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An Air Sampling System for Evaluating the Thyroid Dose Commitment Due to Fission Products Released From Reactor Containment

Final Report

Prepared by C. Distenfeld, J. Klemish

Brookhaven National Laboratory

Prepared for
U. S. Nuclear Regulatory Commission

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Abstract

Accidental releases of radioactivity from fission reactors will consist of active vapors and aerosols. Composition of the released plume or cloud will depend on the energy of release and fission product volatility. In accidents at Windscale and SL-1, ^{131}I was the predominant isotope present in both the initial cloud and later release. Thus an air sampling system was developed for efficient radioiodine collection.

The air sampling, readout, and dose assessment system was developed to be used in the environment after loss of containment accidents. The system can detect less than 1 rem dose commitments to thyroids of 5 year old children for immersion times of 10 hours or less.

The air mover can be operated on either 110V AC power or 12V DC power available from vehicles with cigar lighter sockets.

An inorganic silver loaded silica gel adsorber was developed for high methyl iodine, HOI, and elemental iodine efficiency and low noble gas efficiency.

A peal away high efficiency particulate filter permits the gaseous and particulate sample fractions to be evaluated separately. Predicted particulate iodine is combined with the adsorbed component to account for the total radioiodine in a given sample.

Acknowledgments

The authors would like to thank Dr. John Baum of Safety and Environmental Protection, Brookhaven National Laboratory, for many excellent suggestions and for an excellent review of this paper.

Victoreen Instrument Division staff members provided the test GM tubes for our use. Mr. Edward Williams, Chief of RADEF, Instrument Test Facility, assisted us in obtaining the GM tubes, and Mr. Gerry Achtellik of TGM Detectors, Incorporated, provided the modified TGM detectors in a timely and efficient manner.

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1. Introduction

Nuclear reactors are considered to be safe power sources. In spite of a low accident history, a small possibility(1) exists for damaging accidents. This could lead to radioactive releases from containment and to human exposure. Ingestion and inhalation allow radioiodine to efficiently enter the thyroid gland. The thyroid's small size and affinity for iodine and postulated significant iodine containment release fractions result in large predicted potential exposures should an accident occur.

Inhalation is expected to be the most important initial pathway. Air monitoring can provide the data base for exposure control.

Approximately 45 relatively volatile radionuclides may be released including the five prominent iodine isotopes. Radionuclide mix is affected by the detailed failure mode and delay time. Thus, an air monitoring means must be specific for iodine in the presence of noble fission gases and other particulate fission products.

Costly measurement methods using gamma analysis can be avoided by developing a sample specifically for iodine, thereby permitting any beta or gamma detector to be used for measurement, Figure 1.1. Particulate fission products include dozens of noniodine radionuclides. Use of a prefilter, Figure 1.2, before the adsorber bed separates the activity into gaseous and particulate fractions, and allows a determination of gaseous radioiodine. Appendix A-1 contains information on particulate collection efficiency and cannister evaluation with significant activity on the particulate filter.

Adsorption of fission gases relative to iodine can be reduced by using an appropriate inorganic adsorber. Several commercial inorganic adsorbers were tested, but were too expensive or inefficient for the organic or hypoiodous acid forms of iodine. A silver impregnated silica gel adsorber was developed that had over 90% efficiency for collection of radioiodine for sampling times of several minutes. The material provided corresponding Xenon efficiencies of less than .04% at temperatures above 7°C.

The air sample size needed for reliable detection of a given air concentration depends on detector sensitivity, flow rate, and sampling time. Field monitoring under accident conditions requires prompt measurements for proper use of time, equipment, and operator exposure. For these reasons, the Federal Interagency Task Force on Off-Site Emergency Instrumentation for Nuclear Incidents set a maximum of 5 minutes for air collection. Two degrees of freedom remain, detector sensitivity and flow rate.

Flow rate is governed in part, by the power available for air movement. Air sampling away from power lines requires portable generators or power derived from automotive electrical systems. Battery power supplies are inappropriate due to excessive weight and expense. As mentioned earlier, the desirable solution is a significant number of inexpensive air sampling apparatus. Thus, use of automotive electrical systems is the least expensive solution, Figure 1.3. Two power connections to automotive batteries are economically possible, direct clamping, or use of cigar lighter sockets. The safer and generally better solution is the latter. Factory installed wiring limits this source to about 150 watts. Vacuum motors of this size can move 4 to 7 ft ^{3} min^{-1} through the pressure drop of an adsorber-filter, thereby setting the flow rate at $\sim$ 5 ft^3 min^{-1}.

For operational flexibility, the air sampler can also be used on standard 110V AC power. Air flow regulation and control assures a uniform sampling rate for either power source.

Mechanical and electrical reliability of the air sampler must be considered. Average motor lifetime must exceed the projected total maintenance running time and the running time for an accident.

The remaining variable is detector sensitivity. Economy and long term calibration stability make Geiger-Müller detectors desirable. Large numbers of CDV-700 G.M. instruments were manufactured for civil defense purposes and are readily available at little or no cost. G.M. detectors are known for high beta and low photon efficiency. Photon sensitivity can be increased by changing the standard G.M. tubes, with stainless steel cathodes, to ones with higher Z cathodes. The higher sensitivity can also be used to lower the minimum detectible levels for water, milk, pasturage, and thyroid uptake.

Field testing of the air sampler and detailed operating instructions are a requirement for effective use of this device. The operating instructions should include general reactor accident orientation, air sampler team exposure control methods, instrument checkout procedures, air sampling, filter-adsorber measurement methods, and prediction of the dose-commitment instructions.

Summary

An air mover was developed to draw $5 \pm .5$ ft ^{3} min^{-1} through a combined HEPA filter and absorber. The air mover can be operated on 110V alternating current or 12V direct current available from standard automotive electrical systems. Air mover cost was a major design consideration. The third (last) prototype was used to estimate production cost of 100 air movers. The overall unit cost for an air mover and a filter-canister assembly was between $157 and $207.

A 4% silver loaded silica gel adsorber was developed that would trap organic iodine, hypoiodous acid, and elemental iodine with better than 90% efficiency under severe ambient conditions, for a 5 minute collection cycle. The principal advantage of the 4% silver loaded silica-gel adsorber was low noble gas adsorption efficiency. Xenon adsorption efficiency was less than $5 \times 10^{-3}\%$ at $55^{\circ}C$ and $4 \times 10^{-2}\%$ at $7^{\circ}C$. The last figure is about 200 times better than charcoal at the same temperatures.

High photon efficiency G.M. detectors were tested for improved filter-adsorber readout sensitivity. A specially filtered Victoreen 6306 tube provided a sensitivity improvement of more than 10 times the standard CDV 700 probe. The new Victoreen probe was designed to be about a factor of 2 less sensitive to ^{135}Xe than ^{131}I. The standard CDV 700 probe is more sensitive to ^{135}Xe than ^{131}I.

