes and their amplifiers constitute a balanced measuring circuit. The signal phototube (Type 935) is sensitive to both visible and ultraviolet radiation, whereas the reference phototube (Type 935) is only sensitive to visible radiation. With normal lamp current and no mercury vapor present the signals from the two phototubes are balanced by means of the zero control to produce a zero reading on the vapor meter connected between the outputs of the two amplifiers. In the balanced condition the signals from the phototubes must be between +0.8 and +1.1 volts (as measured with a vacuum tube voltmeter from the negative terminal of the bias battery to either phototube cathodes).

   The two amplifiers utilize Type CK 526AX subminiature tubes, which are pre-aged for 24 hours and matched within 10%. The amplifiers are balanced with a potentiometer in the plate circuit (with the two phototube cathodes connected together).

   The amplifier voltage supply is referenced to ground through a resistor and potentiometer (LAMP CURRENT control). This provides the 1U4 lamp current regulator with the proper signal level from the plate of the reference phototube amplifier.

4. Vapor Calibration Circuit - The measurement range is variable by shunting the meter with the "RANGE" potentiometer. This shunt is connected across the meter in the CALIBRATE position of the OPERATE - CALIBRATE control with a micro switch actuated by the pyrex filter. Calibration is accomplished with the CALIBRATE potentiometer in series with the meter.

SECTION II - PREVENTIVE MAINTENANCE (Monthly)

CAUTION: A 1200 volt battery supply is utilized in this instrument; remove the four 300 volt batteries before working inside the instrument.

1. Clean lamp, phototubes, and calibration filter with brush or soft cloth. Dirt or finger prints on these components attenuate ultraviolet transmission.

2. Check batteries. See Section III, Paragraph 1.

3. Check amplifier balance. See Section III, Paragraph 2.

4. Check for proper instrument operation as described in the operating procedure.

SECTION III - TROUBLESHOOTING

Do not replace tubes unless proved faulty by localization of trouble by logical deduction, or voltage and resistance measurements. A new calibration curve should be determined by means of a mercury vapor generator if the tubes are changed, or after adjustment of the vapor range control (located in battery compartment).

Refer to Portable Mercury Vapor Detector Schematic Diagram, Union Carbide Nuclear Co. Drawing No. C-E-20984 for circuit details.

All voltage measurements should be made with a vacuum tube voltmeter, with the common connected to the negative terminal of the battery supply of the circuit being tested.

1. Batteries - Batteries are checked with the selector switch and BATTERY meter on the instrument. Change any battery that produces a reading less than 35 microamperes (as indicated by the red line).

2. Amplifier Balance - In operate condition jumper tube 934 pin 3 to tube 935 pin 8. Observe VAPOR meter and adjust balance potentiometer for zero reading. If a balance cannot be obtained, check amplifier tubes and circuitry.

3. Low-Lamp Current - With controls in operating position and the meter selector switch in the lamp current position, adjust LAMP CURRENT control to the mid-position and increase with coarse control in battery compartment to set indicator on red line. Replace batteries if necessary.

4. No Lamp Current - Check batteries if necessary.

5. Zero Erratic or Insufficient Adjustment - Check lamp for broken column of mercury within lamp or unequal distribution of mercury in ends of lamp. Check amplifier balance. Either phototube may be weak, which can be checked by replacement and observed by change in position of zero control for zero vapor meter reading.

6. Normal Voltage and Current Values

a. Phototubes (cathode to neg. terminal of bias battery)

	OPERATE (Balanced)	CALIBRATE
934	0.8 to 1.1 volts	Same as Operate Voltage
935	0.8 to 1.1 volts	0.15 to 0.35 volt

b. Amplifier (plate to cathode or neg. terminal of filament battery) measured with calibrate potentiometer fully counter-clockwise and amplifier balanced).

	OPERATE	CALIBRATE
934 Amplifier	16 to 19 volts	Same as Operate
935 Amplifier	16 to 19 volts	1.2 volt higher

Amplifier (plate to ground under balanced condition) 0 to -3 volts.

c. Lamp (with lamp current adjusted to red line on meter)

Voltage drop across lamp - 225 volts
Current through lamp - 0.75 to 1.0 ma

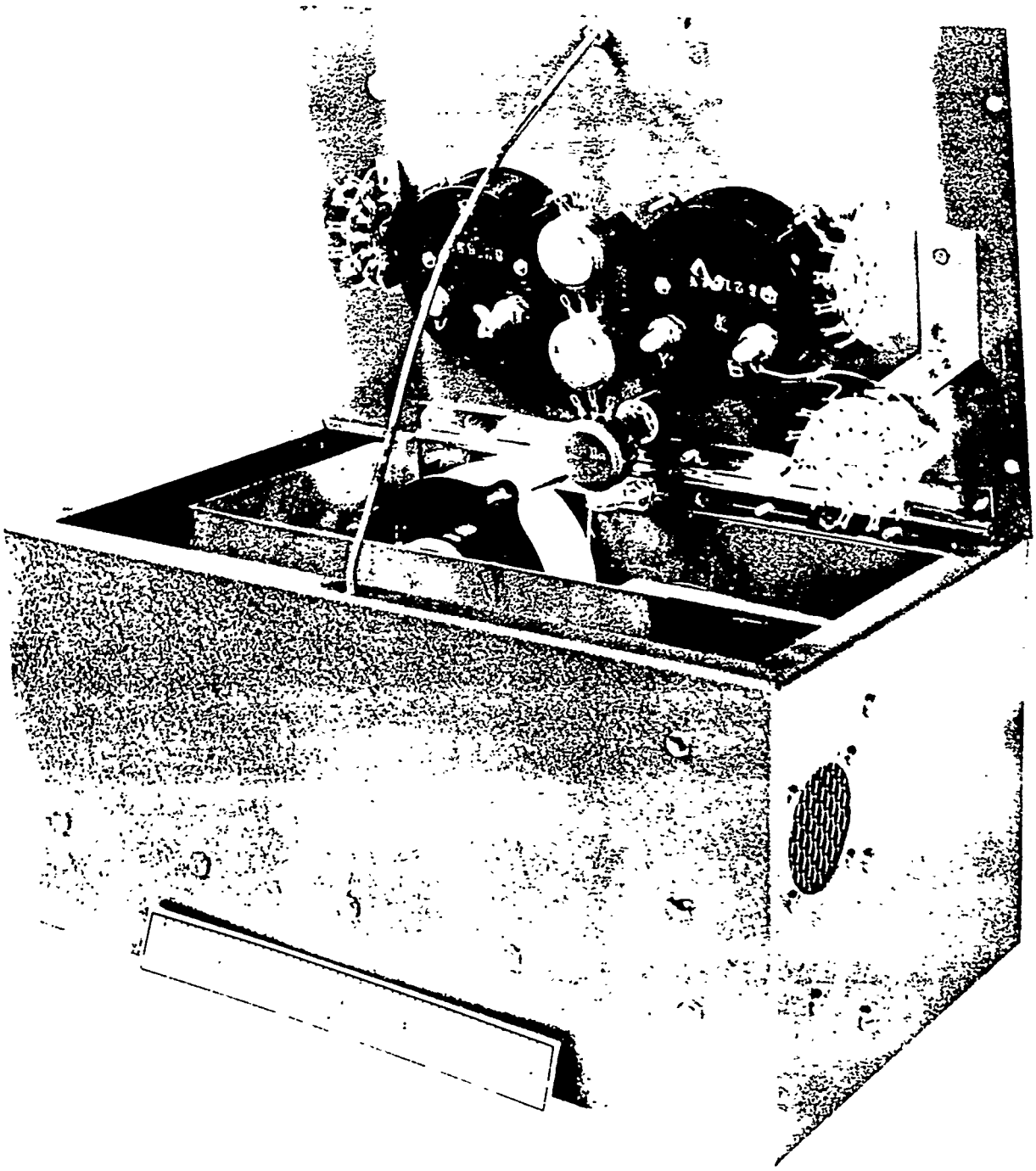
d. Lamp Regulator Tube (1U4)

Voltage (plate to ground with normal current through lamp) - 20 to 150 volts variable by means of LAMP CURRENT control.

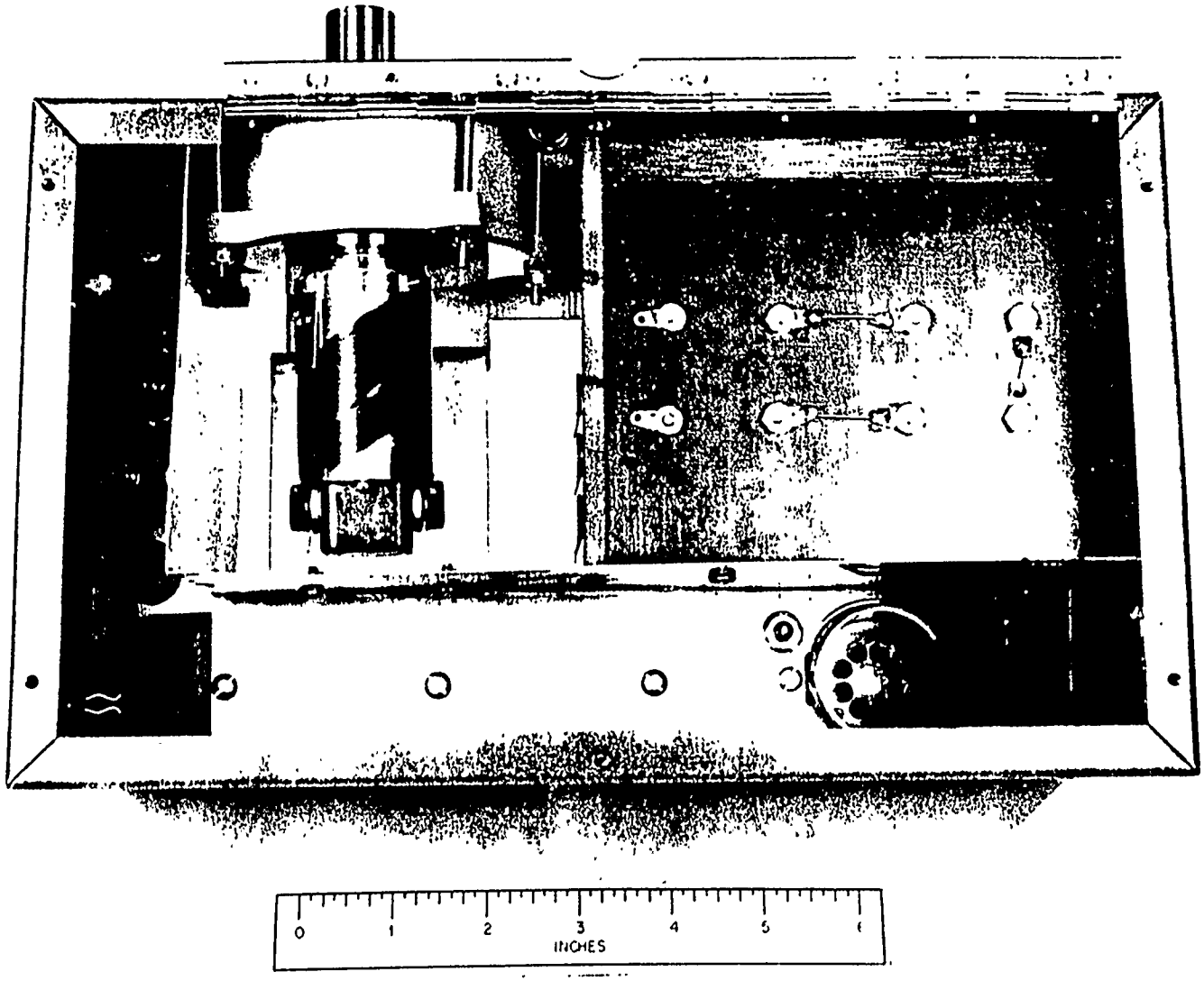
APPENDIX C

ENGINEERING DRAWINGS

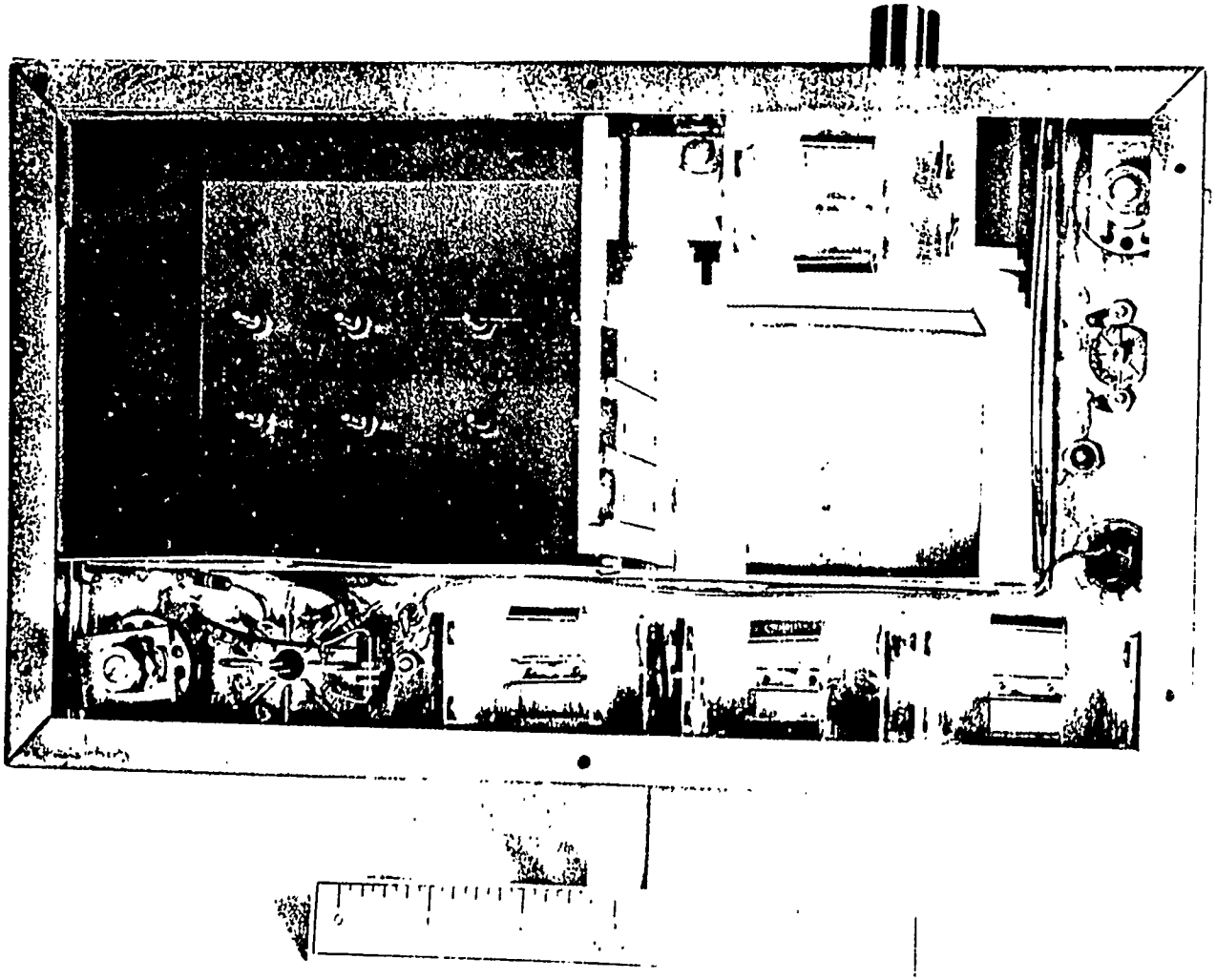
PHOTOGRAPHS (ASSEMBLY)



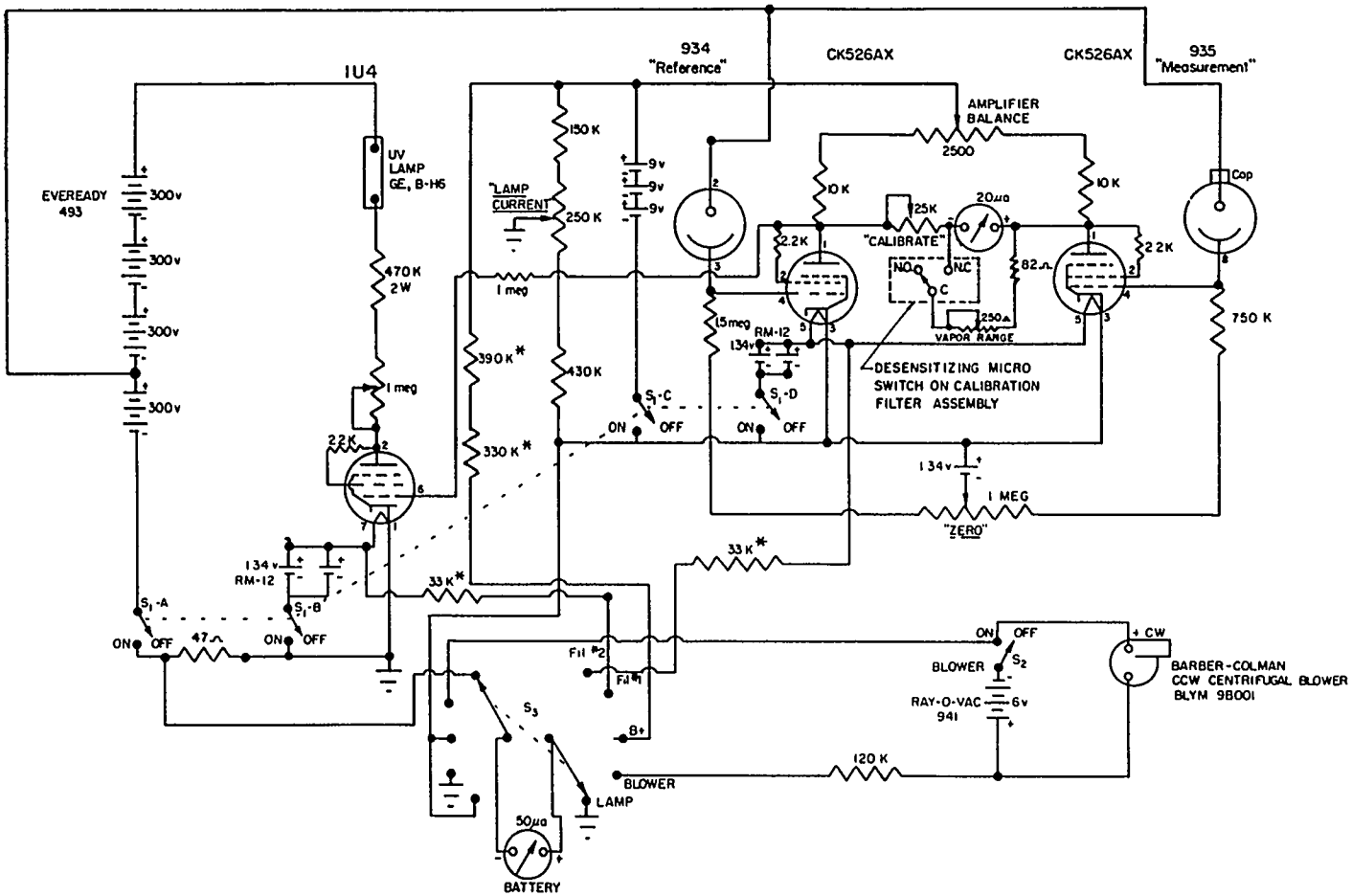
APPENDIX C - FIGURE 1. PORTABLE MERCURY VAPOR DETECTOR INSTRUMENT PANEL - REAR VIEW



APPENDIX C - FIGURE 2. PORTABLE MERCURY VAPOR DETECTOR ABSORPTION CELL AND BATTERY COMPARTMENT - TOP VIEW



APPENDIX C - FIGURE 3. PORTABLE MERCURY VAPOR DETECTOR BATTERY COMPARTMENT - BOTTOM VIEW



NOTE 1. S_1 - Power On-Off 4P2T Lever Action
S_2 - Blower On-Off 4P2T Lever Action
S_3 - Meter Selector Switch 2 Pole 5 Position Rotary

Drawing Number C-E-20984

NOTE 2. All Resistors $^1/_2$ W Unless Otherwise Indicated

NOTE 3. Resistors Noted by Asterisk (*) are Selected from 10% Tolerance Stock for Valves that Produce 40 ± 1 amp. Reading on Battery Monitor with new Batteries.