Reliability of the air mover was tested in a warm environmental chamber. Average lifetime was measured and found to be about 85 hours. This compared favorably with an estimated 7 hours needed for a 20 year service life.

The overall system was evaluated by 6 student groups who received no prior instruction on use of the system and derived all necessary information from the detailed procedures given in Appendix A-2. All groups were able to take successful air samples. About half did not succeed in evaluating their air samples correctly due to confusion with this part of the procedure. Separate procedures for air collection, measurement of the filter-adsorbers, and conversion of the measured values to the dose commitment should reduce confusion and improve results.

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The probability of a reactor accident was estimated (1) to range from 1×10^{-4} to 5×10^{-7} per reactor year. The less probable, and more damaging, accidents would have U.S. probability of about 4×10^{-3} per hundred power reactors life times of 40 years assumed per reactor. The small aggregate accident probability and large geographic area potentially involved lead to a desirable solution of a significant number of inexpensive air sampling apparatus which can be stored indefinitely.

Figure 1.1 Canister Evaluation with a CDV-700 GM Counter

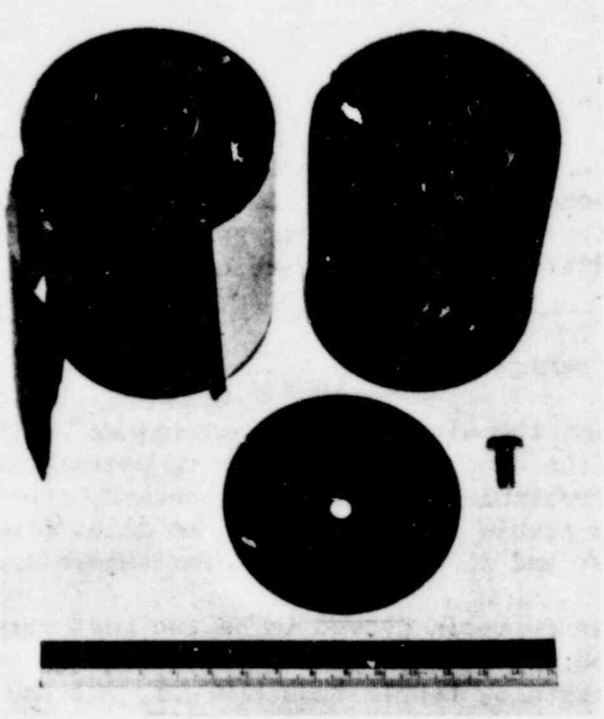

Figure 1.2 Canister Assembly

Figure 1.3 Sample Collection Utilizing 12 Volt DC Power from an Automobile Cigar Lighter Socket

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2. AIR SAMPLER

2.1 Introduction

An air sampler is considered to be an appropriate integration of components to collect, measure, and evaluate airborne activity. In this section, the air mover mechanism and cost of hardware and assembly are considered.

2.2 Air Mover Design Criteria

Design of the air mover is constrained by three criteria. First, the device must be able to operate on standard 110V AC and vehicular 12V DC power; second, the flow rate should be both stable and high enough to allow 5 minute sampling periods; and third, the air mover should cost about $100.

The cost criteria proved to be the most pervasive of all. Unit cost is an aggregate of the price of stock components and materials, fabrication charges, and the cost of labor for assembly. The total material cost was less than $30. per unit. Fabrication cost and assembly charges per unit are expected to be about 5 times this value.

Fabrication represents the largest cost component. Air mover quantities of 100-500 are very small to effectively amortize tooling and die costs. For this reason, the air mover was designed with many stock or modified stock components. Figures 2.1 and 2 .2 are views of nearly all the pieces. The fabricated parts consist mainly of the motor mounting plate, the front bulkhead plate, and the adsorber canister pieces.

Optional use of battery or 110V AC power limits selection to single voltage units for AC or DC, DC to AC invertors or AC generators, or dual voltage motors(3). The dual voltage motor requires ∿ 150 watts DC which can move 5 $\text{ft}^3 \text{min}^{-1}$ through a HEPA filter followed by an adsorber bed. Thus the criteria for low cost, DC operation, and 5 minute sampling significantly reduced design latitude.

2.3 The Air Mover

The air mover housing, shown on Figures 2.1, 2.2, and in Appendix A2, consists of a tubular support structure, a front and back plate, and a perforated motor impeller safety guard. The tubular structure contains a handle, two plate mounting rings and a switch mounting hole.

The front plate is shown on the lower right on Figure 2.1. Filter-adsorber canisters are placed on the central suction tube and retained with the rubber cord. The flow rate control screw is located in the central suction tube and is used to adjust spring tension on the bellows. The remaining two holes ventilate the bellows interior to maintain normal atmospheric pressure within the bellows. A rear view of the bellows is shown on Figure 2.2. The bellows consist of two metal cups, one attached to the front plate and the other capable of longitudinal movement. The flow rate control screw is used to adjust the spring loading. This tends to direct the movable bellows half toward the front plate, closing the air bleed port shown to the left of the spring. During motor operation, the reduction in atmospheric pressure will counteract the loading spring, opening this port. Thus, spring adjustment controls the pressure inside the air mover. The pressure difference between ambient and air mover governs the flow rate through the filter adsorber. Dust loading is not a problem for the 5 minute, 5 ft^3 min^{-1} sample.

The rear plate serves as a vacuum bulkhead and mounting plate for the dual volt motor and AC speed control. The impeller and AC speed control adjusting stub are shown in Figure 2.1. The remaining perforated plate protects the operator.

The Dual Volt motor is designed for about 240 watts on alternating current, nearly double the DC power value. A 600 watt household lamp dimmer is used to reduce the AC power for the proper flow rate.

Direct current power is derived from the cigar lighter socket of any 12 V vehicle. An adapter plug provides for DC operation. Drawings of the air sampler and canister are included in Appendix A-3.

2.4 Air Mover Production Cost

Prices for stock parts and material are itemized in Appendix A-1. A total of $25.50 per air mover includes all hardware costs. The corresponding single canister plus adsorber material cost was $3.57. Quantities for pricing individual items are included in the appendix and vary from 1 to 1000.

The unit labor charges for assemblying 100 air movers and canisters was quoted(4) as $52.00. We think this estimate is high by about a factor of 2 since construction experience is likely to reduce labor cost.

Fabrication estimates were difficult to obtain. A mechanical designer, assigned to Central Shops at Brookhaven National Laboratory, distributed construction drawings to a number of likely private sheet metal companies. Quotations were requested on the basis of 100 units. The sheet metal concerns were too busy to accept what appeared to be a small work order. The BNL mechanical designer estimated $75-125 per unit. Using this range, one complete air mover and filter-adsorber should cost between $157 and $207 for the full assembly charge.