APPENDIX C - FIGURE 4. PORTABLE MERCURY VAPOR DETECTOR - SCHEMATIC DIAGRAM

+ drawing through p. 45

7/8024

DOCUMENT DESCRIPTION (Completed By Requesting Division)

Document No	Author's Telephone No	Acct. No.	Date of Request
Y/TS-1563	6-0263	23366-0002	7/23/96

Unclassified Title: MISCELLANEOUS INTERNAL CORRESPONDENCE 1953/1954 (Box # 18-10-2) Hg vapor meter development

Author(s) Requested by Steve Wiley

TYPE. ☐ Formal Report ☐ Informal Report ☐ Progress/Status Report ☐ Co-Op Report ☐ Thesis/Term Paper

☐ Oral Presentation (identify meeting, sponsor, location, date):

☐ Journal Article (Identify Journal):

☒ Other (Specify): To Be Released for Phase II of HSA

Document will be published in proceedings ☑ No ☐ Yes

Document will be distributed at meeting ☑ No ☐ Yes

Document has patent or invention significance ☑ No ☐ Yes (Identify)

Document has been previously released ☑ No ☐ Yes (Reference)

DIVISION REVIEW AND APPROVAL (Completed By Requesting Division)

TECHNICAL CLASSIFICATION REVIEW (Divisional Classification Representative)

Title(s): U Abstract: NA

DOCUMENT: Level U Category –

R J Fraser 7/23/96
Signature Date

DOCUMENT REQUEST APPROVED (Division or Department)

Wm G. Wiley 7/23/96
Signature Date

Signature Date

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Date Received | Date Initiated 7/23/96

☑ CLASSIFICATIONS

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Level Unclassified Category –

Weapons Data – Sigma –

K.F. Leigh 24 July 1996
Y-12 Classification Office Date

☐ Editor Date

☑ Patent Office Date

☐ Other Date

☐ Other Date

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Technical Information Office 7/24/96
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18-10-2

INTER-COMPANY CORRESPONDENCE

(INSERT NAME) COMPANY CARBIDE AND CARBON CHEMICALS COMPANY LOCATION Post Office Box P OAK RIDGE, TENN.

TO Edw. G. Struxness
LOCATION Bldg. 9202

DATE September 24, 1953

ANSWERING LETTER DATE

ATTENTION

COPY TO File

SUBJECT Mer Vac Cleaner Investigation

I. Purpose

Establish an operation procedure for the Mer Vac Cleaner which will provide more effective service with minimum exposure to operating personnel.

II. Objectives

A. Formulation of pre-operation check list, e.g., check vacuum hose, traps, connection and etc.

B. Determine the performance of the Mer Vac Cleaner under different operating conditions.

1. Moist operation
2. Dry operation
3. Continuous operation (dry and moist)
4. Short operations (dry and moist)
5. Regeneration capacity of Hopcalite

C. Determine a method of reactivation of spent Hopcalite.

III. Equipment

A. Mer Vac Cleaner
B. Continuous Mercury Vapor recorder
C. Supply of Mercury (30 lbs)
D. Photographic Tray
E. Furnace (with temperature control)
F. Miscellaneous

1. One 2 gallon bottle
2. Suitable hose (rubber or tigon)
3. Rubber stoppers, connections ~~and etc.~~

APPROVED FOR PUBLIC RELEASE
Technical Information Office Date

The equipment to be employed in the proposed investigation can be obtained within the area of Y-12 at a minimum cost. This project will be accomplished on a part time basis, with little, if any interference of the normal routine work schedule.

Merwyn Sanders
Inspector, Industrial Hygiene Section
Health Physics Department

MS:cs

LCE 8/30/54

-COPY-

INTER-COMPANY CORRESPONDENCE

(INSERT NAME) COMPANY CARBIDE AND CARBON CHEMICALS COMPANY LOCATION Post Office Box P OAK RIDGE, TENN.

TO Mr. Don Hill
LOCATION Bldg. 9706-2

ATTENTION
COPY TO File

DATE August 13, 1954

ANSWERING LETTER DATE

SUBJECT Mercury Vapor Detectors

With reference to Mr. Braungart's visit to Y-12 in regard to consulting with us on the operation, maintenance, and calibration of G.E. mercury vapor detectors, a preliminary report on his findings and observations is enclosed for your consideration. A formal report will follow within the next several weeks.

I have talked over the calibration set-up with Mr. Whitson and he stated that he would approve a work order covering the cost (about $1,000) of this installation. A complete description of the mercury generator and auxillary equipment will be found in Mr. Braungart's final report.

W. H. Baumann
Medical Department

WHB:dmw

-COPY-

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WCX-80 (3-53)

1. One man should be given the primary responsibility for the care of the mercury vapor detectors. If this is possible, the following advantages may be obtained:

    a. More efficient and more satisfactory operation of the instruments.
    b. More efficient and rapid repair of the detectors.
    c. Possible modifications of existing equipment which will make them more applicable for our specific needs.

2. The instantaneous detectors should be adjusted with the aid of a small perforated container and a supply of nitrogen. This arrangement was demonstrated in the field and appeared to give the desired results.

3. The outward appearance of the chasis of the detectors suggests that the equipment be cleaned, checked and rebalanced on a periodic schedule. If this procedure is followed for a period, the instrument repair personnel may get an idea which equipment gives satisfactory or faulty operation.

4. A running log should be kept on each instrument. This log should include the following:

    a. Troubles encountered.
    b. Repair needs.
    c. Calibration information.
    d. Any and all remarks pertinent to future servicing of equipment.

5. In an effort to minimize the effect of drift due to apparent temperature variations, the instruments should be adjusted every couple of hours. Data should be kept on temperature variations and magnitude of drift between adjustments. In this manner, the effect of temperature variation may be established. Following this experiment, it may be possible to lengthen the adjustment period for some instruments or shorten this period for other instruments as indicated.

6. In view of the continuous service and adverse conditions under which some of the equipment is operating, it would be advisable to set up a mercury generator and such other auxillary equipment so that the detectors may be calibrated periodically.

7. The same degree of care and servicing should be afforded the L and N recorders as is given the Hg detectors.

8. The type B (selenium sulfide discoloration) mercury vapor detector should be checked at frequent intervals by:

    a. Cleaning and oiling the blower.
    b. Checking the temperature of the air stream striking the paper.

9. A certain degree of care will have to be taken in the handling of the selenium sulfide paper so that it does not become contaminated with finger marks. The person(s) handling the paper should wear clean light cotton or nylon gloves.

10. It is advisable not to have more than three months supply of paper on hand. A preliminary estimate of 10 rolls of paper per month was calculated, based on 34 type B detectors in 9201-5 and rolls of 42 feet. Stores should be advised on setting up a minimum and maximum. Paper should be stored at a temperature of 75° F. or lower.

11. With a mercury generator it will be possible to check any paper that you believe is of questionable quality. Also random checking of paper is recommended.

12. It is recommended that paper be exposed not longer than 8 hrs. (Calibration curves for paper discoloration will be set up for 2, 4, 8 and 16 hrs. It may not be possible to expose paper continuously for 16 hrs. because paper loses its sensitivity and also discolors slightly due to exposure to elevated temperature (55°C).

ZCC 11/5/54

NOV 4 1954

18-10 2

[redacted]

INTER-COMPANY CORRESPONDENCE

To Mr. W. C. Moore
Mr. L. P. Twichell
Mr. W. A. Pfeiler
Mr. O. W. Briscoe
Mr. L. C. Emerson
Mr. H. R. Gwinn
Mr. L. A. Stephens
Mr. H. T. Kite
Mr. J. W. Morfitt

Date November 2, 1954

Copy Analytical Development Personnel
No Y-12RC

Subject Organizational Changes
Analytical Development
Department

In an effort to expedite the program of the Analytical Development Department, the program and personnel have been divided into four sections as defined below. These changes are effective immediately.

1. Instrument Development

J. W. Redmond will assume responsibility for this section, with J. F. Been, H. H. Hendon, and C. S. McMurray reporting to him. This section is primarily concerned with the development of the continuous monitoring assay meter and a continuous concentration meter for the Colex plant; a 90° mass spectrometer; and the supporting instrumentation development for other groups in the Development Division.

2. Mass Spectrometer Development

C. R. Fultz will assume responsibility for this section, with H. S. Corey and J. W. Wachter reporting to him. This section will be concerned with the development of high resolution mass spectrometers; source and receiver development; and the evaluation of production equipment for increased efficiency in the operation of the mass spectrometers in the production laboratory.

3. Chemistry and Optical Spectroscopy

W. R. McIntosh will assume responsibility for this section, with W. C. Dietrich, R. F. Fenske, R. C. McIlhenny, and R. E. Sladky reporting to him. This group will be primarily concerned with the development of spectrochemical methods of analysis; the development of optical equipment for the isotopic assay of lithium, uranium, and hydrogen; the development of counting techniques for determining small amounts of uranium in solutions and solids; and support the needs of the spectrographic and chemical laboratories.

[redacted]

18-10-2

[redacted]

4. Health Physics Section

W. B. Wright will assume the responsibility for this section, with R. E. Cofield, E. E. Grassel, J. O. Hibbits, and J. H. Rowan reporting to him. This section will be primarily concerned with checking the calibration of indium foil badges; renovation of the present film badge procedures; radiation detection in the Y-12 creek; depth dose studies; evaluation of the present urine counting program; and support the needs of the Health Physics Department in the Laboratory Division.

This Department in general will support the needs of the Y-12 plant as the personnel may be peculiarly suited to contribute to the solution of the plant problems. The selection of leaders and sections is subject to change as the program demands.

L E Burkhart

L. E. Burkhart

[redacted]

1954 LCE 11/11/54 NOV 9

1810-2

INTER-COMPANY CORRESPONDENCE

(INSERT NAME) COMPANY CARBIDE AND CARBON CHEMICALS COMPANY LOCATION Post Office Box Y OAK RIDGE, TENN.

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G. Evans
R. A. Walker
L. W. Bagwell
L. C. Emerson
File

DATE November 9, 1954

ANSWERING LETTER DATE

SUBJECT Smoking in Solvent Areas of Building 9201-2

Increased incidence of smoking in Solvent areas of 9201-2 by both operations and maintenance personnel has been observed.

Since smoking in or around solvent vapor increases the potential health hazard and the fact that this area has been designated as a NO SMOKING AREA, strict observance of this rule should be enforced.

Leo J. LaFrance
Leo J. LaFrance
Industrial Hygienist

C. R. Sullivan
C. R. Sullivan, Jr., M.D.
Medical Director

drw

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WCX-80 (6-54)

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OAK RIDGE Y-12 PLANT INFORMATION CONTROL FORM

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Unclassified Title: A RAPID DETERMINATION OF MICRO QUANTITIES OF MERCURY IN URINE AND WATER USING THE MERCUROMETER (M-1

Author(s) W. T. McBRYDE AND F. WILLIAMS

TYPE: ☐ Formal Report ☐ Informal Report ☐ Progress/Status Report ☐ Co-Op Report ☐ Thesis/Term Paper

☐ Oral Presentation (identify meeting, sponsor, location, date):

☐ Journal Article (Identify Journal):

☒ Other (Specify): To Be Released for Phase II of HSA

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DOCUMENT: Level Category

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A RAPID DETERMINATION OF MICRO QUANTITIES OF MERCURY IN URINE AND WATER USING THE MERCUROMETER

W. T. McBryde
and
Fred Williams

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A DIVISION OF UNION CARBIDE CORPORATION
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A RAPID DETERMINATION OF MICRO QUANTITIES OF MERCURY IN URINE AND WATER USING THE MERCUROMETER

W. T. McBryde
and
Fred Williams

Oak Ridge, Tennessee

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ABSTRACT

The mercurometer is a combination of instruments that were assembled to detect mercury in urine and water by measuring the flow of mercury vapors volatilized from a cadmium sulfide-asbestos pad. A more rapid and precise procedure was realized through the use of this instrument.

SUMMARY

Mercury is isolated by filtering a sample of urine or water through an asbestos pad impregnated with cadmium sulfide. The pad, containing the mercury as the sulfide, is placed in the vaporizer chamber connected to a General Electric Instantaneous Mercury Vapor Detector equipped with an integrating device that records on a count register. Each count represents a known quantity of mercury.

The method as outlined allows the determination of from 1.0 to 10 micrograms of mercury, with no significant interference from the numerous impurities normally present in urine. Greater sensitivity may be achieved; however, this range was suitable for the mercury monitoring program at Y-12.

INTRODUCTION

A colorimetric procedure that applied the diphenylthiocarbazone reversion technique was employed by the Special Testing Department for the determination of mercury in urine at this installation. The assembly used consisted of a variac, a heating mantle, a two-arm flask, a dropping funnel and a condenser. The expense of keeping this equipment in operation increased with usage and breakage. A procedure that-required less equipment and maintenance was desired along with increased efficiency in sample output per manhour.

The use of a General Electric Mercury Vapor Detector to measure trace quantities of mercury in urine was suggested from the investigations reported by Ballard[1,3], Zuehlke[2], and Monkman[4]. Monkman, Maffett, and Daherty[4], used the process of cold digestion of the urine and filtered the prepared sample through a glass filter pad impregnated with cadmium sulfide. They heated the pad in a micro gas chamber connected to a GE Instantaneous Vapor Detector equipped with a recorder. The evolved vapor was swept through the detector with air and the corresponding response was traced on a strip chart recorder. The area under the curve was measured with a planimeter and compared with areas obtained with standard amounts of mercury. Ballard and Thornton[1,3], used pre-ignited asbestos fiber impregnated with cadmium sulfide to isolate mercury from organic solvent solutions. The method described by Monkman, Maffett and Daherty did not increase the speed of the analysis of mercury in urine to the point that it was advantageous for use in this laboratory.

A procedure has been adapted whereby the urine sample, as received is filtered through the cadmium sulfide-asbestos pad on which the mercury is retained as the insoluble sulfide. This pad is then placed in the vaporizer chamber with temperature controlled to approximately 420° C, which is adequate to completely volatilize the mercury. The response of the GE Instantaneous Vapor Detector is fed through an integrating linear amplifier and counting unit where the final reading is displayed as total counts per pad. A machine factor is applied to convert the count value to micrograms of mercury. The machine factor is determined by processing standard solutions of mercury. Six minutes is the average time per aliquant when analyzed in series of ten.

REAGENTS AND APPARATUS

Distilled water
Cadmium acetate, crystal
Hydrogen sulfide
Asbestos, long fiber, acid washed
Gooch crucible, No. 3
Methyl alcohol
Dispenser, cadmium sulfide-asbestos
Filtration system, See Fig. 1
Cadmium sulfide-asbestos pad
100 gms cadmium acetate, crystal
100 gms asbestos fibers, pre-ignited to 800°C
3600 ml distilled water
Combine and bubble the mixture with H_2S for 30 minutes. Pad is formed in a Gooch No. 3 crucible.

Mercurometer, See Figs. 1 and 2

Mercury vapors are evolved from the prepared pad by a vaporizer chamber (Fig. 3) that is joined by rubber tubing to a GE Instantaneous Mercury Vapor Detector. The response of the detector was adapted by connecting the microammeter in series with a 2000 ohm potentiometer. This potentiometer was coupled to a Brown Amplifier DC converter as shown in Fig. 4.

The converted signal is fed through a linear AC amplifier whose output supplies voltage to the voltage coil of a watt meter*. A constant voltage transformer provides 4.5 amperes to the current coil of the watt meter.

The revolutions of the watt meter disc is directly proportional to the current flow through the microammeter. An adjustment with the 2000 ohm potentiometer was made to deliver 110 volts AC to the watt meter voltage coil with the microammeter reading 100. An increased response in numbers was obtained from the watt meter by drilling forty equally spaced holes in the outer perimeter of the disc. A light source was placed above the disc in direct alignment with a photo-electric cell that responds as the light beam is interrupted. The light beam generates a pulse which is amplified to drive a digital register. A rate of 400 counts per minute is realized with the microammeter reading 100.

PROCEDURE

1. Shake the cadmium sulfide-asbestos mixture and dispense approximately one-half to two-thirds Gooch crucible of the material.

2. Open stopcock on the filtration system and allow pad to form.

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*Five ampere kilowatt hour meter.

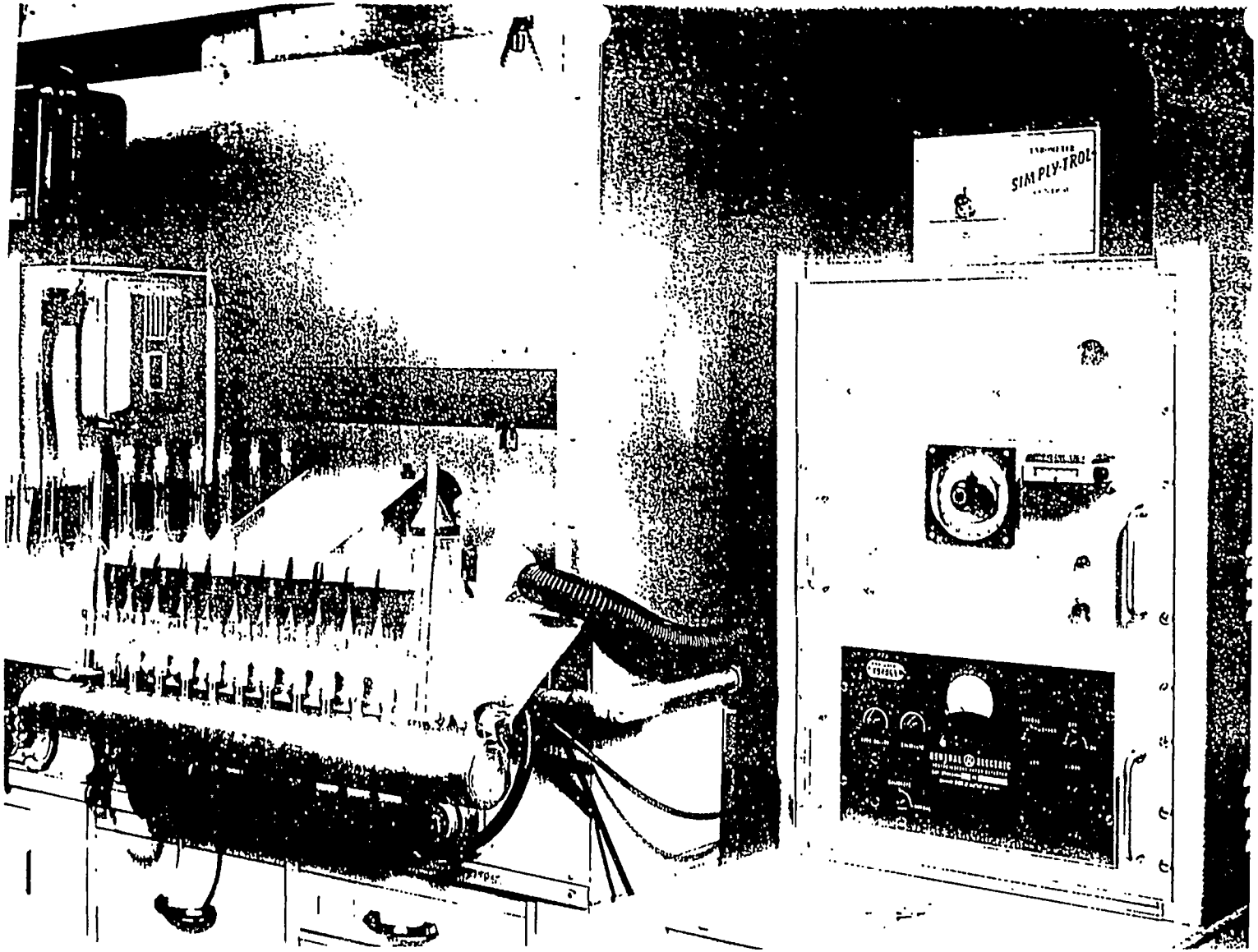

FIGURE 1.

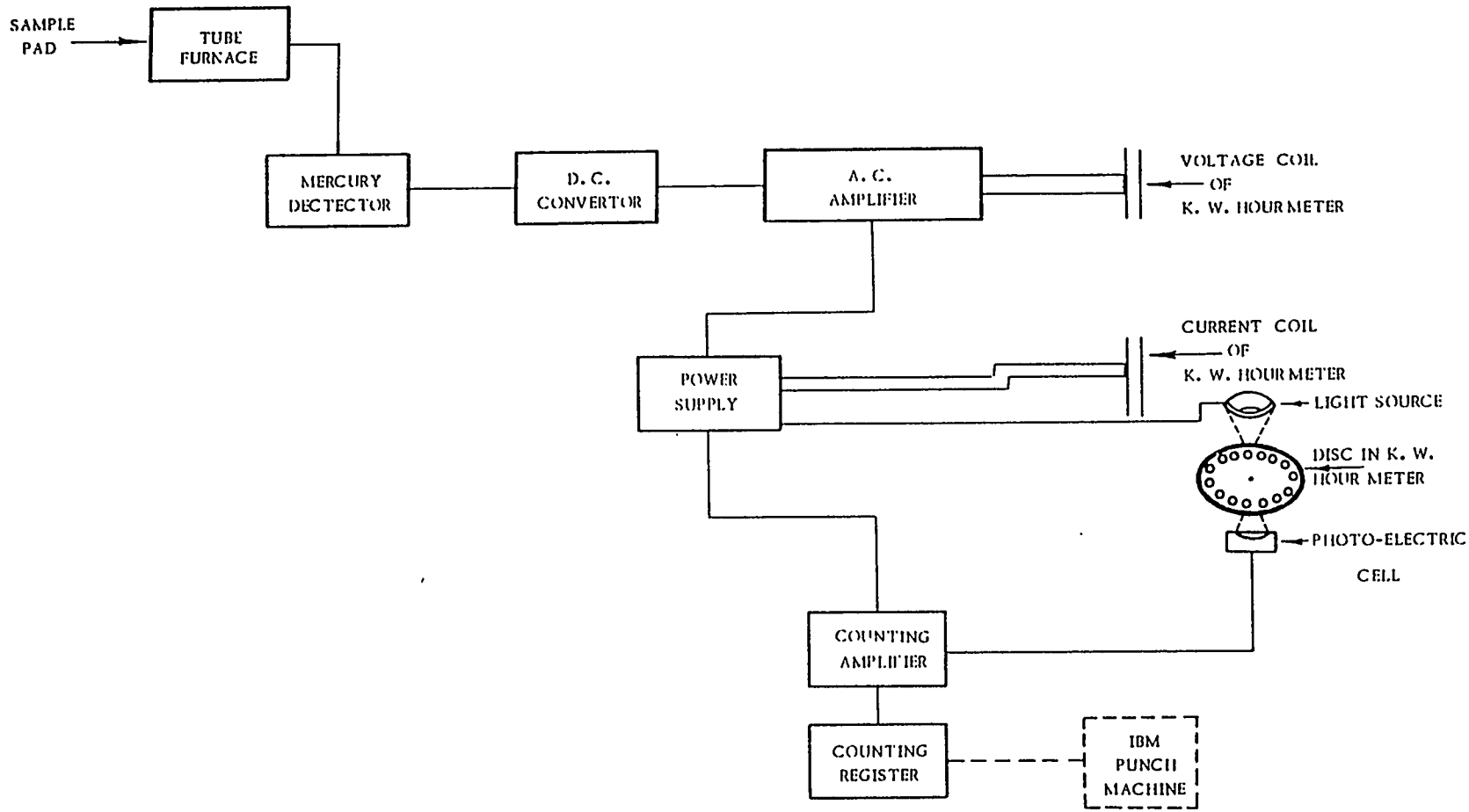

FIGURE 2. MERCUROMETER

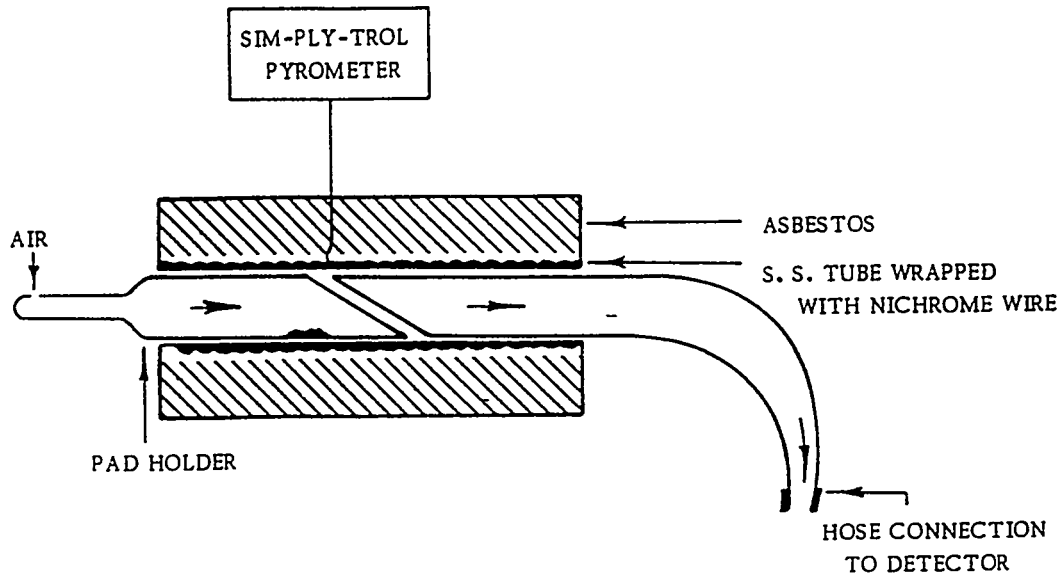

FIGURE 3. VAPORIZER CHAMBER

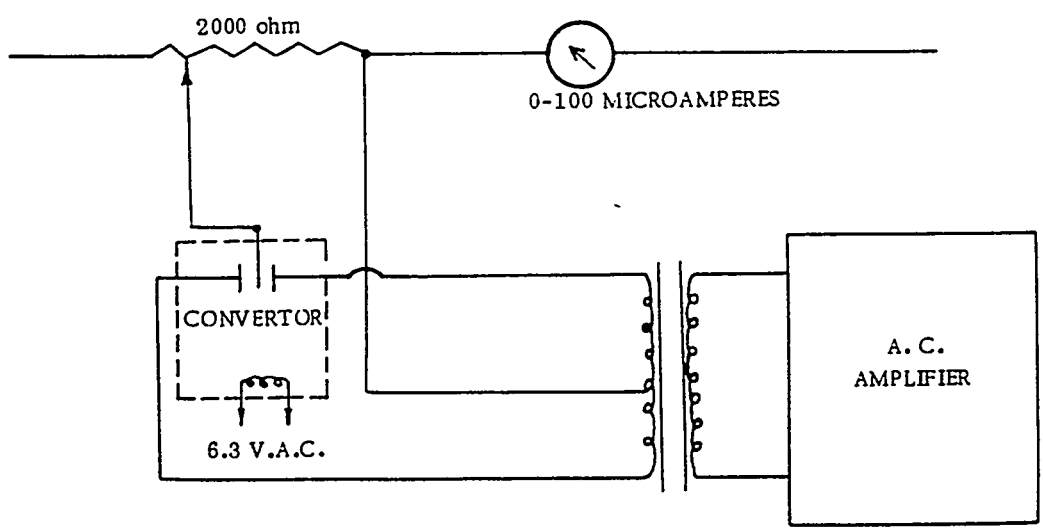

FIGURE 4.

3. Rinse sides of crucible and let water be sucked through, then rinse with approximately 10 ml of distilled water.

4. Pour 10 ml of urine into the crucible and allow to filter through the pad.

5. Rinse twice with 10 ml portions of distilled water.

6. Rinse four times with 5 ml portions of methyl alcohol and allow to air dry with filtration system stopcock open.

7. Remove the pad, intact, from the crucible and place in the vaporizer chamber.

8. Push the start button and count for four minutes.

9. Record the counts and apply the machine factor.

The reagent blank values should not exceed 25 counts in four minutes. Thorough rinsings with methyl alcohol will keep the blank value at an insignificant level.

DISCUSSION

The reproducibility of the method was evaluated by running four samples of known concentration at each of the levels 0, 0.1, 0.2, 0.4, 0.6, 0.8, and 1.0 milligram per liter. These 28 samples were prepared in another laboratory and submitted for analysis in such a way as to simulate routine conditions. Each sample was assigned a random number at the time of preparation, but the samples were not identified as to concentration to the laboratory running the analysis.

The estimated precisions of single determination consisting of two aliquants are as follows:

Milligrams/liter Concentration	Percent LE of One Analysis (95% Confidence)
0.1	± 40%
0.2	± 30%
0.4	± 28%
0.6	± 25%
0.8	± 15%
1.0	± 18%

Results for an individual sample may be obtained within a period of 10-15 minutes as compared to 90-120 minutes by the colorimetric procedure.

The rate of filtration is controlled by the thickness of the pad which should be approximately 1/8 inch. No loss of mercury was detected in the filtrate analyzed by the colorimetric method.

This procedure may be adapted for laboratory use with very little equipment and space requirements. The fact that practically no skill is necessary in any step of the procedure makes it ideal for production analyses.

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DETERMINATION OF SUBMICROGRAM QUANTITIES OF MERCURY IN LITHIUM METAL, ITS HYDRIDE, OR HYDROXIDE

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DETERMINATION OF SUBMICROGRAM QUANTITIES OF MERCURY IN LITHIUM METAL, ITS HYDRIDE, OR HYDROXIDE

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ABSTRACT

A method has been developed for determining submicrogram quantities of mercury in lithium metal, lithium hydride, or lithium hydroxide. Mercury was concentrated as the dithizonate from an acetate system by a dithizone-chloroform extraction, then determined spectrophotometrically as liberated dithizone after dissociating the mercury dithizonate with potassium iodide.

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INTRODUCTION

The determination of submicrogram quantities of mercury in lithium metal, lithium hydride, and lithium hydroxide requires an analytical method of great sensitivity. A direct analysis would not be feasible because of the lack of methods of sufficient sensitivity. A possible scheme of analysis appeared to be a dithizone-chloroform extraction(1) to concentrate the mercury, followed by a spectrophotometric measurement. The dithizone system could be made very specific for mercury by dissociating the mercury dithizonate with potassium iodide and measuring the liberated dithizone absorptiometrically.(2)

SUMMARY

A method has been developed for determining submicrogram quantities of mercury in lithium metal, lithium hydride, or lithium hydroxide. Mercury was concentrated as the dithizonate from an acetate system by a dithizone-chloroform extraction and determined spectrophotometrically as liberated dithizone, after dissociating the mercury dithizonate with potassium iodide.

Synthetic lithium acetate solutions were spiked with 0 - 6 μgs Hg(II) and analyzed for mercury (Table 2 and Figure 2). The limit of error (0.95) for a single determination over this range was ± 0.2 μg Hg. Based on the analysis of samples containing eight grams of lithium, the minimum detectable quantity of mercury was 0.03 μg Hg/gm Li.

Samples of lithium hydroxide were analyzed for mercury (Table 3).

ANALYTICAL PROCEDURE

EQUIPMENT

Spectrophotometer (Beckman DK-2 Ratio Recording)

Centrifuge (International, Size 2, Model V)

Centrifuge Bottles (250 mls)

Absorption Cells (two, special)[3]

Separatory Funnels (four, 125 mls, Kontes with Teflon valve; one each, 250, 500, and 1000 mls, Squibb)

Water Bath (18 x 12 x 2-inch phototray, half filled with cold water)

REAGENTS

Dithizone Stock Solution

To prepare this solution, dissolve 0.3 ± 0.01 grams of diphenylthiocarbazone in 50 milliliters of chloroform and filter the solution into a 250-milliliter separatory funnel. Extract the dithizone from the chloroform with three 100-milliliter portions of 1:100 reagent-grade ammonia solution. Discard the chloroform layer and filter the aqueous solution into a 500-milliliter separatory funnel through a small cotton plug. Make the filtrate slightly acid with 1:10 hydrochloric acid, add about 50 milliliters of chloroform, and extract the precipitated dithizone into the organic phase. Separate the organic phase and repeat the extraction with 20-milliliter portions of chloroform until the color of the organic phase is a pale green. Discard the aqueous phase, combine the chloroform extracts in a 250-milliliter separatory funnel, and wash two or three times with 20-milliliter portions of reversion reagent (Page 12). Thoroughly wash the organic phase with four 50-milliliter portions of water to completely remove any reversion reagent. Transfer the purified dithizone-chloroform solution to a 500-milliliter volumetric flask and dilute to volume with chloroform. Protect the flask from light and store it in a refrigerator.

Dithizone Working Solution

Dilute two milliliters of stock dithizone solution to 500 milliliters with chloroform. Protect the solution from light and store in a refrigerator when not in use. Monitor the spectrostability of the dithizone working solution by comparing absorbance values to those of a freshly prepared solution. A significant change in absorbance indicates the need for a fresh solution.

Reversion Reagent

Dissolve 20.4 ± 0.02 grams of potassium acid phthalate and 60 ± 1 grams of potassium iodide in 1000 milliliters of distilled water. Add 1% W/V sodium thiosulfate solution dropwise until the iodide solution is colorless then add two drops in excess. Extract the reversion reagent with 25-milliliter portions of dithizone working solution until the organic phase remains green. Store over a 25-milliliter portion of dithizone solution in a refrigerated dark bottle. Reagent is good as long as the dithizone remains green. As needed, pour out 100 milliliters into a suitable flask, add one or two drops of fresh 1% thiosulfate, and protect the solution from light.

Lithium Acetate Stock Solution

Add 920 milliliters of glacial acetic acid (Baker Analyzed Reagent) to 494 grams of lithium hydroxide monohydrate (Fisher Scientific Company) and dilute the solution to 2000 milliliters with mercury-free water. The absolute mercury content in 200 milliliters of acetate stock solution should not exceed 0.5 μgm. The final apparent pH of the solution should be 5.4 ± 0.4.

Chlorine Solution

Add 7.0 grams of calcium hypochlorite (Fisher Certified Reagent; 70.0% available chlorine) to 250 milliliters of water. Stir the mixture for 10 minutes and centrifuge to remove solids. Prepare fresh every day and protect the solution from light.

Hydrogen Peroxide Solution

This reagent can be prepared by adding six milliliters of 30% hydrogen peroxide (Baker and Adamson, ACS) to 200 milliliters of water. Prepare daily.

Potassium Permanganate Solution

This solution requires one gram of potassium permanganate (Baker and Adamson, Crystal) in 100 milliliters of water.

Hydroxylamine Hydrochloride Solution

Add two grams of hydroxylamine hydrochloride to 100 milliliters of water. Remove any mercury contamination by extracting this solution with the dithizone working solution.

Ethylenediaminetetraacetic Acid

By adding 4.65 grams of disodium dihydrogen ethylenediaminetetraacetic acid to 250 milliliters of water a 0.05 M solution will be prepared. Remove any mercury contamination by extracting the solution with the dithizone working solution.

Glacial Acetic Acid

Use Bakers Analyzed reagent-grade acid.

Mercury Stock Solution

A 1000 μgs ml solution will result if 0.6767 gram of mercuric chloride is added to 500 milliliters of 1 N sulfuric acid.

Mercury Working Solution

Dilute 0.50 milliliter of 1000 μgs/ml mercury stock solution to 500 milliliters of 0.25 N sulfuric acid as the diluent. This ratio gives a concentration of 1 μg/ml.

Absorbent Cotton

Johnson and Johnson nonsterile cotton blended 50% with Safron is suitable.