2.5 Initial and Periodic Flow Rate Adjustment

The air mover is operated at 12.8 V DC measured at the cigar lighter socket. A filter canister is connected to a venturi flow rate meter which in turn is connected to the air mover suction tube with tygon tubing. A venturi flow meter is a straight through flow device that operates with an acceptable pressure drop of about .25 inches of water. The flow rate is adjusted to 5 ft^3 min^{-1} by alternately disconnecting, adjusting the flow adjusting screw shown on Figure 2.1, and reconnecting the tygon tubing to the air mover suction tube.

The Dual Volt motor developed about twice as much power on AC as it did on DC. For proper balance the AC voltage must be reduced.

After DC adjustment, the adaptor plug is removed and the air mover is operated on 110 ± 1 volt AC power. The AC speed control stub shown on Figure 2.1 is turned to provide an indicated flow of 5 ft^3 min^{-1}.

Air flow control characteristics for AC and DC power are shown on Figure 2.3. The regulated DC flow rate change is less than 0.4% per % voltage change, while the regulated AC flow rate change is about 0.8% per % voltage change.

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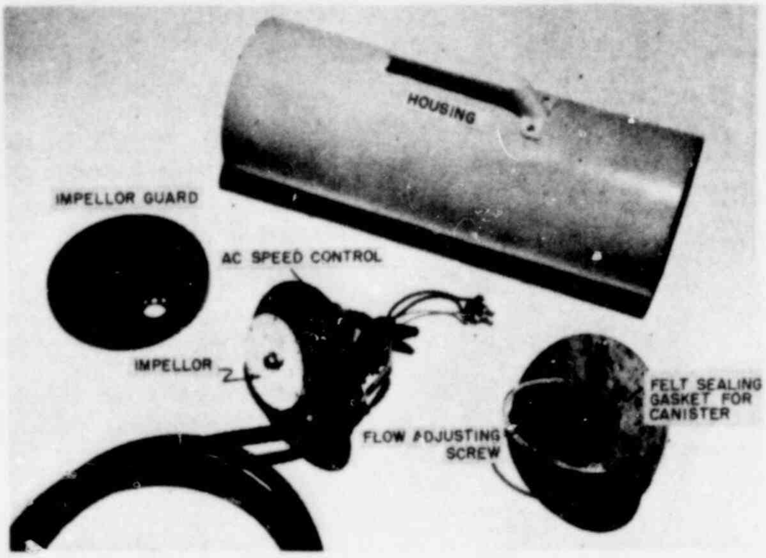

Figure 2.1 Air Mover Components: Exterior View of Vacuum Bulkheads

Figure 2.2 Air Mover Components: Interior View of Vacuum Bulkheads

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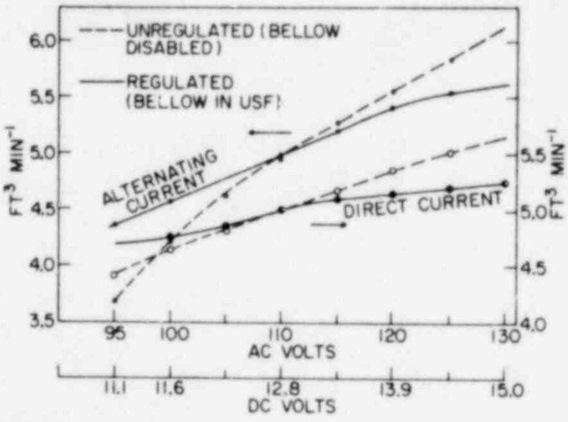

Figure 2.3 Flow Rate Regulation

3. RELIABILITY TESTING

3.1 Introduction

The air sampler can be used to obtain iodine air concentration data during release from containment reactor accidents. It is estimated that less than 20 operating cycles per unit would satisfy this need.

Accident probabilities have been included in WASH 1400(1) for a number of hypothetical PWR and BWR accidents. The most probable accident considered was PWR 9 with a probability of 4 X10^{-4} per reactor year. Assuming a clustered siting of 20 PWR's, the annual site probability would be $\sim 10^{-2}$ and the mean time for an accident would be 100 years.

Assuming a 40 year lifetime for the air sampler, it is unlikely that the samplers would be used for even the most probable accident type.

Maintaining the air samplers and training monitoring teams will require periodic use. Assuming one annual test and a two cycle training exercise, 15 minutes of annual operation per unit is estimated. A 40 year lifetime requires the air sampler to have a mean running lifetime of at least 10 hours. Adding 20 cycles for an unlikely accident, the total running lifetime should be at least 12 hours.

3.2 Environmental Test

An environmental chamber was constructed and divided into separate cells to test 4 air samplers simultaneously, 3 on 115 Volt alternating current and 1 on 12.8 Volt direct current. Each cell temperature control was individually adjusted to approximately 45°C by use of an inlet air butterfly valve. The organization of the 4 cells of the chamber with the top removed is shown in Figure 3.1. An air sampler can be seen through the Lucite view port in position 3.

In general, three temperatures were monitored per cell. Inlet air temperature was measured in the air regulator bellows. The two vacuum motor bearing temperatures were obtained by thermocouples packed into small drilled holes through the bearing support frame to the exterior of either the inlet sleeve or outlet ball bearing case.

AC voltage was common to three of the cells and each air sampler had individual current monitoring. The DC cell received power from a pair of regulated supplies assuring reliable power for the test.

3.3 Results and Discussion

Fifteen motor assemblies were available for the test and the units tested were selected at random from this stock. The test was divided into two runs to allow reloading of failed units with air samplers containing new motor assemblies. At the end of the test all motor assemblies were disassembled and inspected for cause of failure. Results of the tests are shown on Table 3.1. Tests 1 to 4 corresponded to run 1 and the rest were run 2. Tests 4 and 5 were performed on the same unit, initially on DC to failure and then on AC to failure.

Continuous running at high ambient air temperature is considered to be more severe than cyclic operation. The inlet sleeve bearing, always hotter than the better ventilated ball bearing, required 4 minutes to reach 35°C from a 22°C start. Half the units suffered lubrication failure. Continuous high temperature operation would tend to evaporate the lubricant fractions with smaller molecular weights. Polymerization is a competing process and may explain the hard residue observed around the sleeve bearings. Both lubricant distillation and polymerization would be reduced by lower average temperatures produced by cyclic operation. This would tend to increase mean motor life.

The other motor failure causes are due to carbon brush consumption and a need for improved quality control for motor assembly.

It was suggested earlier that 12 hours was a reasonable minimum lifetime. The second test unit failed after 6 hours. This could have been easily averted by inspection prior to installation.

3.4 Summary

a. Minimum operating lifetime of an air sampler was estimated to be $\sim$ 12 hours.

b. The average lifetime of 7 units tested for continuous operation at 45°C was greater than 88 hours.

c. Average lifetime can be increased by inspecting motor assemblies prior to installation.

d. Lubrication with silicone based oils should improve lifetime by reducing thermal degradation.