PROCEDURE

Sample Preparation

Accurately weigh an aliquant of lithium sample (metal, hydride, or hydroxide) equivalent to eight grams of lithium. Finely divided metal or hydride should be pressed into a pellet. Transfer the sample to a 500-milliliter, tall-form beaker, cover with a watchglass, and place the beaker in a waterbath. Add 90 milliliters of glacial acetic acid to the metal and hydride samples. Add 50 milliliters of water to the hydroxide samples, permit the mixture to cool before slowly adding the 90 milliliters of glacial acetic acid. As the dissolution rate of the metal and hydride samples subsides, add small increments of water and swirl the contents of the beaker. Since the effect of each water increment is delayed, do not add water too rapidly. When dissolution is complete, dilute the sample with water to about 200 milliliters.

Extraction

Heat the sample solutions to 80° C and add two milliliters of chlorine solution. Wait five minutes, add two milliliters of hydrogen peroxide, and swirl the contents gently. Wait ten minutes and add potassium permanganate until the solution is tinted pink by an excess of one or two drops. Cool the sample and add two milliliters of hydroxylamine and one milliliter of ethylenediaminetetraacetic acid solution. Mix the contents for one minute and pour the sample into an extraction flask (one liter volumetric flask). Add as quickly as possible 20 milliliters of the dithizone working solution and vigorously agitate the contents of the flask for two minutes. Pour the mixture into a 250-milliliter centrifuge bottle, cover the bottle with a plastic cap, and centrifuge the mixture for two minutes. (If the centrifuge is not available, add 100 milliliters of water to the sample in a suitable container to facilitate phase

separation.) Decant as much of the aqueous phase as possible from the centrifuge bottle. Wash the chloroform phase twice by refilling the bottle with water and decanting the aqueous. Transfer the mixture to a 125-milliliter separatory funnel (Kontes), add 10 milliliters of water and shake the contents for one minute. Insert a dry cotton plug in the stem of the separatory funnel, collect the organic solution, and discard the aqueous. Reserve one half of the organic solution for the airect measurement and return the other half to the separatory funnel. Add ten milliliters of reversion agent to the separatory funnel, and shake the contents for one minute. Place a second dry cotton plug in the stem of the funnel and collect this reversed organic solution for colorimetric measurement.

Measurement

Prepare the spectrophotometer for operation according to the manufacturer's instructions.[4] Select the following spectrophotometer parameters:

Scale Expansion	2x
Scanning Time	5 minutes
Wavelength (initial)	650 mμ
Time Constant	0.1
Sensitivity	10
Photomultiplier	1x
Operation Selector	Absorbance
Operation Range	1 - 2

Fill the sample absorption cell with nonreversed organic solution and the reference cell with chloroform. Record the absorbance, scanning from 650 to 560 mμ, to obtain the dithizone peak at 606 mμ. Rinse out the sample cell with chloroform and dry by drawing air through the cell. Fill the cell with the reversed organic solution and repeat the measurement procedure. Obtain the absorbance difference between the reversed and nonreversed solutions and designate this difference as gross sample absorbance difference. Calculate the net sample absorbance difference by subtracting the reagent blank absorbance difference from the gross sample absorbance difference. Determine the mercury concentration by comparing the net sample absorbance difference to a standard curve.

Reagent Blank Absorbance Difference

Add 20 milliliters of dithizone working solution directly to 200 milliliters of lithium acetate stock solution and extract any mercury present. Determine the absorbance difference due to mercury and designate this value as the stock solution absorbance difference as ΔAb_S.

Add 90 milliliters of glacial acetic acid, used in the sample preparation, to another 200-milliliter aliquot of lithium acetate stock solution and follow the recommended procedure, with the exception of sample dissolution, to determine the absorbance difference due to mercury in all of the reagents plus the lithium acetate stock solution. Designate this value gross blank absorbance as ΔAb_G.

Calculate the reagent blank absorbance difference from the following relationship:

$$\Delta Ab_R = \Delta Ab_G - \Delta Ab_S,$$

where:

ΔAb_R represents the reagent blank absorbance difference,

ΔAb_G the gross blank absorbance difference, and

ΔAb_S the stock solution absorbance difference.

Calibration

Spike 200-milliliter aliquots of the lithium acetate stock solution with 0, 1, 3, and 6 μgs of mercury. Analyze for mercury according to the procedure. The unspiked samples are to be considered as blanks. Plot net absorbance difference as a function of the mercury concentration.

EXPERIMENTAL STUDY AND RESULTS

The effect of the reagents, chlorine, peroxide, permanganate, hydroxylamine, and ethylenediaminetetraacetic acid was evaluated by comparing two different sets of synthetic samples, where Set I excluded these reagents. These synthetic samples were prepared by spiking 200-milliliter aliquots of lithium acetate stock solution with divalent mercury.

Mercury was then determined in both sets after direct extraction of Set I and pursuing the entire procedure for Set II. In all cases unspiked samples were considered as blanks. Tables 1 and 2 list the experimental data.

Table 1

DETERMINATION OF MERCURY IN LITHIUM ACETATE, SET I

Sample	LiAc (gms)	Hg Added (µgs)	Absorbance Difference Gross	Net
1	77.89		0.040	
2	77.89		0.035	
3	77.89		0.035	
4	77.89	0.50	0.077	0.040
5	77.89	0.50	0.077	0.040
6	77.89	0.50	0.077	0.040
7	77.89	1.00	0.122	0.085
8	77.89	1.00	0.112	0.075
9	77.89	1.00	0.117	0.080
11	77.89	2.00	0.197	0.160
12	77.89	2.00	0.202	0.165
13	77.89	2.00	0.192	0.155

Table 2

DETERMINATION OF MERCURY IN LITHIUM ACETATE, SET II

Sample	LiAc (gms)	Hg Added (µgs)	Absorbance Difference Gross	Net
1	77.89		0.015	
2	77.89		0.030	
3	77.89		0.020	
4	77.89		0.020	
5	77.89	0.50	0.070	0.049
6	77.89	0.50	0.060	0.039
7	77.89	0.50	0.075	0.054
8	77.89	0.50	0.075	0.054
9	77.89	1.00	0.110	0.095
10	77.89	1.00	0.120	0.099
11	77.89	1.00	0.120	0.099
12	77.89	1.00	0.115	0.094
13	77.89	3.00	0.310	0.295
14	77.89	3.00	0.330	0.309
15	77.89	3.00	0.325	0.304
16	77.89	3.00	0.300	0.279
17	77.89	6.00	0.625	0.604
18	77.89	6.00	0.630	0.609
19	77.89	6.00	0.640	0.619
20	77.89	6.00	0.610	0.589

Samples of lithium hydroxide were analyzed for mercury, and the results are reported in Table 3.

A plot of the net absorbance differences for acetate samples (Sets I and II) resulted in the linear curves shown in Figures 1 and 2. These curves exhibited comparable slopes, thus establishing the compatibility of the reagents. The limit of error (0.95) for a single determination over the range 0 - 2 µgs Hg was ± 0.14 µg Hg for Set I; over the range 0 - 6 µgs Hg was ± 0.20 µg Hg for Set II.

Table 3

ANALYSES OF LITHIUM HYDROXIDE SAMPLES FOR MERCURY

Sample	LiOH (gms)	Hg Found (µgs Hg/gm Li)
1[1]	26.71	124.00
2	27.06	1.84
3	27.16	1.55
4	27.12	1.27
5	27.72	2.41
6	27.00	0.10
7	27.00	2.04
8	27.00	6.20
9	27.00	1.41
10	27.00	1.27
11	27.00	0.11
12	27.00	0.10

(1) Initial material.

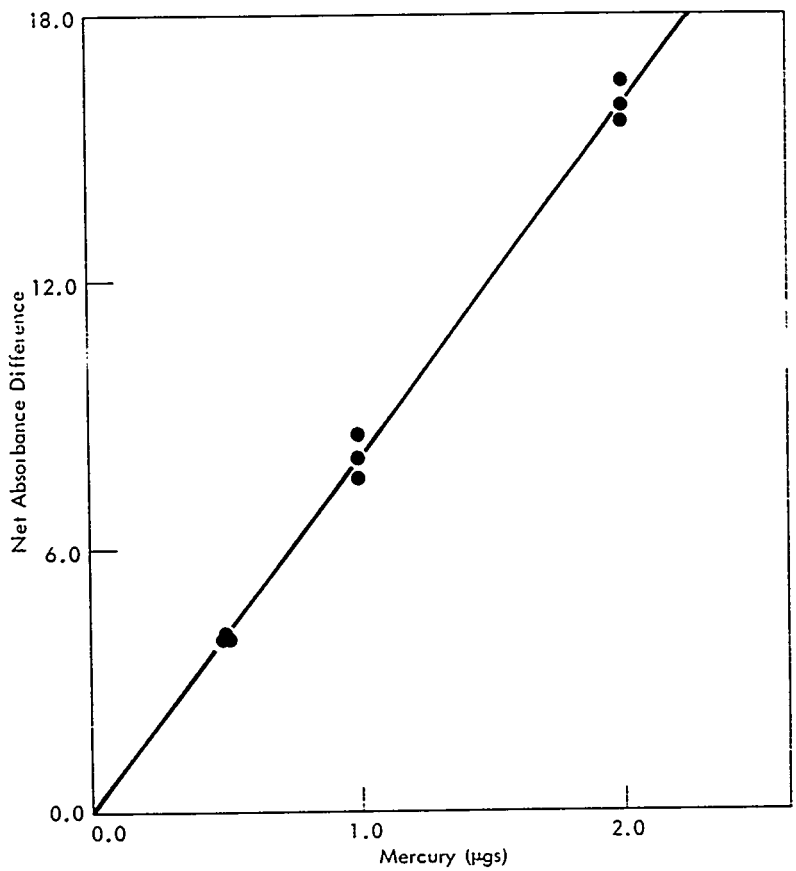

Figure 1. DETERMINATION OF MERCURY IN LITHIUM ACETATE. (Set I)

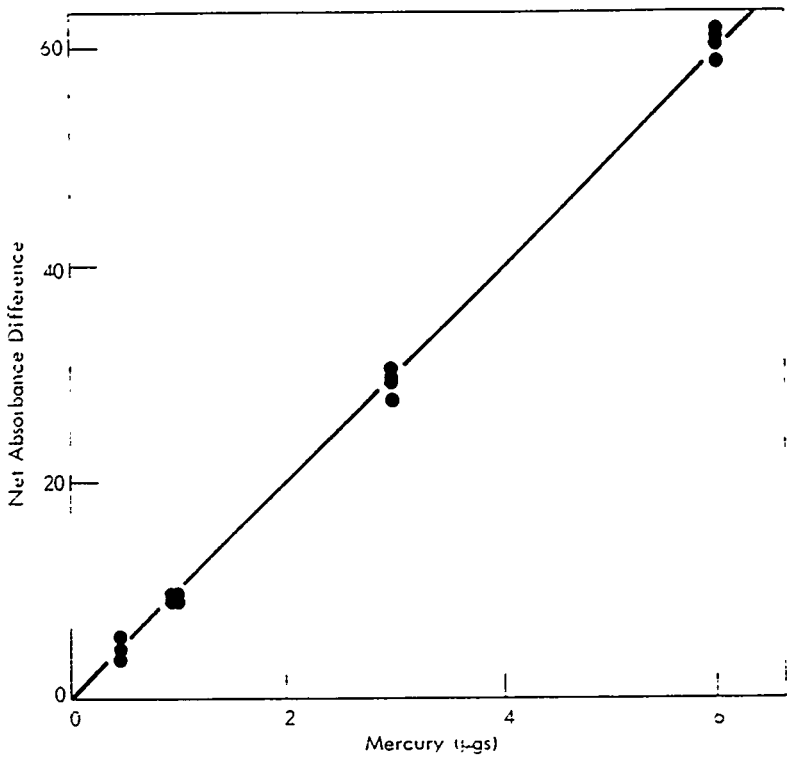

Figure 2. DETERMINATION OF MERCURY IN LITHIUM ACETATE. (Set II)

DISCUSSION

The developed method takes advantage of dithizone in chloroform as an efficient collector of submicrogram quantities of mercury. The dithizone-chloroform extraction is equivalent to a sulfide precipitation insensitivity and requires no foreign collectors or filtrations to separate mercury from the aqueous solutions. Mercury in a 200-milliliter sample containing 77.89 grams of lithium acetate and 0.50 micrograms of mercury (0.061 µg Hg/gm Li) was readily collected by a single extraction.

The high acetate concentration of the samples resulted in relatively dense, syrupy solutions. Separation of the dithizone-chloroform phase following the extraction was facilitated by centrifugation. A sulfide precipitation would have required excessive filtration time.

Preference of an acetate system for the analysis was abetted by the moderate dissolution rate of lithium metal and hydride in glacial acetic acid, the high solubility of lithium acetate, and the low mercury content of reagent-grade glacial acetic acid. The reaction rate of lithium metal and hydride with weakly ionized glacial acetic acid was found less than with methyl alcohol which is commonly used in the decomposition of these sample types. The initial reaction decreases from moderate to slow and requires small increments of water to sustain the reaction at a practical rate.

The final solution for analysis can be prepared, as concentrated, as two grams of lithium acetate per milliliter of water. Highly concentrated sample solutions are essential to the accumulation of sufficient mercury for analysis. The detective limit in the present routine (method) was about 0.25 micrograms mercury, absolute. With such low limits of detection it is essential that the acetic acid be pure. General reagent-grade glacial acetic acid contains about 0.50 - 0.80 μg Hg/100 ml. Purification of glacial acetic acid was not attempted. However, a single dithizone-carbon tetrachloride extraction of 11 M acetic acid resulted in a fourfold purification. Greater acid concentrations could not be used due to the increasing solubility of the carbon tetrachloride. Purified acid was not used in the present procedure.

Mercury in the sample solution could be presumed to be present as the metal, mercury (I) or mercury(II). To assure the presence of mercury(II) without subsequent interference, the solution was subjected to a series of chemical reactions involving chlorine, peroxide, permanganate, and hydroxylamine. Chlorine oxidized mercury to mercury(II), peroxide reduced excess chlorine, permanganate oxidized excess peroxide, and hydroxylamine reduced excess permanganate. Efforts to reduce chlorine directly by hydroxylamine in the acetate medium resulted in inconsistent recoveries. Potassium permanganate was unsuitable as a direct oxidant because of its reduced oxidation potential in cold solutions of low acidity.[5] Ethylenediaminetetraacetic acid (EDTA) solution was added subsequently to mask the interfering cations. Mercury(II) was separated from the aqueous solution as mercury dithizonate by extraction into chloroform. The extract was divided into two equal portions and the mercury dithizonate in one portion was dissociated with potassium iodide to release an equivalent amount of free dithizone. The absorbance of the two dithizone solutions was then measured at 606 mμ (Figure 3), where dithizone absorbs strongly and mercury dithizonate only weakly.

Typical absorbance scans from 650 to 560 mμ of dithizone-chloroform extracts from Set II samples, Table 2, are shown in Figure 3. The absorbance differences of the dithizone solutions were compared to a standard curve for the corresponding mercury value (Figure 2). Thus, mercury dithizonate is not measured, but rather the absorbance change of free dithizone when the mercury dithizonate is dissociated by iodide is measured. This treatment is generally known as reversion.[2] The advantage of reversion is to increase the specificity for mercury. Few metal dithizonates with the exception of mercury and silver are dissociated by iodide. Silver will not form a dithizonate if the chlorides are present in an acid medium, and the reduction of chlorine in the procedure assures their presence. Further specificity was assured by the addition of EDTA.

The effect of redox reagents and EDTA in the determination of mercury was evaluated by analyzing two sets of mercury-spiked synthetic samples, where Set I excluded these reagents (Tables 1 and 2). A plot of net absorbance difference as a function of the mercury concentration gave a linear curve, as shown in Figures 1 and 2. The limit of error (0.95) for a single mercury determination over the ranges studied was ± 0.14 μg mercury for Set I, and ± 0.20 μg mercury for Set II. No significant effect was observed due to the presence of the redox and EDTA reagents.

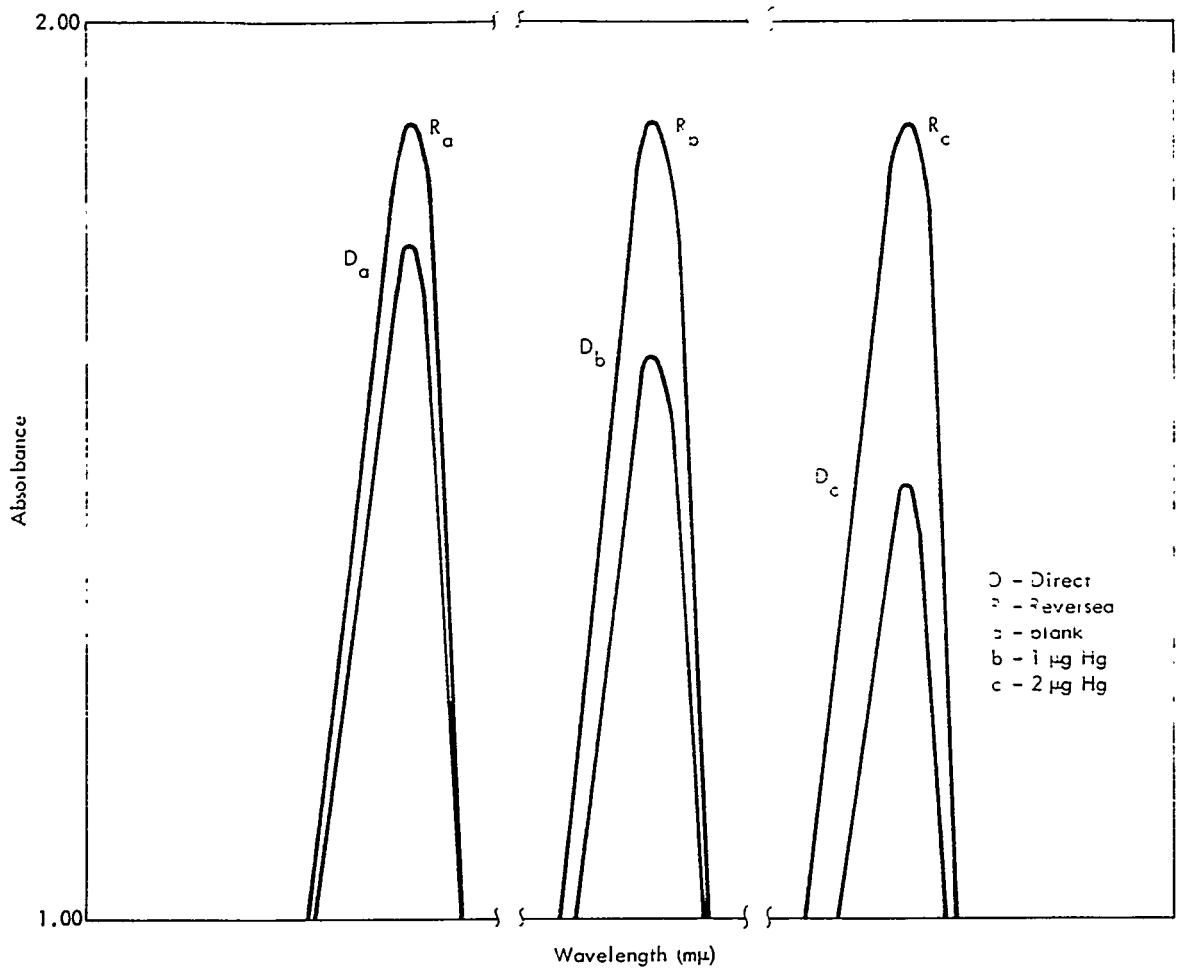

Figure 3. SCANS OF REVERSED AND NONREVERSED DITHIZONE-CHLOROFORM EXTRACTS.

Samples from batches of lithium hydroxide submitted to various schemes of decontamination from mercury, were analyzed for mercury (Table 3).

The analyst must be continuously conscious of contamination. Any mercury in the reagents must be corrected for by adequate blanks. All glassware must be dipped in nitric acid and rinsed with mercury-free water. Contamination can occur subtilely. In one instance a hand cream used by an analyst was later found to contain 3% mercury. This situation caused erratic results for several days. Careless use of reagents is especially detrimental to accurate mercury determinations. Minute residues of iodides can prevent mercury extraction; chlorine, peroxide, or permanganate will oxidize dithizone; and iodide solution used in reversion can cause negative results if unnecessarily exposed to light. Excess EDTA could also prevent the extraction of mercury.

Determination of the reagent blank is beset with several inherent difficulties. If the glacial acetic acid or lithium hydroxide monohydrate used in preparing the stock

solution should contain mercury in an unreactive form (such as the metal), the analysis would fail to detect this mercury since the blank on the lithium acetate stock solution is determined in the absence of redox reagents. Since the reagent blank is the difference between the gross blank involving all the reagents and the lithium acetate stock solution blank, a high reagent blank would be a direct consequence of this error in the stock solution blank. In all cases during the development of the procedure, the reagent blank was consistent and never exceeded 1 μg Hg/gm Li.

In the event of a high reagent blank, the acetate stock solution could be checked out by spiking the stock solution aliquot, while keeping the other reagents constant.

If the mercury contamination is not in the acetate solution, all remaining reagents must be analyzed for mercury. This step could be accomplished by a selective pairing of the four redox reagents: chlorine, peroxide, permanganate, and hydroxylamine, into the form of four simultaneous equations and solving for the contaminated reagent. Contamination in the hydroxylamine should be inconsequential since this reagent was purified by dithizone extraction. The developed method is very sensitive and relatively free from interference. The lower limit of detection (0.02 μg Hg/gm Li) might be considerably lowered by measuring mercury in the dithizone-chloroform extract by atomic absorption.

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ABSTRACT

A method has been developed for determining submicrogram quantities of mercury in water and lithium hydroxide. The detection limit is 2×10^{-4} micrograms per milliliter. The mercury is reduced to metal and then expelled from a solution as vapor. The vapor is measured using an atomic absorption spectrophotometer.

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SUMMARY

An atomic absorption spectrophotometric method for determining submicrogram amounts of mercury has a detection limit of 2×10^{-4} µgs/ml and a precision of ± 10 percent at the 2×10^{-3} µgs/ml level, when based upon a 50-milliliter sample. The total mercury content of an aliquant must be less than one microgram for the determination by this method.

The method consists of: (1) converting the mercury ions to the metal, (2) expelling the metallic mercury as the vapor, and (3) measuring the vapor in an absorption cell. Time required for an analysis is approximately five minutes per sample.

The only interferences found were vapors which absorb at 2537 A and metallic ions which are reduced to the metal and form an alloy with the metallic mercury.

INTRODUCTION

The Biology Division of the Oak Ridge National Laboratory asked that some water samples be analyzed to see if the mercury concentration exceeded 1×10^{-2} μgs/ml. A new method had to be found because the lower limit of the mercurometer was 5×10^{-2} μgs/ml; the colorimetric procedure[1] was too time consuming.

Several papers on mercury analysis by atomic absorption have been published,[2] but most of these methods require a solvent extraction of the mercury ion into an organic phase to concentrate the mercury before atmoizing into the flame. These methods are often inadequate because: (1) mercury in the water is usually in the metallic form, and (2) extraction does not concentrate the mercury sufficiently, if one is interested in submicrogram quantities.

Russian workers published an article on the analysis of mercury in the gas phase using atomic absorption[3]. This principle, adapted to the Laboratory's samples and equipment, was utilized in developing the present method of determining submicrogram quantities of mercury in water and in lithium hydroxide solutions.

METHOD FOR MERCURY DETERMINATION

REAGENTS AND EQUIPMENT

Reagents

The following reagents are required:

Stannous Chloride Solution, 20% - Dissolve 20 grams of CP tin(II) chloride dihydrate in 100 milliliters of 6 normal hydrochloric acid.

Mercury Solution, 100 μgs/ml - Dissolve 108 milligrams of mercury(II) oxide in 50 milliliters of 5 normal nitric acid. Dilute with water to the mark in a 1000-milliliter volumetric flask.

Mercury Solution, 0.1 μgs/ml - Pipette one milliliter of the standard mercury(II) oxide solution (100 μgs/ml) into a 1000-milliliter flask and dilute with 0.25 normal nitric acid to the mark.

Equipment

The following major items of equipment are needed: an atomic absorption spectrophotometer[a] equipped with a recorder readout, and an absorption cell and reaction train (see Figure 1).

RECOMMENDED PROCEDURE

Preparation of Standards

The standard solutions should be prepared as follows:

1. Pipette the mercury standard solution (0.1 μgs/ml) into the reaction flasks in known amounts to give a series of five standards to cover the expected range of samples. (The highest standard that can be used is 1.0 μg Hg total.)

2. Dilute the standard solution in the reaction flask to a 50-milliliter volume.

(a) Model 303, Perkin-Elmer Corporation.

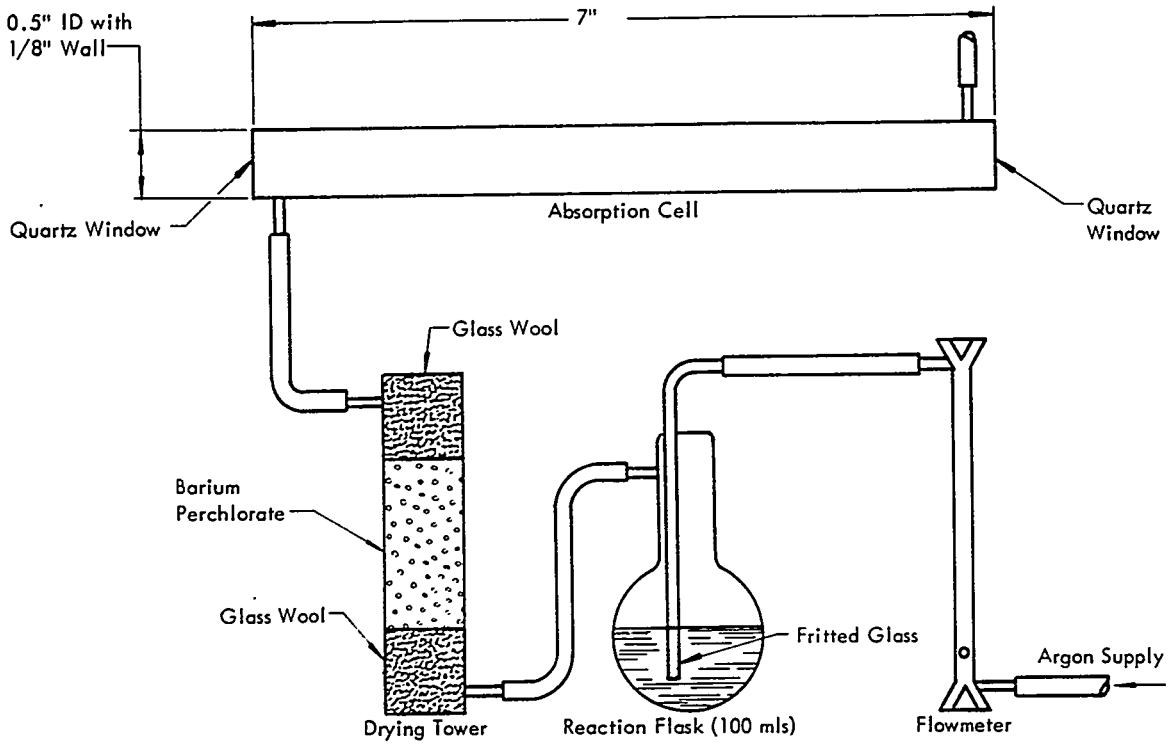

Figure 1. MERCURY ABSORPTION CELL AND REACTION TRAIN.

3. Add 0.5 milliliter of tin(II) chloride solution to each reaction flask. Stopper the flask and invert five times to provide thorough mixing.

4. React the standard within ten minutes after the addition of the tin chloride.

Preparation of Samples

Samples should be prepared as follows:

1. Pipette into the reaction flask a portion of sample which gives a total mercury value corresponding to the standard curve.

2. If the sample is basic, add nitric acid until the pH is less than 7.

3. Dilute the sample in the reaction flask to a 50-milliliter volume.

4. Add 0.5 milliliter of tin(II) chloride solution to the reaction flask. Stopper the flask and invert five times to provide thorough mixing.

5. React the samples within ten minutes after the addition of the tin chloride.

Analytical Procedure

The analysis for mercury should be conducted according to the following procedure:

1. Remove the burner from the instrument and install the mercury absorption cell.

2. Align the absorption cell to obtain maximum intensity of the mercury source lamp through the cell.

3. The instrument operating conditions are:

Source Lamp	- mercury germicidal
Lamp Current	- 350 milliamperes
Slit Width	- 3 (0.3 mm)
Wavelength	- 2537 A
Noise Control	- 1
Scale Expansion	- 1X
Gain Control	- 2.5
Argon Flow	- 2.0 liters per minute (at 760 mm and 24° C)

4. Adjust the recorder to zero absorbance, then insert the gas dispersion adapter into the reaction flask and allow it to remain until the recorder returns to zero absorbance.

5. Compare the sample absorbance data to the absorbance data of the standards to obtain the total micrograms of mercury in the reaction flask.

6. Calculate the results by the following equation:

$$\mu\text{gs Hg/ml} = \frac{\text{Total } \mu\text{gs Hg Found in Reaction Flask}}{\text{mls of Sample Used}}.$$

EXPERIMENTATION

Synthetic samples were prepared by adding mercury(II) nitrate to water and lithium hydroxide solutions. The lithium hydroxide concentration was approximately 2.5 mgs Li/ml. Typical results of these experiments are summarized in Table 1.

found that expelled as quickly as possible. All reacted similarly to acetone, shown in Figure 2.

The samples can be checked for the interference of metallic ions by spiking with mercury and checking the recovery. Failure to recover the spike indicates interfering metallic ions.

The glass frit in the reaction tube is necessary to produce a fast and constant rate of expelling the mercury vapor. An open-end tube was found unsatisfactory for use.

It is necessary to dilute the samples and standards to the same volume. The gas flow rate must be held constant since this determines the rate at which the mercury is expelled and the number of atoms in the absorption path at any given time.

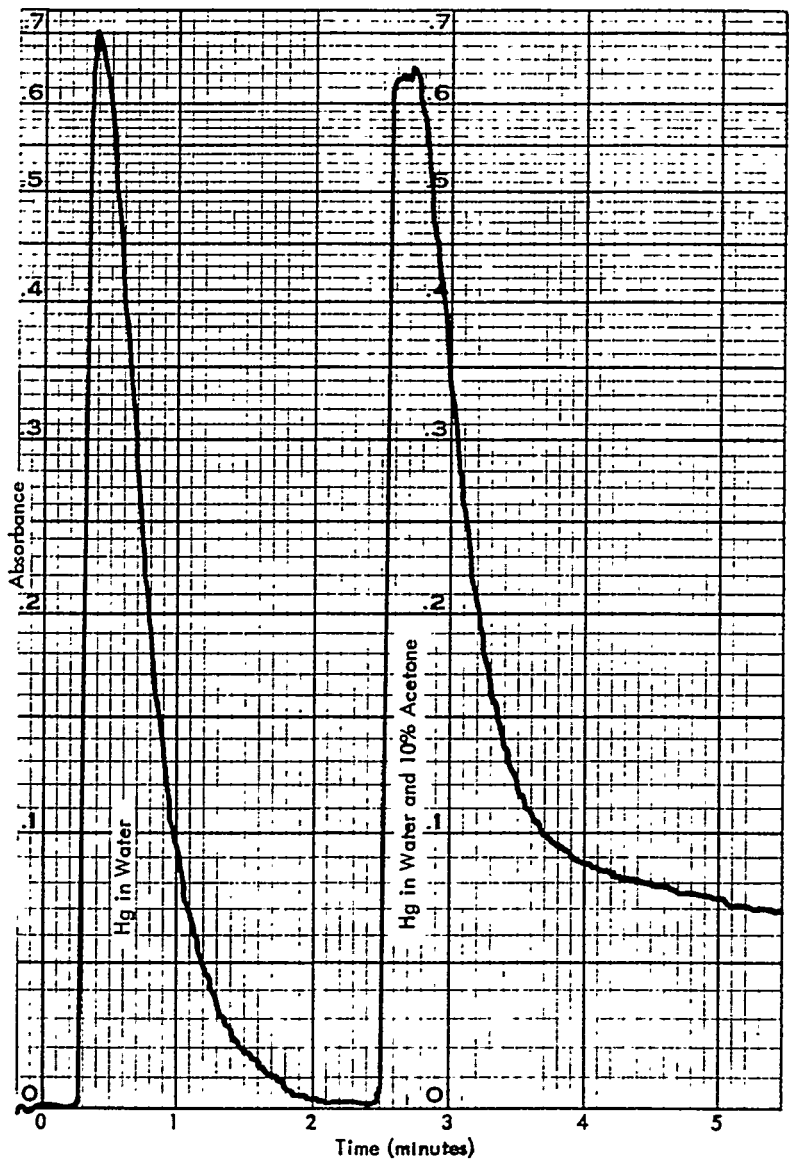

Figure 2. EFFECT OF ORGANIC VAPORS ON ABSORBANCE.

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(4) Ibid; p 941.

REPORT NUMBER Y/DK-253
DATE: 08/05/80
TITLE: MICROCOMPUTER CONTROLLED OPTICAL EMISSION SPECTROMETER
AUTHOR(S): FUTRELL, JL, GOODPASTURE, RT, LARSON, GF,
MISC: SLIDES PRESENTED AT 22ND ROCKY MOUNTAIN CONFERENCE, DENVER, CO, AUG 11-14, 1980
TYPE DOCUMENT: OP PAGES: 17
CLASSIFICATION: U AVAILABILITY: UCCND (B)

REPORT NUMBER Y/DK-254
DATE: 05/22/80
TITLE: DETERMINATION OF MERCURY IN ROCKS, SEDIMENTS, AND SOILS BY FLAMELESS ATOMIC ABSORPTION
AUTHOR(S): WHITE, LE, CARTER JR, RH,
TYPE DOCUMENT: IR PAGES: 15
CLASSIFICATION: U AVAILABILITY: NTIS (H) available through NTIS (public release)

REPORT NUMBER Y/DK-255
DATE: 09/18/80
TITLE: THE ANALYSIS OF SELECTED ORGANIC PRIORITY POLLUTANTS IN ENVIRONMENTAL SAMPLES
AUTHOR(S): MCELHANEY, RJ, MANN, ML,
MISC: PRESENTED AT 24TH CONFERENCE ON ANALYTICAL CHEMISTRY IN ENERGY TECHNOLOGY, GATLINBURG, TN, OCT 7-9, 1980
TYPE DOCUMENT: OP PAGES: 36
CLASSIFICATION: U AVAILABILITY: NTIS (H)

REPORT NUMBER Y/DK-256
DATE: 09/18/80
TITLE: APPLICATION OF PLASMA TO ANALYSIS OF MATERIALS RELATED TO RECOVERY OF RESOURCES FROM RESIDUES OF SOLID FOSSIL FUELS
AUTHOR(S): LARSON, GF, VIATOR, RA,
MISC: SLIDES PRESENTED AT 24TH CONFERENCE ON ANALYTICAL CHEMISTRY IN ENERGY TECHNOLOGY, GATLINBURG, TN, OCT 7-9, 1980
TYPE DOCUMENT: OP PAGES: 19
CLASSIFICATION: U AVAILABILITY: UCCND (B)

REPORT NUMBER Y/DK-257
DATE: 10/08/80
TITLE: AN EVALUATION OF A LASER-INDUCED FLUORESCENCE SYSTEM FOR URANIUM ANALYSIS
AUTHOR(S): WHITE, LE,
MISC: SLIDES PRESENTED AT 24TH CONFERENCE ON ANALYTICAL CHEMISTRY IN ENERGY TECHNOLOGY, GATLINBURG, TN, OCT 7-9, 1980
TYPE DOCUMENT: OP PAGES: 11
CLASSIFICATION: U AVAILABILITY: UCCND (B)
AVAILABLE FROM NTIS IN FORMAL REPORT Y-2205

REPORT NUMBER Y/DK-258
DATE: 09/15/80
TITLE: NMR STUDY OF THE REACTION OF CARBON DIOXIDE WITH A SPECIAL MATERIAL (U)
AUTHOR(S): SMITHWICK III, RW, RUTENBERG, AC,
TYPE DOCUMENT: IR PAGES: 18
CLASSIFICATION: CRD AVAILABILITY: TIC (C)

REPORT NUMBER Y/DK-259
DATE: 10/31/80
TITLE: THERMOGRAVIMETRIC DETERMINATION OF VAPOR PRESSURE OF DIFFUSION PUMP OILS BY KNUDSEN EFFUSION CELL TECHNIQUE
AUTHOR(S): STECKEL, LM,
TYPE DOCUMENT: IR PAGES: 16
CLASSIFICATION: U AVAILABILITY: NTIS (H)

REPORT NUMBER Y/DK-261
DATE: 11/07/80
TITLE: NITROGEN DETERMINATION IN BORON NITRIDE
AUTHOR(S): SWEENEY, RE,
TYPE DOCUMENT: IR PAGES: 16
CLASSIFICATION: U AVAILABILITY: UCCND (A)