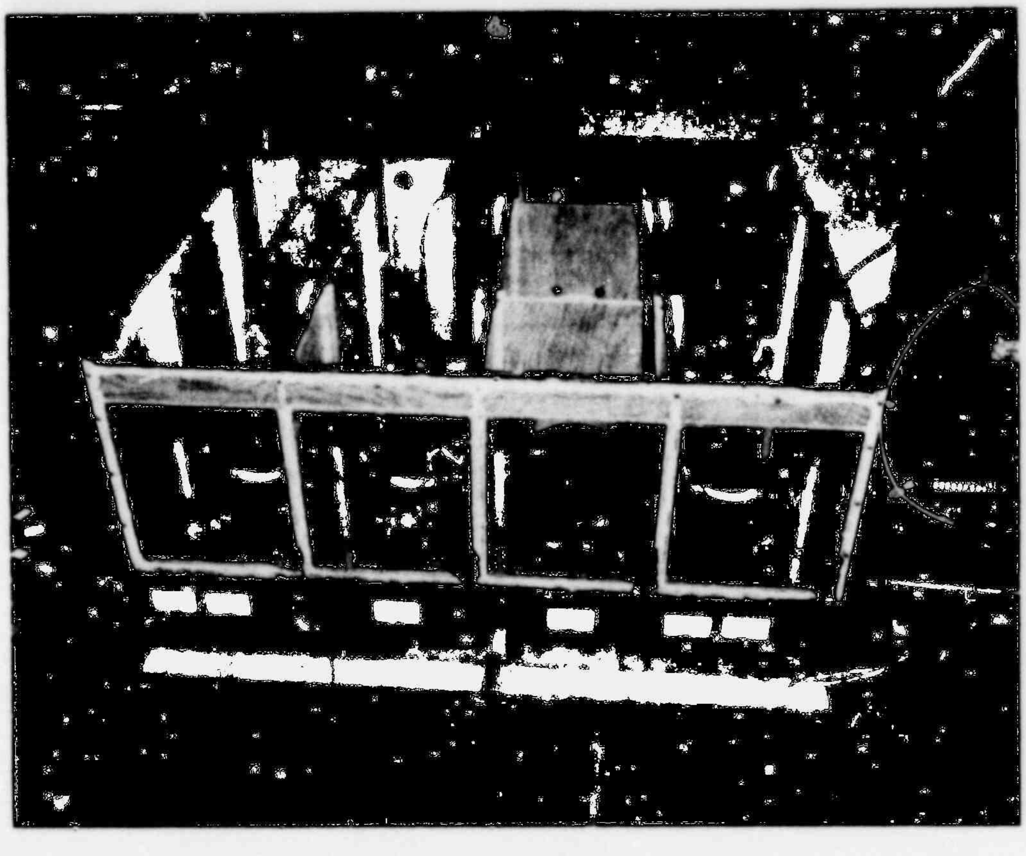

Figure 3.1 Environmental Test Chamber

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Table 3.1 Air Mover Motor Failure Analysis

TEST #	1	2	3	4	5*	6	7
Hours to Failure	158	6	47	80	91(171)	160+	72
Avg. Inlet Air Temp. °C	45	46	45	45	46	43	45
Voltage	115 AC	115 AC	115 AC	12.8DC	115 AC	115 AC	12.8DC
Current, Amps	1.5 AC	1.72AC	1.65AC	11.9DC	1.55AC	1.64AC	12.6DC
Avg. Front Bearing Temp. °C		65		56	63	65	57
Avg. Rear Bearing Temp. °C	55	53	52	54.3	53	52	54
Max. Front Bearing Temp. °C		80		61	74.8	82.7	64
Max. Rear Bearing Temp. °C	55	57	58.4	53.6	66.9	62.1	56
Analysis of Failure	a. Lubricant Failure b. Poor lateral allignment of armature c. Brushes overlapping commutator d. Front (sleeve) bearing & shaft tight	a. Front sleeve bearing & shaft too tight causing excessive bearing temperature b. Poor tolerance control of shaft & bearing	a. Excessive lateral clearance of armature b. Shim washers missing causing uneven brush wear & impeller rubbing	DC Brushes worn out. Note: This unit was then operated on AC. Results are given on Column 5	a. Lubricant Failure b. AC brushes not centered on commutator	Still operational - test terminated	a. Lubricant failure b. Insufficient clearance between shaft & sleeve bearing

* Test conducted on same unit to failure at 171 hours.

4. DEVELOPMENT OF AN INORGANIC ADSORBER WITH LOW NOBLE GAS RETENTION

4.1 Summary

A silver loaded silica gel was developed as an adsorber for air monitoring subsequent to a release from containment power reactor accident. Requirements of high efficiency for known radioiodine species under wide ambient conditions of humidity and temperature and low noble gas adsorption efficiency are satisfied by the material.

Silver loadings from 2 to 24% by adsorber weight have been tested against organic radioiodine, hypoiodous acid, elemental radioiodine, and noble fission gases. Relative humidity was varied between 5 and 99%, and stay times of .11, .073, and .055 seconds were used.

Silver loading requirements depend on sampling duration and relative humidity. Environmental monitoring required about 25 ft^3 of air be sampled and analyzed for a dose projection. The proposed analysis system consists of an air mover, an adsorber, and a civil defense readout instrument fitted with a special 6306 probe that is discussed in chapter 5. This combination provides adequate sensitivity for dose predictions. A silica gel adsorber can be used with a 4% silver loading for an efficiency of better than 93% with a .11 second stay time, and for all ambient conditions tested. Similar tests using 4% silver loaded 13X molecular sieve or about 60% silver zeolite yielded lower efficiencies.

Xenon adsorption was $<5 \times 10^{-3}\%$ at $55^{\circ}C$ with no post-release flushing. This value was about 1/20 of the value for charcoal under the same conditions.

A silver loading apparatus was developed to easily process ∿5 kg of silica gel per day. The method involves prehumidification, boiling under high vacuum, oven drying, sieving. and finally packaging.

4.2 Adsorber Loading Method

Solutions of silver nitrate were used to impregnate molecular sieve and silica gel. Since cost is an important factor, silver loadings of less than 8% by weight were extensively studied. Loadings of >20% by weight were easily accomplished with about the same loading efficiency.

The loading method(5) started with prehumidification of factory dry silica gel (4) material. J. Keller, Allied Chemical Co. Idaho Falls, Idaho found that dry zeolite pore structures would fracture with addition of liquid water. Prehumidification with moist air allowed the heat of adsorption to be controlled to prevent fracturing.

Kilogram quantities of dry silica gel sieved to >30 mesh were prehumidified by 4 liters per minute of lab air bubbled through distilled water maintained at 60°C. The process required about 18 hours for complete saturation. The wet gel was slurried with an aqueous solution of the silver salt and boiled under vacuum for about 2.5 hours. After boiling, the material was transferred to drying trays and heated in an air-circulated oven at 105°C for 24 hours. The dried adsorber was resieved and the >30 mesh fraction was stored in clean gallon sized metal paint cans ready for use.