REPORT NUMBER Y/DK-262
DATE: 03/18/81
TITLE: NMR STUDY OF AN EPOXY RESIN (U)
AUTHOR(S): RUTENBERG, AC, SMITHWICK III, RW,
TYPE DOCUMENT: IR PAGES: 21
CLASSIFICATION: SRD AVAILABILITY: TIC (B) (C-24)

REPORT NUMBER Y/DL-553
DATE: 01/17/77
TITLE: IMOG ENVIRONMENTAL TESTING SUBGROUP MEETING (Y-12 PLANT CONTRIBUTION)
AUTHOR(S): LONG, PJ,
MISC: PRESENTED AT IMOG ENVIRONMENTAL TESTING SUBGROUP, GENO, JAN 25-27, 1977
TYPE DOCUMENT: IMOG-CM-0177 PAGES: 4
CLASSIFICATION: U AVAILABILITY: UCCND (C)

REPORT NUMBER Y/DL-557
DATE: 04/15/77
TITLE: REAL TIME SYSTEMS - DEFINITION AND USE
AUTHOR(S): CHAPMAN, SL,
MISC: PRESENTED AT SEMINAR ON SMALL-COMPUTER REAL-TIME SYSTEMS, ORNL, MAY 12-13, 1977
TYPE DOCUMENT: OP PAGES: 3
CLASSIFICATION: U AVAILABILITY: UCCND (B)

REPORT NUMBER Y/DL-563
DATE: 05/12/77
TITLE: MEASURING THE THERMAL EXPANSION OF SOLIDS WITH STRAIN GAGES
AUTHOR(S): POORE, RW, KESTERSON, KF,
MISC: A PAPER PUBLISHED IN THE ASTM JOURNAL OF TESTING AND EVALUATION, VOLUME 6, NO. 2, PAGES 98-102, MAR, 1978
TYPE DOCUMENT: JA PAGES: 5
CLASSIFICATION: U AVAILABILITY: JOURNAL (H)

M-205

Y/DK-254

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DETERMINATION OF MERCURY IN ROCKS, SEDIMENTS, AND SOILS BY FLAMELESS ATOMIC ABSORPTION

L. E. White
M. H. Carter, Jr.

May 1980

APPROVED FOR PUBLIC RELEASE
3/4/80
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DEPARTMENT OF ENERGY

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Y/DK-254

DETERMINATION OF MERCURY IN ROCKS, SEDIMENTS, AND SOILS BY FLAMELESS ATOMIC ABSORPTION

L. E. White
M. H. Carter, Jr.

Plant Laboratory Department
Y-12 Product Certification Division

Oak Ridge Y-12 Plant
P. O. Box Y, Oak Ridge, Tennessee 37830

Prepared for the Department of Energy
Under US Government Contract W-7405-eng-26

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Procedure 6
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INTRODUCTION

The National Uranium Resources Evaluation Project required the development of a relatively fast procedure for the analysis of mercury in rocks, sediments, and soils. Many of these samples were unusually high in organic matter (10-30%). Since organic matter can lead to high and erroreous readings, a strong oxidation of the sample was required. A sulfuric acid and hydrogen peroxide digestion was chosen and after sample preparation, standard flameless atomic absorption spectroscopy was employed.

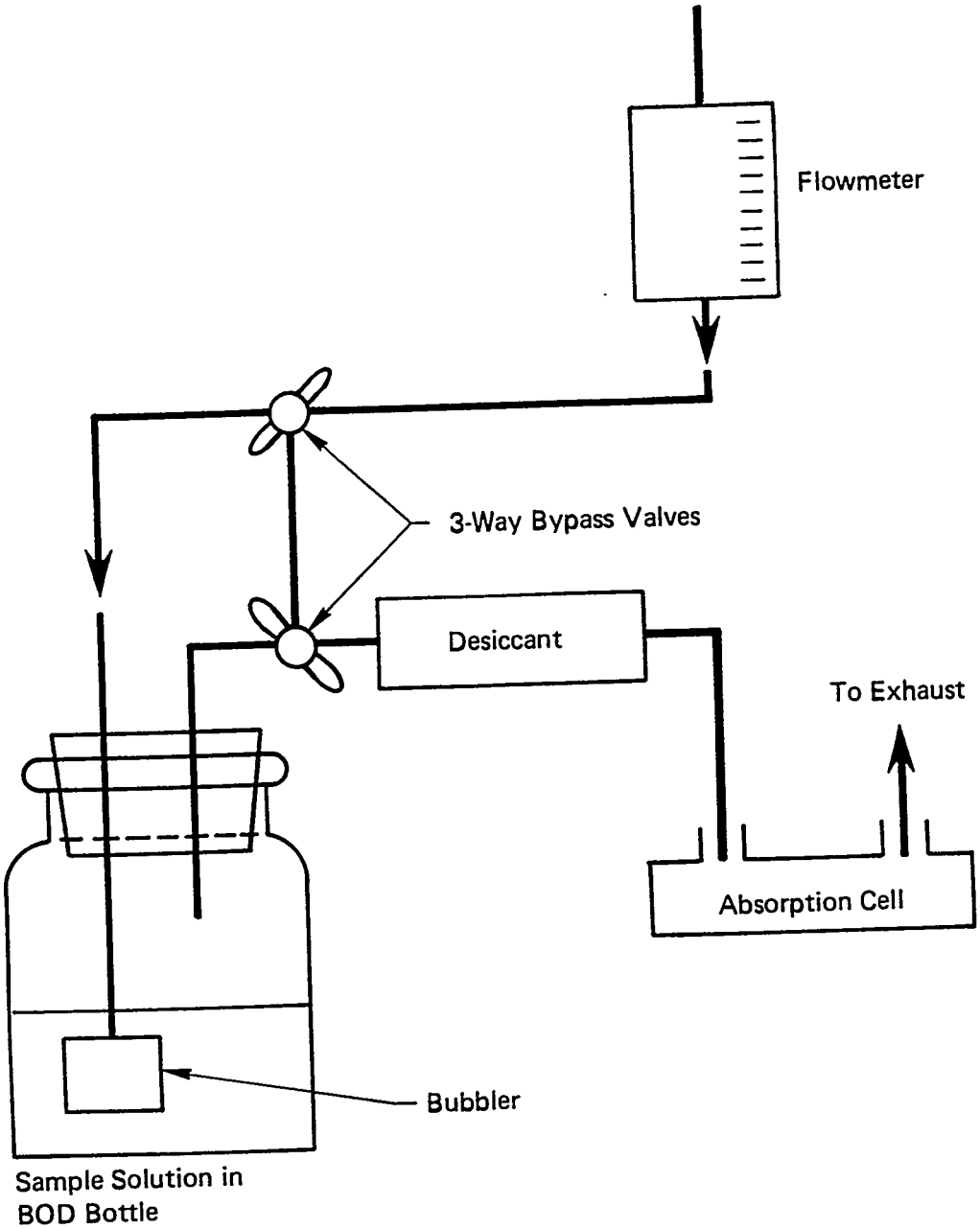


Figure 1. APPARATUS FOR FLAMELESS MERCURY DETERMINATION.[2, 5]

aeration apparatus.

10. Introduce argon through the sample and record the mercury peak. Channel B is operated at one-half the scale expansion of channel A. (See Figures 2 and 3.)

CALCULATIONS

1. Determination of Mercury From a Standard Curve

   a. Determine the peak heights of each of the standards used. Divide each standard concentration by the peak heights measured. Calculate an average factor from the results.

   b. Determine the peak height of the sample from the strip chart.

   c. Calculate the mercury concentration of the sample from:

$$H = \frac{S \times P}{G}$$

   where: H = mercury concentration in ppm,
   S = standard factor,
   P = peak height of sample, and
   G = sample weight in grams.

2. An Alternate Method

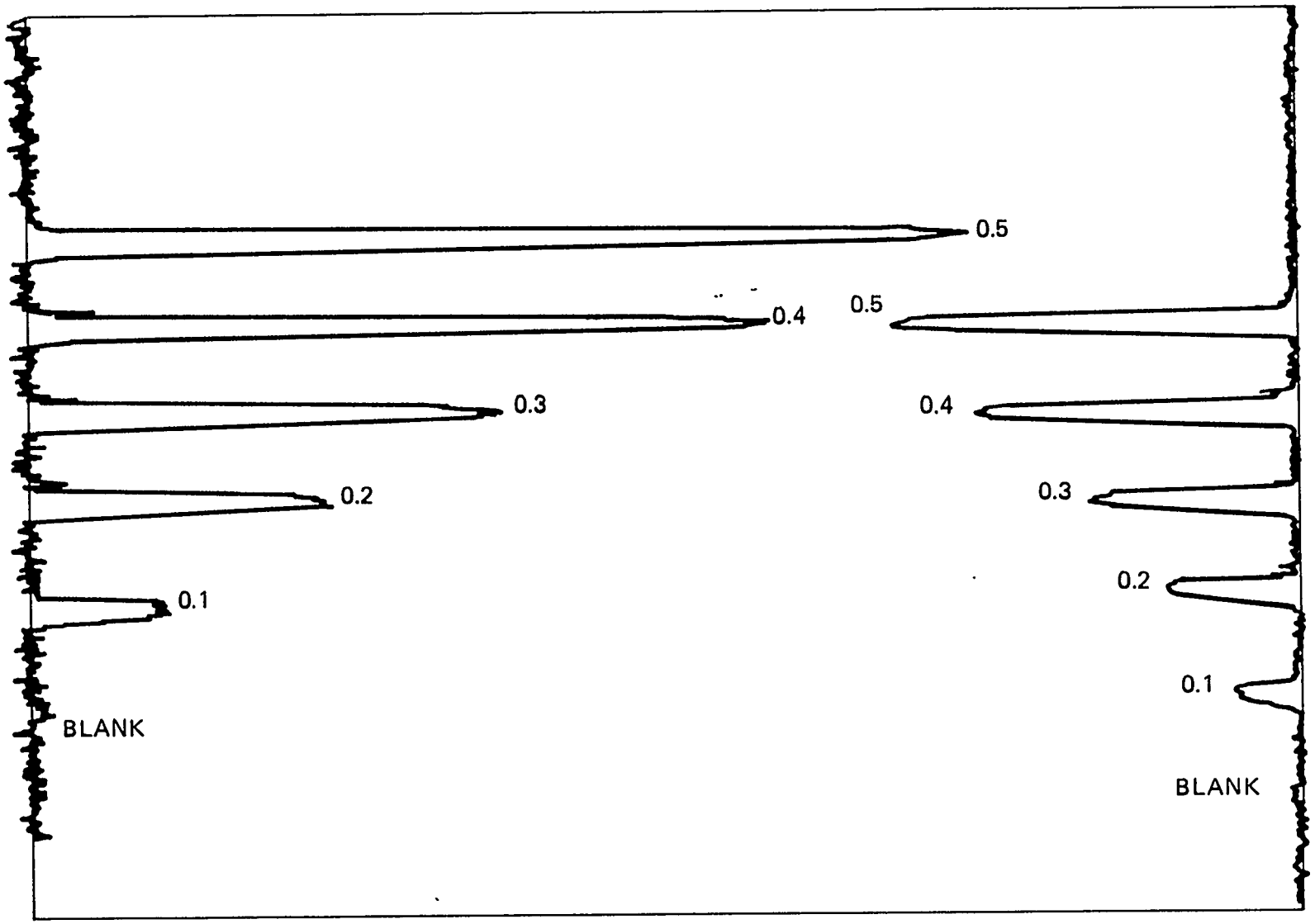
   a. Determine the peak heights of the sample from the strip chart.

   b. Read the mercury concentration of the sample from the standard curve.

   c. Calculate the mercury concentration of the sample from:

$$H = \frac{M}{G}$$

   where: H = mercury concentration in ppm,
   M = micrograms of mercury in sample solution, and
   G = sample weight in grams.



Channel A

Figure 3. STRIP CHART PRINT-OUT OF MERCURY STANDARDS

Channel B

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Oak Ridge Y-12 Plant

Andrew, R. E.
Barton, T. H., Jr.
Bernander, N. K.
Briscoe, O. W.
Carter, M. H., Jr. (5)
Cagle, G. W.
Cole, S. H.
Dorsey, J. G.
Ferguson, J. E.
Franklin, J. C.
Kent, R. H.
Mills, J. M., Jr./DOE-TIC (28)
White, J. C.
White, L. E. (5)
Y-12 Central Files (Y-12RC)
Y-12 Central Files (5)

Paducah Gaseous Diffusion Plant

Katzel, V. C.

Rockwell International - Rocky Flats

Carpenter, R. L.
Nelson, R. C.

Savannah River Laboratory

Hyder, M. L.
Stetson, N.

United States Geological Survey - Denver

Clebsch, A., Jr.
Offield, T. W.

Source Term Uncertainty

air

CONCENTRATIONS

AIR FLOW

Hg vapor meter:

?

11-14-57

.01 – 1.5 mg/m³

reliable range

Upper LOD

> 2.50 mg/m³

Water

CONC

FLOW

1956 Lower LOD

< 0.1 mg/L

per Napier, "off by factor of 2"

1962 Lower LOD

<0.01 mg/L

send evidence to: Lindberg
Bloom
Turner
and poll!

* get Jade HP Report

DETECTION OF MERCURY VAPOR

VAPOR DETECTION EQUIPMENT

As soon as large quantities of mercury were utilized in the ADP processes, methods were investigated by the Health Physics and Industrial Hygiene Groups for detecting the mercury vapor present in the air. Only three commercially available instruments were found. One, manufactured by the Co. and operating on a phototube absorption method was found unreliable and difficult to keep in repair. A second, the Mercury Vapor Detector, Type B, which employed the principle of the color change of selenium sulfide coated paper, was found too unreliable due to its high sensitivity to temperature and atmospheric conditions. The third, the Instantaneous Mercury Vapor Detector, was found reliable and although it is not a fully portable instrument, it has been used successfully in the Colex Plants.

The General Electric Instantaneous Vapor Detector

The Instantaneous Vapor Detector, operates on 110 volts alternating current, weighs 35 pounds, and is equipped with a neck strap harness which, within the limitations of the power cord, makes the instrument "portable". The harness allows the operator full use of both hands to make zero adjustments, to hold the air sampling tube at any desired level (usually at breathing level), and to record the mercury vapor concentration. The air is continuously drawn in to the instrument by means of suction from a blower and passed through a chamber containing two phototubes one of which is shielded by Pyrex glass. An ultra violet mercury lamp emitting 78% of its energy at 2537 angstroms (which is absorbed by the Pyrex glass) is directed toward the phototubes. The tubes are connected in a bridge circuit. Since the air sample passes by both tubes, any substance which alters the beam of light with energy other than 2537° A., affects both sides of the bridge circuit equally. The bridge circuit is balanced with pure air just prior to use. When air containing mercury vapor passes through the unit, the mercury vapor absorbs the ultra violet light at 2537° A. and unbalances the bridge. The degree of unbalance is proportional to the mercury vapor concentration in the air. The output is read directly on a milliammeter. Each vapor detector has its own milliampere-mercury vapor concentration calibration chart from which the vapor concentration is obtained. The meter has been found accurate and sensitive over the range 0.01 to 1.5 mg/m^3.

Greater Sensitivity - When greater sensitivity was desired for the study of respirator contamination, a Vapor Detector was modified slightly. The blower was removed and two quartz cells (500 cc volume) were placed between the phototubes and the U.V. lamp. The cells were so installed that they could be evacuated and a small volume of air admitted for measure. The meter, so modified, was used successfully in the testing of rubber and other small samples.

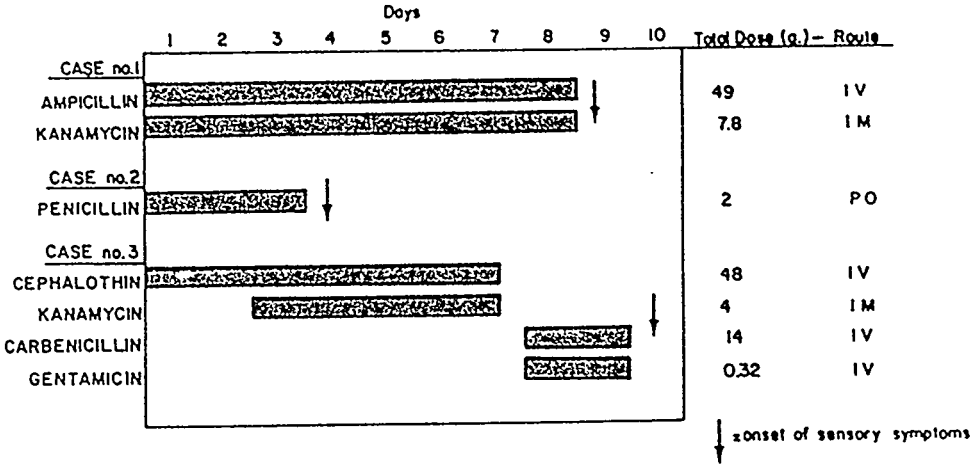

Fig 1. Relationship of antibiotic dosage level and route to the onset of sensory symptoms.

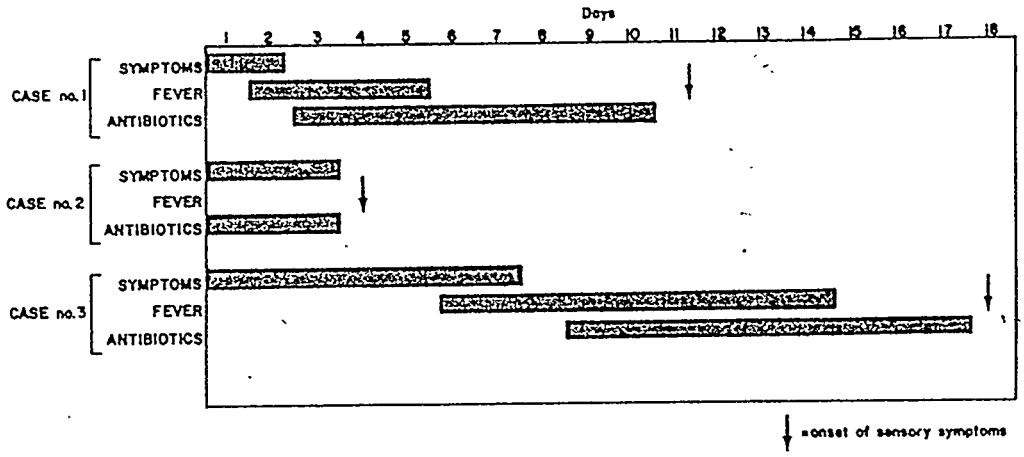

Fig 2. Temporal relationship of antibiotic therapy and fever and other symptoms of infection to the onset of sensory symptoms.

ropathy syndrome associated with malignancy, for the following reasons: (1) there has been no evidence of malignancy after long intervals in two cases; (2) the pattern of clinical disability preferentially affected functions of large-diameter fibers (in contrast to the carcinomatous subacute sensory neuropathy, in which sensory loss involves all modalities); (3) the time course was that of a rapidly progressive, monophasic illness; (4) there were no associated neurological abnormalities in these patients, while dementia and cranial nerve and brainstem signs occur in about half the cases of subacute sensory neuropathy associated with malignancy [3, 4].