Loading efficiency was studied(7) by measuring the quantity of silver on the adsorber surface. This was accomplished by tumbling the silica gel pellets for 4 to 76 hours to allow self abrasion to remove the surface layer. Three fractions, which proved to be time independent, were developed by sieving, using 30 and 80 mesh screens. Nearly all of the material was retained on the 30 mesh screen, and broken pellets corners and sharp edges were trapped on the 80 mesh screen. Particles smaller than 80 mesh were assumed to represent the silica gel pellet surface and constituted less than 0.2 by weight of the total. Analysis for silver indicated that about.2 to .4% of the silver was on the <80 mesh fraction for 4 to 24% silver loaded silica gel stock. Clearly the pore loading efficiency was better than 99.6% since some part of the <80 mesh fraction consisted of pellet fragments.

A water leaching experiment(7) was conducted with prehumidified 4% silver loaded silica gel. A silver recovery efficiency of 88% ± 3 indicated that the impregnated silver was in the nitrate form since the oxides and nearly all silver salts are not ver soluble. Further, the silver nitrate appeared to be weakly held by the silica gel.

4.3 CH_3I Generator

A fission iodine generator was constructed(8) using 3 micron thick ^{235}U alloy foil positioned around a 10^8 neutron/sec AmBe source. Approximately $3m^2$ of foil, contaiing 16.2 gm of ^{235}U, was assembled in a 12 cm wide strip. The foil was positioned on a continuous strip of .15 cm thick by 12 cm wide open mesh polyethylene-polypropylene and wound on a form around the neutron source. The resulting 22 cm spool was placed in an aluminum pressure tank and all voids, except in the mesh, were filled with paraffin. The assembly provided an average thermal neutron flux of about 7×10^4 cm^{-2} sec^{-1} along the outer end of the spool.

The pressure chamber, filled with argon gas, 180 psig, containing .3% CH_4, was used for iodine exchange reactions. Approximately 5.4% of the ^{135}I theoretical yield was measured, corresponding to a CH_3 ^{135}I activity of 0.16 microcuries. A method outlined by Keller (9) was used to test and confirm the chemical species. The species differentiator indicated the discharged mixture consisted of 95 to 99% organic iodine and 1 to 5% HOI. Since both oxygen and water are absent in the generator, the HOI indication was probably due to HI.

The generating method used had the advantage of also producing all of the fission gases; so that tests were made with noble gases as well as organic radioiodine.

4.4 HOI Generator

The HOI Generator was patterned after Kabat(10,11). Carrier free ^{131}I was added to a 3×10^{-5} M KIO_3 water solution. The pH was adjusted to 2.0 with H_2SO_4, and the mix was placed in a fritted bubbler. Helium gas was used to strip HOI from the solution. Demisting was accomplished with a Gelman glass fiber filter. A second helium stream of about the same flow rate, .04 CFH, was used to dry the combined stream prior to passing through a stack of six 40 mesh copper screens described by Barry(12). The screens were routinely pickled in HI, washed in distilled water, and air dried immediately before use.

The Keller species differentiator indicated that about 95% of the iodine was adsorbed on the p-iodaphenol impregnated alumina adsorber. The remaining 5% was trapped on the TEDA impregnated charcoal backup filters.

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4.5 I_2 Generator

Convenience and economy of multiple use prompted the conversion of the easily generated and controlled HOI into I_2. This required the reduction of I^+ by oxidation of Cr_2O_3 at 510°C.

The HOI - He generator stream was passed through a 1 cm diameter quartz tube mounted in a tube furnace. Glass wool was used to center the Cr_2O_3 in the furnace. Nichrome heating wire was wound around the discharge end of the quartz tube and the teflon tubing used to transfer the I_2 to the air stream leading to the test adsorber chamber. A minimum transfer line temperature of 100°C was maintained with an average temperature of >160°C.

A modified Keller species differentiator was used to analyze the I_2 discharge stream. The elemental iodine fraction was measured with a bank of 6 Barry(12) screens replacing the standard cadmium iodide loaded chromasorb. Results indicated that 18% of the iodine was on the Gelman glass filter, followed by 73% on the screens, 2% on the HOI adsorber, and finally by 7% on the TEDA impregnated charcoal. The 18% trapped by the glass filter was probably due to adsorption rather than particulate filtration. In any event, at least 91% of the total was elemental iodine.

4.6 Results

Attempts were made to summarize the results graphically. However, the number of parameters were too extensive requiring a tabulation of important variables. Some of the parameters may require specification. Pre-run, run and flush times refer to the number of minutes that the temperature and humidity controlled air passed through the trial adsorber. Test CH_3I, HOI, I_2. or Xe were released during the run stage. Flow conditions were set by the stay time defined as the quotient of adsorber bed volume and volume flow rate. Pre-running will tend to saturate the adsorber with water. Flushing will tend to remove weakly absorbed material, and both pre-run and flush stress the adsorber to a greater extent. In general, the data shown in Tables 4.1, 4.2, 4.3 and 4.4 are arranged in terms of increasing silver impregnation from 0 to 8%, decreasing stay time, and increasing relative humidity. Results for certain other inorganic adsorbers are given next with results for charcoal and a cloth filter material completing the list.

Adsorber criteria(8) dominated the testing scheme. In general the adsorber material had to be highly efficient, better than 90%, for any known species of iodine under all expected conditions of temperature and humidity. Sampling time was changed in mid-experiment from a maximum of 15 minutes to 5; so that two sampling times appear in the data. Finally the adsorber must be at least 2 orders of magnitude less efficient for noble gases than iodine.

The CH_3I results are summarized on Table 4.1. The unimpregnated silica gel was inefficient for CH_3I adsorption. For high humidity and a stay time of 0.11 seconds, 4% silver loaded silica gel had an adsorption efficiency of 93% for an 8 minutes sampling time. Increasing the silver content increased the efficiency; but was not considered to be cost effective.

The commercial silver zeolite had a surprisingly low efficiency considering the >60% silver loading and small particle size.

Charcoal impregnated with TEDA was more efficient than 4% Ag-silica gel. However, high noble gas adsorption efficiency of several percent, Table 4.4, precluded its use.

HOI results are presented on Table 4.2. It is interesting to note that HOH and HOI have one polar end in common. Hydrophilic adsorbers, such as silica gel, should be efficient for HOI, and this was confirmed with silica gel. Increasing silver impregnation tends to increase adsorption efficiency, but again 4% Ag - silica gel is adequate.

Silver zeolite had a poor efficiency of 26%. Addition of a 30 minute equilibration run under test conditions of temperature, humidity, and flow rate apparently saturated the zeolite with water thereby reducing efficiency. The same effect was expected and noticed during the longer runs with silica gel.

The charcoal HOI results were similar to the organic iodine test. All of the charcoals were highly efficient. Impregnation doesn't appear to be as important for HOI as for CH_3I.