The details of antibiotic treatment and relation to onset of sensory symptoms are set forth in Figure 2. Although two of the three patients received kanamycin, which is known to be ototoxic, the only antibiotic common to all three was penicillin or its semisynthetic derivatives ampicillin and carbenicillin. In no case was there an excessive total dose of penicillin or its derivatives, nor was there a recognizable pattern of multiple antibiotic usage to suggest drug interaction. Considering just penicillin and its derivatives, sensory symptoms began on the eighth, fourth, and fourth days, respectively, after initiation of antibiotic treatment. If these three instances of acute sensory neuronopathy are related to preceding administration of penicillin or its derivatives, this range of latency (four to eight days) suggests direct toxic action on large primary sensory neurons. For example, in experimental doxorubicin neuronopathy, morphological changes occur in four days.

It is also possible that infectious or parainfectious-related damage of craniospinal sensory ganglia, broadly analogous to the immune-mediated Guillain-Barré syndrome, occurred in these individuals. Craniospinal sensory cell bodies might be directly

from Y-1185-DEL
"Control of Hg Vapor in Colex Ops" 42
11-14-57

Portable Mercury Vapor Tester

Although the G. E. Detector is considered portable, it has two disadvantages. First, the weight of 35 pounds is somewhat excessive for carrying around process areas. The second, and major disadvantage, is the long (up to 275 ft) cord needed to supply the necessary alternating current. In addition, a Sola voltage regulator is necessary. Several attempts have been made to overcome these difficulties with the greater effort being placed on a self powered meter. The first battery powered unit designed used a photomultiplier to obtain the desired voltage for the standard General Electric supplied U. V. lamp and phototubes. That meter was tested and found unstable in the region of 0.1 mg/m^3 mercury vapor concentration. The second meter was designed with lower voltage phototubes and with no photomultiplier. This meter was not found stable enough to use.

A third, battery operated, self-contained mercury vapor detector was designed incorporating a low voltage blower. All components of this meter have been field tested and found satisfactory; several units are now in routine use.(8)

Hand Monitors

Since the use of hand "counters" or monitors had proven successful in causing personnel to be aware of possible hand contamination on projects involving radioactive chemicals it was felt advisable to adapt the principle for use with personnel whose work involved contact with mercury. Thus, an instrument was designed which would provide an indication of mercury contamination on the hands. Adequate sensitivity was provided in a range from zero to one milligram per cubic meter of air.

The instrument provided simultaneous sampling of the atmospheric environment of the instrument at two ports, plus the mercury vapor from the hand at one port. The two air samples were drawn through similar ultraviolet absorption cells where phototubes provided electrical signals inversely proportional to the mercury vapor present. The two signals were compared in a vacuum tube voltmeter circuit, and the output was displayed on a microammeter calibrated in terms of mercury contamination.

The electronics provided an alternating current excitation for the ultraviolet lamp, and a regulated direct current voltage for the phototube detectors and the voltmeter. Electrical balance adjustments for the phototubes and voltmeter, as well as a sensitivity control, were provided.

A schematic diagram (Figure 14) and a photograph (Figure 15) provide an adequate visual description.

Instruments were installed in both Colex plant lunch rooms and have provided over one year of continuously satisfactory operation.

Badge Type Vapor Detector

Considerable effort was expended in attempting to develop a personnel badge-type monitor that would detect the total vapor to which an employee was

Complete blood count, erythrocyte sedimentation rate, and urinalysis were normal, and the chest roentgenogram cleared completely. Lumbar puncture revealed cerebrospinal fluid protein of 175 mg/dl and no cells. Electrodiagnostic studies showed normal motor nerve conduction velocities and distal latencies but absence of all sensory potentials. Diagnostic studies to rule out an occult neoplasm were negative, including intravenous pyelogram, upper gastrointestinal series, serum protein electrophoresis, tomograms of the lung and mediastinum, and bronchoscopy with bronchial washings. He was discharged unchanged.

In the five years since his initial admission there has been no substantial change in the patient's sensory deficits. He walks uncertainly with a broad-based, unsteady gait, and dresses and feeds himself with difficulty. He had received antibiotics, including penicillin and ampicillin, before his illness, and in the five years since his admission he has been given erythromycin without incident.

Discussion

We report three adult patients who developed rapidly progressive sensory symptoms, profound generalized impairment of position and vibration sense, and severe sensory ataxia. All tendon reflexes were absent. Strength was normal, and there was no muscle atrophy or signs of denervation on electromyography. Nerve conduction studies were consistent with a purely sensory process. The sensory disturbance was maximal within one week of onset and subsequently remained static. There has been no evidence of occult neoplasm after follow-up of two, three, and five years, respectively. This constellation of findings is most compatible with an acute, diffuse alteration in extramedullary sensory neurons and represents a well-defined, easily recognized clinical entity.

A recent nosological scheme of toxic peripheral nervous system disease proposes that three of the basic structures—axons, myelin, and neuron cell bodies—may be selectively vulnerable to exogenous toxins [9]. Thus, many of the toxic neuropathies can readily be classified as toxic *distal axonopathies,* toxic *myelinopathies,* or toxic *neuronopathies.* A reasonably consistent clinical profile exists for disorders in each of these subgroups. For example, the toxic axonopathies are characterized by gradual or subacute onset of symmetrical sensorimotor dysfunction which starts distally and evolves proximally, as if "dying back." Upon removal of the toxin, recovery follows slowly. The toxic myelinopathies often have a rapid onset of predominantly motor dysfunction in cranial and extremity nerves, which need not be most pronounced distally. These conditions may be associated with a high cerebrospinal fluid protein, and recovery is relatively rapid. Toxic neuronopathies are usually sensory, and the clinical pattern consists of acute or subacute loss of sensory and autonomic functions of cranial and extremity nerves with poor recovery [9]. The classification, although propo for the toxic neuropathies, also applies to some o causes of peripheral nervous system disease: i.e., the Guillain-Barré syndrome is a peripheral myelinopathy, uremic and nutritional neuropathies constitute axonopathies, and the subacute sensory neuropathy associated with carcinoma is a ganglion neuronopathy. Because of the simultaneous onset throughout the body including the face, rapid evolution, and limitation to the sensory system, the likely location of the primary lesion in our three patients is in the extramedullary sensory neuron cell bodies. Large primary sensory neurons appear to be most vulnerable, as evidenced by the predominant proprioceptive defect. One might predict that secondary posterior column degeneration of the spinal cord would occur with passage of time. Low-amplitude or unobtainable sensory potentials are consistent with secondary breakdown of peripheral axons associated with degenerating neurons in the dorsal root ganglia.

It is extremely unlikely that our patients had a demyelinating neuropathy, because of the pure sensory nature of the disease, normal motor nerve conduction velocities, and poor recovery [2]. Axonal neuropathy also seems a remote possibility since these generally are distal, have a slower evolution, and rarely aff the short trigeminal axons.

In two of the patients, symptoms appeared first in the distribution of the short trigeminal nerve fibers. This observation accords with the notion that in the *neuronopathies*, the effects of secondary degeneration may be apparent in the short axons of the gasserian ganglion pari passu with changes in long axons emanating from the dorsal root ganglia in the lumbar region. Observations in the experimental neuronopathy produced by doxorubicin and pyridoxine have confirmed this simultaneous pattern of ganglion cell change [8, 10]. The properties which may render the dorsal root ganglion cell perikaryon selectively liable to toxic, infectious, or immune attack are poorly understood and may include unelucidated biochemical features of cytoplasm or membrane; or they may reflect unique morphological features, e.g., the blood-brain barrier is incomplete in the dorsal root ganglion and may permit penetration by exogenous or endogenous agents [6].

The cause of the sensory neuronal degeneration in our patients is unclear. Potential toxin exposure was limited to treatment with a variety of antibiotics (Fig 1) and, aside from pneumonitis, little direct evidence supports a viral or immunological assault on the sensory ganglia in these individuals. It is also unlik that these cases represent the subacute sensory ne

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INTER-COMPANY CORRESPONDENCE

COMPANY CARBIDE AND CARBON CHEMICALS COMPANY LOCATION Post Office Box Y OAK RIDGE, TENN.

TO LOCATION F. V. Tilson Bldg. 9201-4

ATTENTION

COPY TO G. Jasny, J. E. Perry, J. S. Hurst, J. W. Strobecker, J. Coogin, File

DATE December 9, 1955

ANSWERING LETTER DATE

SUBJECT Source Samples for Solvent Vapor

The following source samples were taken in building 9201-4.

#10 Cascade, 3rd Level

Location	Concentration MG/M³	Remarks
At opening to packing gland on Pump	0.32	
Ditto - Pump	0.53	
1 inch from plate that covers opening to packing gland on Pump	> 2.50	
Ditto - Pump	2.42	
Ditto - Pump	> 2.50	
Ditto - Pump	> 2.50	
Ditto - Pump	1.19	
Ditto - Pump	> 2.50	
Ditto - Pump	> 2.50	
Ditto - Pump	> 2.50	
1 inch above floor drain E of Pump	0.80	
1 inch above floor drain SW corner of cascade	0.52	

1955 Upper Bound = 2.50 mg/m³

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VCX-80 (6-54)

f.56
3/12

INTER-COMPANY CORRESPONDENCE

(INSERT NAME) COMPANY CARBIDE AND CARBON CHEMICALS COMPANY LOCATION Post Office Box Y OAK RIDGE, TENN.

TO LOCATION L. C. Emerson, Y12RC Building 9995

DATE March 9, 1956

ANSWERING LETTER DATE

ATTENTION

COPY TO W. A. Pfeiler
C. R. Sullivan, Jr., M. D.
L. J. LaFrance
L. C. Johnson
File

SUBJECT Results of Poplar Creek Wate Analyses for February, 1956

The following is a listing of the average activity in the east fork of Poplar Creek during the month of February, 1956, as determined from daily water samples composited and analyzed weekly.

Alpha Activity

Week Ending	Results d/m/liter
2-3-56	70
2-10-56	106
2-17-56	163
2-24-56	273

Beta Activity

Week Ending	Results d/m/liter
2-3-56	950
2-10-56	433
2-17-56	2,933
2-24-56	3,600

Mercury Concentrations

Week Ending	Results mg/liter
2-3-56	used→<0.1 (½ LOD?, $\frac{LOD}{\sqrt{2}}$?)
2-10-56	.27
2-17-56	.18 .22 $\bar{x}$
2-24-56	.34

Merwyn Sanders
Merwyn Sanders
Health Physics Department

MS/j

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UNION CARBIDE

INTERNAL CORRESPONDENCE

UNION CARBIDE NUCLEAR COMPANY • POST OFFICE BOX Y. OAK RIDGE, TENNESS

To (Name) J. D. McLendon, Y12RC
Company
Location Building 9711-1

Date October 3, 1962
Originating Dept. Radiation Safety
Answering letter date

Copy to G. J. Angele
Neal Dow
L. C. Johnson
H. T. Kite
J. F. Morehead
J. W. Strohecker
C. R. Sullivan, Jr., M. D.

Subject Surface Water Sampling
August, 1962

The following gives a listing of water sample results taken from Poplar Creek, Bear Creek, and settling pits:

Location	Date	Alpha μc/cc	Beta μc/cc	Mercury mg/l	Total Flow gal/week
Poplar Creek*	8-3-62	2×10^{-7}	8×10^{-8}	.02	91.6×10^{6}
	8-10-62	2×10^{-7}	9×10^{-9}	.01	84.9×10^{6}
	8-17-62	2×10^{-10}	9×10^{-10}	< .01	79.1×10^{6}
	8-24-62	1×10^{-10}	1×10^{-9}	< .01	77.4×10^{6}
	8-31-62	6×10^{-10}	3×10^{-11}	< .01	76.3×10^{6}
Bear Creek*	7-31-62	9×10^{-8}	None detected		
	8-7-62	6×10^{-8}	8×10^{-9}		
	8-14-62	2×10^{-7}	8×10^{-7}		
	8-21-62	1×10^{-10}	9×10^{-10}		
	8-28-62	2×10^{-11}	2×10^{-10}		
SW Settling Pit	7-31-62	3×10^{-8}	1×10^{-7}		
	8-7-62	1×10^{-8}	4×10^{-8}		
	8-14-62	1×10^{-8}	4×10^{-8}		
	8-21-62	2×10^{-8}	5×10^{-8}		
	8-28-62	5×10^{-8}	2×10^{-7}		

*The permissible limit for uranium alpha in drinking water outside of controlled areas is 3×10^{-5} μc/cc (microcuries per cubic centimeter). The permissible limit for unidentified beta emitters in drinking water outside of controlled areas is 2×10^{-5} μc/cc.

M-324 HRS

UNION CARBIDE

INTERNAL CORRESPONDENCE

NUCLEAR DIVISION

POST OFFICE BOX Y, OAK RIDGE, TENNESSEE 37830

To (Name) J. M. Napier
Division
Location Building 9202 — MS 1

Date September 8, 1977
Originating Dept. Process Analysis
Answering letter date Y/HG-0489/1
Subject Mercury Bottle Filling Overage

Copy to D. J. Bostock, J. T. Bradbury, N. Dow, T. H. Ebert, V. B. Gritzner, D. W. Smith, R. D. Williams, File (RC)

A random sample of 77 bottles of mercury were weighed to ascertain the extent to which bottles had been overfilled, i.e., the extent to which the amount of mercury exceeded the nominal amount of 76 lbs per bottle. This sample represented a population of 155,009 bottles of mercury which were filled using the same procedures as were used for the bottles in the sample.* Of the 77 bottles in the sample, 76 bottles were found to have sufficient capacity to hold at least 76 lbs of mercury.

Attached is a histogram of the overages in terms of ounces over 76 lbs in these 76 bottles. The mean of the very skewed distribution is 4.816 oz. If we apply this mean to the entire population of 155,009 bottles, we have a population overage of 46,658 lbs.

The 77th bottle in the sample had capacity to hold no more than 74 lbs 11 oz. Since we have been reusing the bottles in which the mercury was originally received in the rebottling program, it is clear we received 74 lbs 11 oz or less in this bottle. In a sample of 77 bottles, we have found one such bottle. The 95% confidence limits on this number are from 0 to 3 such bottles (inclusive) in samples of 77 bottles from this population.

R. D. Smith

R. D. Smith

RDS:mdh

Attachment

RECEIVED SEP - 8 1977 V. B. GRITZNER

* Per D. W. Smith, Metal Preparation.

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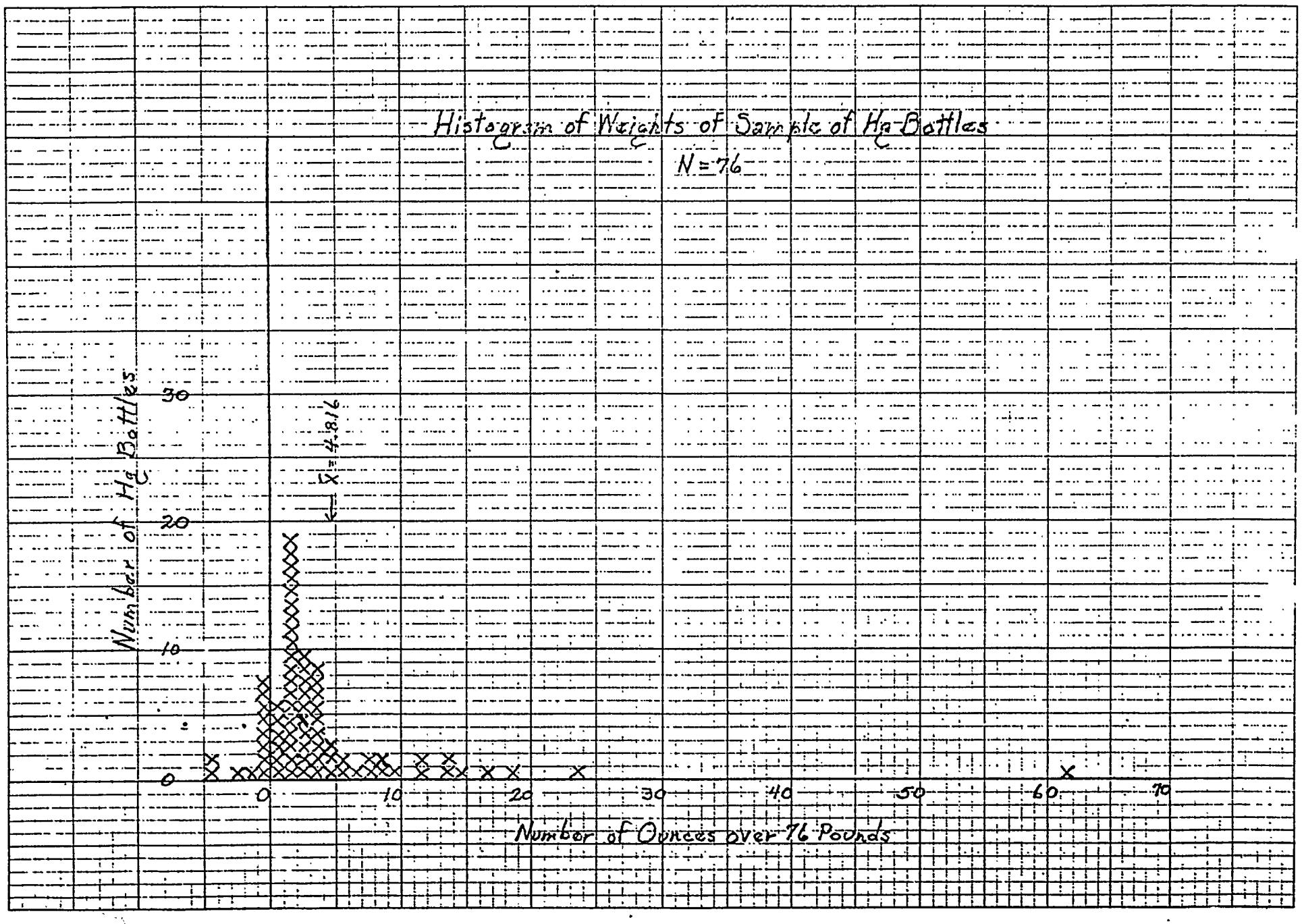
"PRECISE" TRADE MARK 10450 - 10 10 X 10 TO 1 INCH Océ-Elliott Inc. océ



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Uncertainty

Author(s) Requestor: Steve Wiley

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P. L. McKenney Technical Information Office 5/26/95 Date

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Detw -- Early '57?