As expected the elemental iodine results, Table 4.3, are uniformly good. The highly reactive atomic and molecular iodine is attracted by any surface cooler than the sublimation temperature such as the unimpregnated silica gel.

The tests reflecting the Xenon results were more involved. A mixture of noble gases and organic iodines from the fission generator was split into two flow rate monitored and controlled streams. Room temperature, silver zeolite filters were used in each leg to quantatively trap the iodines. One of the streams was sent to an air duct leading to the test chamber, and the other to two sequential charcoal adsorbers maintained at dry ice temperatures.

Ge(Li) analysis of the 250 keV ^{135}Xe line indicated that all of the cold leg Xenon, >99%, was trapped on the zeolite and first cold charcoal adsorber. Analysis of the radioiodine activities in both legs provided reliable flow fractions between the two legs to supplement flow meter results.

Xenon results, Table 4.4, indicate that silica gel is about .09 ÷ .0004 ~200 times less efficient than TEDA loaded charcoal at about 10°C. The charcoal results are comparable to earlier work shown in Figure 4.1. The two BC 845 charcoal results fall slightly below the results obtained independently by Seigworth (13) and Collins (14).

Ratios of Xe to I counting rates expected for perfect adsorbers were calculated for the nine pressurized water and boiling water reactor accidents postulated in WASH 1400 (1). WASH 1400 contains a study of failure modes leading to releases from containment. Release fraction predictions were made for a range of modifiers including core temperatures build-up and operation of the containment sprays. The release fractions and standard core inventory were used to determine xenon to iodine gamma intensity ratios. Intensity values for Xenon 133, 135, 138 and iodine 131, 132, 133, 134 and 135 were computed for the gamma energy dependence of the shielded Civil Defense CDV-700 GM detectors. The ratios reflect core inventory, release fraction and activity to dose rate conversion. Results were first calculated in reference 2 and are shown on Figure 4.5 for 2 and 24 hours following reactor shutdown for the 9 PWR and 5 BWR WASH 1400 cases. In general, more decay means a larger Xe/I ratio. Xenon exceeds iodine intensity in four of the more probable cases.

Selection of 4% Ag - silica gel would allow clear iodine detection in all but the BWR 5 case. At 7°C ambient air temperature, the iodine concentration would be overestimated by a factor of 2.7 for 2 hours total decay and 7.5 for 24 hours. Since the average temperature is >7°C and the adsorber bed temperature is normally appreciable due to water absorption, the overestimation will be largely reduced. For typical conditions of 20°C and 50% RH the air leaving the bed was measured to 20°C higher than the entering air. This would reduce the overestimate by a factor of 3 to 5. Further the magnitude of the radioactive release for the BWR 5 case is the smallest of the cases considered, and would result in a total iodine release of only about 2 curies. This would lead to a very small iodine exposure problem.

The ideal adsorber for radioiodine monitoring subsequent to a release from containment accident should have the following properties:

a. The adsorber should be highly efficient for all speciies of iodine expected in the environment.

b. Noble gas adsorption efficiency must be at least two orders of magnitude smaller than the iodine.

c. Long term storage should not degrade the adsorber.

d. The adsorber must be economical as hundred of kilograms are required.

All of the criteria are satisfied by 4% silver loaded silica gel in a system requiring a sampling time of several minutes and a .11 stay time.

Table 4.1 CH_3I Adsorption Tests

Material	Impregnant Wt.%	Mesh U.S.	Relative Humidity %	Temp. °C	Pre-Run Minutes	Run Minutes	Stay Time Seconds	Flush Minutes	Efficiency
Silica Gel	0	6x16	45	41	-	23	.11	-	.01
Silica Gel	0		84	40	-	25	.11	-	.003
Silica Gel	2% Ag	6x16	17	66	-	23	.11	-	.99+
Silica Gel	2% Ag		80	41	-	26.5	.11	-	.75
Silica Gel	3.5% Ag	6x16	17	66	-	23	.11	-	.99+
Silica Gel	4% Ag	6x16	6	47	-	8	.08	-	.99+
Silica Gel	4% Ag		7	49	-	8	.05	-	.98
	4% Ag		36	44	-	8	.08	-	.93
	4% Ag		35	45	-	8	.05	-	.89
	4% Ag		67	42	-	8	.11	-	.98
	4% Ag		67	42	-	8	.08	-	.94
	4% Ag		86	40	-	13	.11	2	.79
	4% Ag		88	40	-	24	.11	-	.94
	4% Ag		90	40	-	24	.11	-	.85
	4% Ag		97	42	-	8	.11	-	.93
	4% Ag		96	42	-	8	.05	-	.92

(cont'd)

Table 4.1 continued

Material	Impregnant Wt. %	Mesh U.S.	Relative Humidity %	Temp. °C	Pre-Run Minutes	Run Minutes	Stay Time Seconds	Flush Minutes	Efficiency
Silica Gel	4% Ag		98.5	34	-	8	.05	-	.81
Silica Gel	6% Ag	6x16	98	34	-	8	.05	-	.96
Silica Gel	8% Ag	6x16	1	110	2	22	.11	-	.99+
	8% Ag		8	28	-	8	.05	-	.99+
	8% Ag		17	71	-	27	.11	-	.99+
	8% Ag		22	35	-	25	.11	-	.99+
	8% Ag		36	48	-	8	.11	-	.99+
	8% Ag		36	48	-	8	.08	-	.98
	8% Ag		35	48	-	8	.05	-	.97
	8% Ag		72	45	-	8	.08	-	.96
	8% Ag		62	48	-	8	.05	-	.93
	8% Ag		85	37	-	23	.11	-	.97
	8% Ag		85	38	-	13	.11	2	.94
	8% Ag		92	37	40	24	.11	-	.37
	8% Ag		97.5	40	-	8	.11	-	.97
	8% Ag	6x16	96	39	-	8	.08	-	.98

(cont'd)

Table 4.1 continued

Material	Impregnant Wt.%	Mesh U.S.	Relative Humidity %	Temp. °C	Pre-Run Minutes	Run Minutes	Stay Time Seconds	Flush Minutes	Efficiency
Zeolite	~60% Ag	2 0x40	98	34	-	8	.05	-	.81
Zeolite	~60% Ag		98	34	~40	27	.08	-	.82
Zeolite	~60% Ag		98	35	~40	28	.034	-	.48
13X Mole Sieve	4% Ag	8x12	99	32	-	8	.05	-	.06
Char. G215	(R-51)AO		88	36	-	9	.04	-	.75
Char. G618	TEDA	18x30	91	32	~ 1	8	.113	11@110°C	.95
	TEDA		95	33	~ 1	8	.106	11@110°C	.96
	TEDA		75	35	~ 1	6	.06	11@110°C	.87
Char. W-337	None	8x16	67	45	24	8	.44	8	.79
	None		95	33	120	8	.44	10	.97
	None		96	34	70	8	.05	10	.26
Char. BC845	TEDA	14x30	97	33	-	8	.05	-	.99+
Char. BC540	KI_3	14x30	97	40	-	8	.05	-	.88
MSA #2133	Char.	Cloth	44	35	-	8	.8CFM	-	~.01

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Table 4.2 HO^{131}I Adsorption Tests

Material	Impregnant Wt.%	Mesh U.S.	Relative Humidity %	Temp. °C	Pre-Run Minutes	Run Minutes	Stay Time Seconds	Flush Minutes	Efficiency
Silica Gel	0	6x16	<10	31	-	28	.11	-	.82
	0		85	42	-	26	.11	-	.51
	0		88	40	-	26	.11	-	.31
Silica Gel	4% Ag	6x16	<10	33	-	26	.11	-	.93
	3.7% Ag	6x16	13	41	-	8	.11	-	.99+
	3.7% Ag		12	43	-	8	.08	-	.99+
	3.7% Ag		13	43	-	8	.05	-	.99
	4.0% Ag		35	35	-	8	.05	-	.99+
	4.0% Ag		45	36	-	8	.11	-	.97
	4.0% Ag		65	40	-	8	.05	-	.97
	4.0% Ag		75	41	-	8	.11	-	.99+
	4.0% Ag		85	40	-	26	.11	-	.71
	4.0% Ag		86	42	-	28	.11	-	.81
	4.0% Ag		95	41	-	30	.11	-	.76
	4.0% Ag		97	42	-	8	.11	-	.99+
	4.0% Ag		97	42	-	8	.08	-	.98
	4.0% Ag		97	43	-	8	.05	-	.74

(cont'd)

Table 4.2 continued

Material	Impregnant Wt.%	Mesh U.S.	Relative Humidity %	Temp. °C	Pre-Run Minutes	Run Minutes	Stay Time Seconds	Flush Minutes	Efficiency
Silica Gel	4.0% Ag		~100	40	–	16	.11	14	.63
Silica Gel	8.0% Ag	6x16	5	51	–	8	.08	–	.99
	8.0% Ag		5	52	–	8	.05	–	.98
	8.0% Ag		40	37	–	8	.11	–	.99+
	8.0% Ag		50	38	–	8	.05	–	.79
	8.0% Ag		63	40	–	8	.11	–	.99+
	8.0% Ag		68	37	–	8	.05	–	.98
	8.0% Ag		86	37	–	28	.11	–	.71
	8.0% Ag		96	40	–	8	.11	–	.99+
	8.0% Ag		96	40	–	8	.08	–	.99
	8.0% Ag		98	39	–	8	.05	–	.92
Zeolite	~60% Ag	~20x40	~100	39	–	30	.11	–	.26
13X Mole Sieve	4% Ag		75	40	–	26	.11	–	.18
Char. W-337	0	8x16	71	45	15	8	.44	8	.99+
	0		96	39	15	8	.44	8	.99+
	0		98	35	40	8	.05	10	.66

(cont'd)

Table 4.2 continued

Material	Impregnant Wt.%	Mesh U.S.	Relative Humidity %	Temp. °C	Pre-Run Minutes	Run Minutes	Stay Time Seconds	Flush Minutes	Efficiency
BC-845	TEDA	14x30	7	52	-	8	.05	-	.99
	TEDA		96	42	-	8	.11	-	.99+
	TEDA		95	43	-	8	.08	-	.99+
	TEDA		95	42	-	8	.05	-	.99
Char. BS-540	KI_3	14x30	9	49	-	8	.05	-	.99
	KI_3		97	40	-	8	.11	-	.99+
	KI_3		97	40	-	8	.08	-	.99+
	KI_3		96	40	-	8	.05	-	.99+
MSA-2133	Char.	Cloth	~100	38	-	15	3.8CFM	-	<.01

Table 4.3 $^{131}I_2$ Adsorption Tests

Material	Impregnant Wt.%	Mesh U.S.	Relative Humidity %	Temp °C	Pre-Run Minutes	Run Minutes	Stay Time Seconds	Flush Minutes	Efficiency
Silica Gel	0	6x16	97	37	0	8	.05	-	.92
Silica Gel	4% Ag	6x16	8	46	-	8	.06	-	.99+
			37	36	-	8	.06	-	.99+
			66	36	-	8	.06	-	.99+
			95	34	-	8	.06	-	.99+
			98	36	-	8	.05	-	.98
Silica Gel	8% Ag	6x16	98	35	30	10	.05	-	.94

Table 4.4 ^{135}Xe Adsorption Tests

Material	Impregnant Wt.%	Mesh U.S.	Relative Humidity %	Inlet Temp. ^{o}C	Outlet Temp. ^{o}C	Run Time Minutes	Stay Time Seconds	Efficiency
Silica Gel	None	6x16	45	39	45	23	.11	$3x10^{-5}$
Silica Gel	4% Ag	6x16	75	39	59	25	.11	$5x10^{-5}$
Silica Cel	0	6x16	84	40	61	25	.11	$4x10^{-5}$
Silica Gel	4% Ag	6x16	34	7	12	10.5	.11	$4x10^{-4}$
Char. G618	TEDA	18x30		125	119	18	.11	$1x10^{-3}$
Char. BC845	TEDA	14x30	34	12	12	10.5	.006	$5x10^{-3}$
						Normal to	.11	$9x10^{-2}$

Table 4.5 Xenon to Iodine Shielded OCD-D-103 GM Tube Response for Various WASH 1400 Containment Releases

	Xe/I ------ Decay Time -------	
	2 hours	24 hours
PWR 1	.04	.10
2	.04	.10
3	.11	.30
4	.18	.51
5	.25	.71
6	2.97	8.38
7	4.17	11.70
8	.53	1.50
9	.78	2.20
BWR 1	.07	.19
2	.03	.09
3	.26	.74
4	11.10	31.20
5	6700.00	18900.00