M-836

Mr. W. C. Moore

Solvent Air Analyses

At your request, the results of solvent air analyses have been reviewed. The problem of determining an appropriate rate of sampling has been investigated using two possible criteria. It is recognized that other criteria could be employed. Those discussed below, however, are in my opinion likely to be most useful in this problem.

The first criterion relates to the precision with which monthly averages are determined. The average concentration for each building and for the various areas within each building are computed monthly, and it seems reasonable to require that these averages be determined with fairly small limits of error. The precision of these averages depends both on the variability of the results and on the number of inspections per month. The limits of error to be associated with monthly averages assuming the variability presently observed are related to the frequency of inspection in Chart I. The upper curve shows the limit of error for the average of a specific area and the lower curve the limit of error for a building average. With only five inspections per month the building average could be determined within ± 0.002 and the average of a given area with ± 0.036. The average concentration at present is only about 0.042 mg/m^3 , five inspections per month would be sufficient to establish in almost all cases that the monthly average is significantly below the MPL of 0.10 mg/m^3 .

Chart II shows the limits of error which would apply to monthly averages if the variability were that observed in November, 1956. The average concentration at that time was about 0.056 mg/m^3. Chart III shows limits of error for the conditions of January, 1956, when the average concentration was about 0.19 mg/m^3 . It can be seen from the curves that under present conditions much fewer inspections are required than in the past to obtain averages of similar

Duplicate of letter report McMullen to Moore, [illegible] see Y/HG-0174/2

checked Y/HG-174 Not True -- SMFlack

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reliability. As area average can presently be determined with a limit of error of ± 0.04 mg/m^3 with about 5 inspections per month. In January, 1956, 20 inspections would have been required to establish a month's average with this precision.

A second criterion of appropriate sampling rates might require that any serious change in concentration in a specific area be detected within a specified period of time. We might require, for example, that an increase in concentrations to twice the MPL be detected within 24 hours. If this requirement were rigidly imposed, each area would have to be inspected every twenty-four hours. Even with this polich, however, changes of short duration are not likely to be detected. A change lasting only twelve hours has only a fifty percent chance of detection if the time of inspection were random. The situation may at present be somewhat worse than this, since all inspection is performed on the day shift. Any difficulties peculiar to evening and night shift, or to weekends and holidays, are likely to be overlooked consistently.

The question of the manner in which difficulties of this type are likely to be discovered seems to me to be very critical at this point. Undoubtedly many increases in concentrations result from factors which are known to have this effect. A review by operations personnel of the sources of information leading to corrective action might be in order. If there are numerous instances in which undesirable increases are discovered as a result of routin inspection alone, continued daily inspection may be appropriate. If, on the other hand, such instances are comparatively rare, the requirement of reliable monthly averages of concentration may suffice.

There are, of course, other considerations, such as the psychological effect of having inspectors around most of the time. If any reduction is made in the frequency of inspection, it is recommended that the order in which inspections are performed each week be determined with a chance method. This approach should tend to discourage any relaxation in housekeeping standards which might result

from a knowledge of when the inspector will appear. Also it would improve the chances of early detection of changes in areas adjacent to those inspected.

Chart I
Precision of Solvent Air Analysis Averages
Variability as at Present

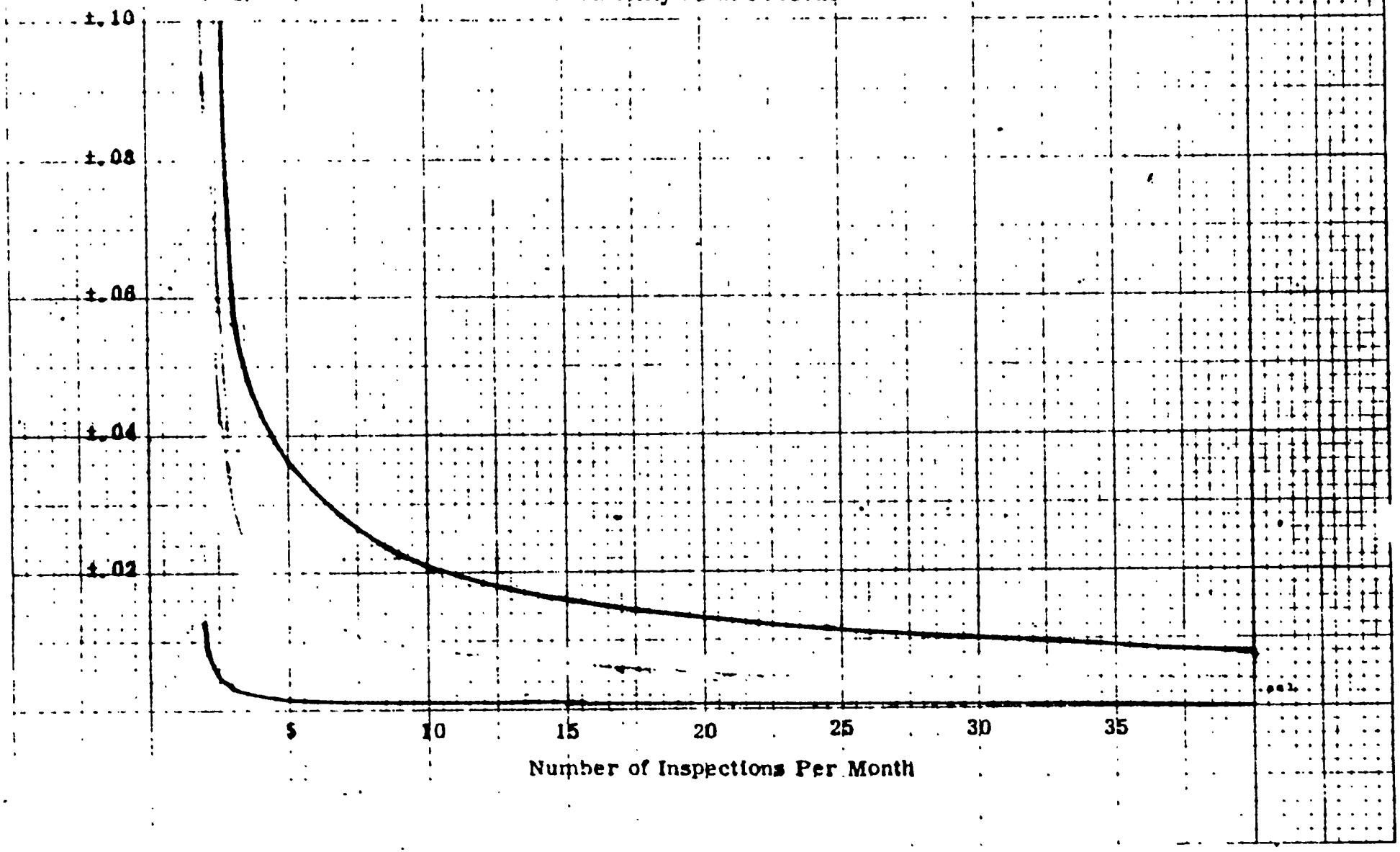
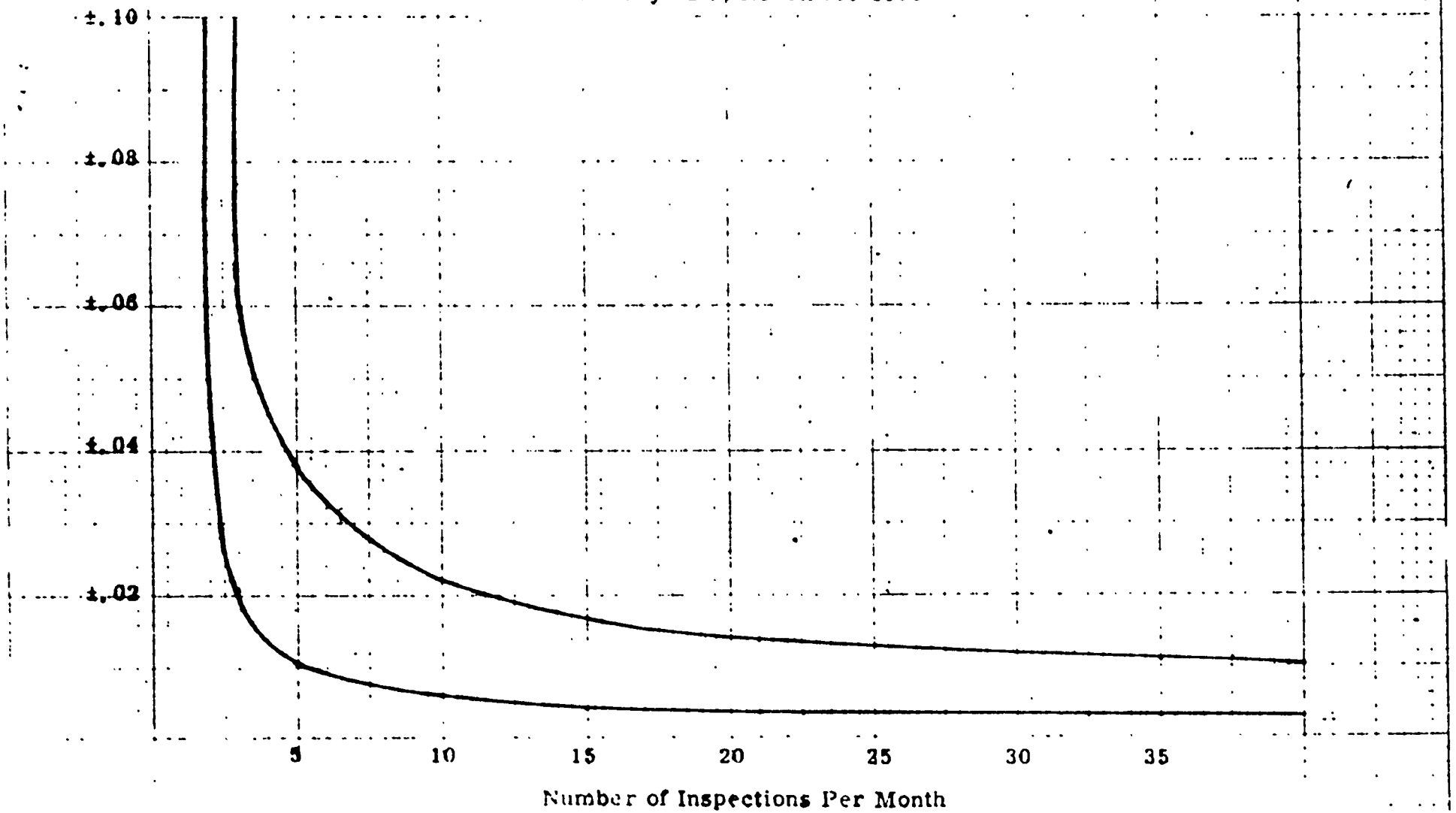


Chart II

Precision of Solvent Air Analysis Averages
Variability as in November 1956



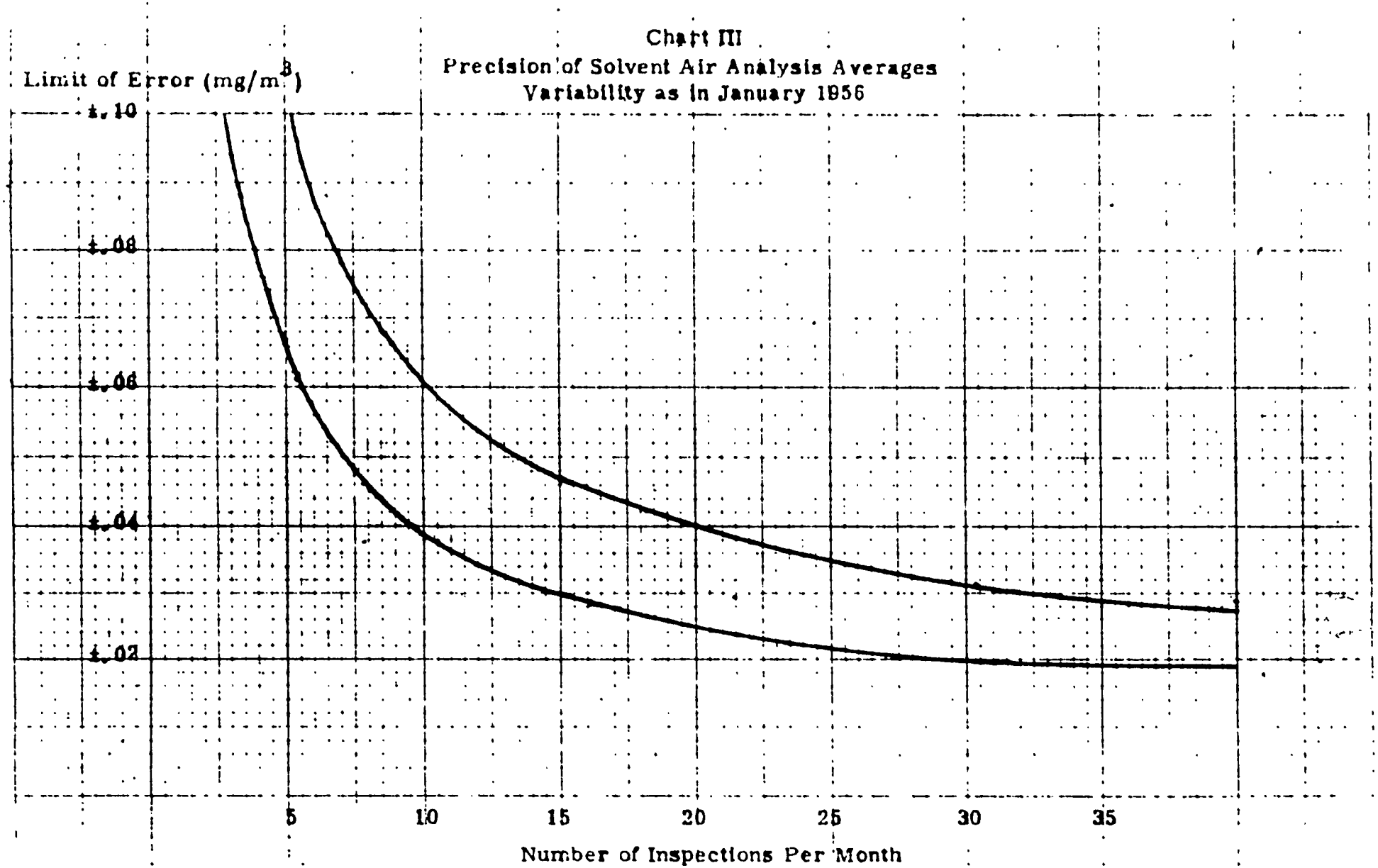


Chart III
Precision of Solvent Air Analysis Averages
Variability as in January 1956
Limit of Error (mg/m³)
±.10
±.08
±.06
±.04
±.02
5
10
15
20
25
30
35
Number of Inspections Per Month

FRONTIER GEOSCIENCES
ENVIRONMENTAL RESEARCH CORPORATION
414 Pontius North • Seattle, WA 98109
(206) 622-6960 • fax: (206) 622-6870

September 5, 1996
Eric M. Prestbo Ph.D.
Atmospheric Hg Group Leader

Ms. Susan M. Flack
Senior Associate Health Scientist
McLaren/Hart Environmental Services
2870 Kalmia Ave., Suite 308
Boulder, CO 80301-5915

Dear Ms. Flack

As requested I have read the two documents you sent, Mercury Building Air Monitoring at Y-12 and Portable Mercury Vapor Detector, in order to estimate the variability in mercury air concentrations determined with a portable mercury vapor detector.

By variability I assume that you are asking for the precision of the measurements in the form of a coefficient of variation (also known as the % relative standard deviation %RSD).

Based on the information presented to me, I estimate the coefficient of variation to be ± 40%.

The principle of the instrument and high concentrations in Y-12 suggest that the precision could be much better than I have estimated, however without data I choose to be conservative. I could better estimate the precision of the portable mercury vapor detector if I had access to some measurements, detection limits and ideally, an instrument to test in our laboratory. If there were duplicate measurements made, or if two measurements were made on separate days, in the same location, under the same conditions, a coefficient of variation could be calculated and provide a much more defensible estimate of precision. I would recommend this course of action to further support your calculations.

I will not estimate the relative accuracy of the instrument. My confidence in the accuracy of the instrument is quite low, considering all of the following potential causes for systematic error.

- During calibration in the field, hopcalite is used to provide zero air. Although hopcalite will adsorb Hg, breakthrough of elemental Hg is likely. The combination of instruments high flow rates (~15 liter/min), likely storage of the hopcalite in Hg contaminated air which will saturate the filter and continued use of the hopcalite over time will all contribute to breakthrough. If breakthrough

occurred during calibration, the Hg air numbers generated would be systematically high proportional to the breakthrough Hg concentration.

- The upper end for calibration was 3.5 mg/m^3 when the quartz shutter was closed. It is not clear to me why full scale is chosen as 3.5 mg/m^3. It is possible that Hg air values in the Y-12 plant, especially during source measurements were much higher than 3.5 mg/m^3. Saturated air is approximately 13 mg/m^3 at 20° C. This error would then underpredict the amount of Hg in the air.

- Both the pump and tubing are potential sources for air Hg loss or contamination during sampling. For example, if very high Hg air concentrations were measured at a localized Hg source within the building, followed by a measurement in a low air Hg location, Hg carryover from the pump or tubing could significantly affect the latter measurement. This would be further exacerbated by temperature changes - higher temperature may result in significant output from the walls of the pump and tubing.

- Many other measurements are part of the calibration sequence, including two flow and temperature measurements. These measurements are also potential source of systematic error which could be further evaluated.

Finally, if possible, the instrument used for these measurements may still be available for evaluation. Our laboratory has the capability to measure both the precision and accuracy of the instrument at the levels of mercury observed in the Y-12 buildings.

Thank you for offering us the opportunity to help you with this project. Please call if you have any further questions or would like to further refine these estimates.

Sincerely,

Eric M. Prestbo Ph.D.

Frontier Geosciences, Inc.

Eric M. Prestbo Ph.D.
414 Pontius Avenue N.
Seattle Washington 98109

Voice: 206 622 6960
FAX: 206 622 6870
Email: ericp@frontier.wa.com

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TO:	Susan Flack
INSTITUTE:	McLaren Hart Env. Serv.
DATE:	9/5/96
PHONE:	303 449 8471
FAX:	303 939 8318
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COMMENTS
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