Xe includes 133, 135, 138

I includes 131, 132, 133, 134, 135

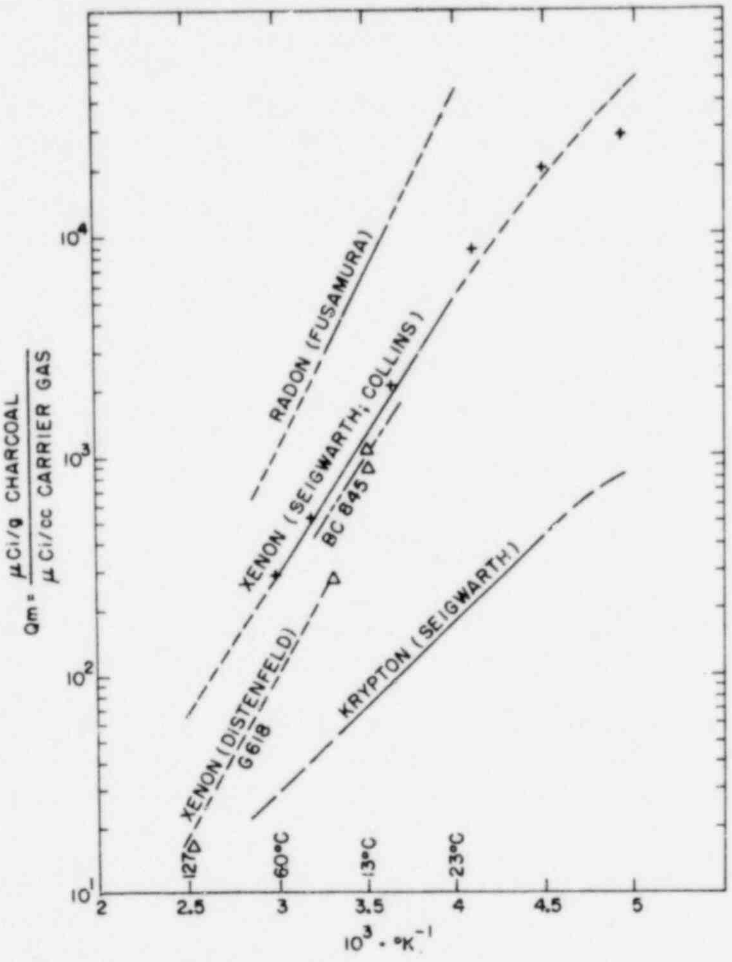

Figure 4.1 Temperature Dependance on Noble Gas Adsorption on Charcoal

5. EVALUATION OF HIGH PHOTON SENSITIVITY GM TUBES

5.1 Introduction

Geiger-Müller, G M, detectors are sensitive to ionizing events initiated by energetic charged particles within the active volume. Uncharged photons can be detected by charged particles liberated by photon interactions in photoelectric, compton, and pair production processes.

Photon detection efficiency depends on the cross section for the three types of events. It is well known(16) that incident photons interact with the entire atom preceeding the release of photoelectrons. The cross section varies as $\sim E^{-3}$ of the photon and as $\sim Z^{4.3}$ of the absorbing atoms.

The compton process is considered to be elastic scattering of photons by electrons. The cross section varies directly with the number of electrons, Z, and as $\sim E^{-1}$. The maximum value is known as the Thompson cross section and is ~2/3 barn per electron; thus the maximum compton cross section for lead is 2/3 Z (~55 barns).

Pair production involves the absorption of photons and the creation of electron positron pairs. The rest mass of a pair is equivalent to 1.02 meV, requiring this minimum energy for non zero values of cross section. Above the minimum energy, the cross section increases with $\sim E^1$ and with $\sim Z^2$.

Photon sensitive GM detectors should have high Z materials within the active volumes. Bismuth is the optimum material since it is the highest Z non-radioactive element.

During ^{131}I decay, 365 keV photons are released and some fraction are converted to photoelectrons of similar energy. Ultimate detector sensitivity depends on the total number of target atoms that are close enough to the active volume for the photoelectrons to retain sufficient energy to ionize the counter gas. An empirical(17) method was used to calculate a 365 keV photoelectron range of 0.11 mm for bismuth. Considering typical G M tube sizes and the small photoelectron range, a bismuth converter depends more on surface than volume.

5.2 G M Detector Types Tested

Two types of high Z G M tubes were evaluated. The Victoreen(18) 6306 G M detectors contained bismuth coated wire mesh screens positioned around the cathodes. Wire screening was used to increase the cathode surface to volume ratio and thereby increase sensitivity. Organic quenching must be used due to the chemical reactivity of bismuth with the Halogens.

TGM Detectors Inc.(19) supplied a number of halogen quenched counters with platinum plated cathodes. Type NP 358 detectors, with an inside diameter of 15.2 mm, were shortened by TGM to 9.8 cm. All of the G M tubes were operated with a standard CDV 700 instrument adjusted to 900 volts.

5.3 Energy Response Criteria For Air Sampling

Decay gamma energy from certain mixed fission products will range from less than 80 to more than 2000 keV. Principal gamma energies for the fission iodines and noble gases are summarized in Table 5.1. Ratios of counts per minute for the fission xenons to the fission iodines, $\Sigma Xe/\Sigma I$, were calculated(2) for standard CDV 700 detectors for the various WASH 1400(1) containment release accidents, and for total collection of a plume aliquot near the containment. Two hours after reactor shutdown, $\Sigma Xe/\Sigma I$ ratios of .78 and 6,700 were calculated respectively, in Chapter 4.6, for the most probable PWR and BWR accident. Twenty-four hours post shutdown the ratios became 2.2 and 18,900 respectively. Thus, for analysis of adsorbers for iodine using GM detectors, the xenon collection efficiency must be much less than the iodine efficiency. Further improvement can be achieved by filtering the GM detectors to enhance the iodine to xenon sensitivity.

5.4 Energy Response Measurements

G M detector energy responses were measured with heavily filtered X-rays and isotope sources. Table 5.2 is a listing of the x-ray parameters and isotope sources used. Effective energies were measured with ^{7}LiF thermoluminescent detectors behind various copper adsorbers. The energy corresponding to the slopes of the least squares fitted log intensity vs. thickness curves were taken to be the effective energies.

The measured energy responses of [illegible] bare Victoreen detectors are shown on Figure 5.1. [illegible] agreement between measurements and sales literature exists below 365 keV, while a sensitivity more constant with energy was measured above. G M detector filter calculations were made to design a shield to attenuate the principal xenon decay photons more than the iodine photons where the calculated and measured response is shown on Figure 5.1 for a two element concentric filter of .127 cm Pb adjacent to the GM tube followed by .08 cm Cu. The shield and 6306 tube are shown on Figure 5.2. A comparison of the bare tube ^{135}Xe to ^{131}I ratio of 350/185 $\sim$ 1.9 to the filtered tube ratio of 123/125 $\sim$ 1 indicates the shielding reduced the xenon to iodine response ratio by a factor of $\sim$ 1.9. The remaining xenon isotopes have lower energy decay gamma rays and are reduced by much larger factors.

A summary of the energy responses of OCD-D-103 probes and TGM NP358 and Victoreen 6306 tubes in the special shield is shown on Figure 5.3. The OCD-D-103 probe has a 30% depressed response at the 365 keV ^{131}I energy relative to 663 keV, but is within ±20% of earlier values measured by NBS.

Detector response due to solid fission products can be estimated from earlier calculations outlined in Chapter 4.6. Ratios of iodine to total fission products, other than noble gases, were determined for a standard OCD-D-103 GM detector in a CDV 700 shield. For a PWR accident, solid noniodine fission products account for $\sim$ 20% of the total CDV 700 response, two hours after shutdown. Three days later the solid fission products account for about 65% of the total response. BWR accidents tend to release more solid fission products relative to iodine. For the BWR class percentages of solid noniodine fission products to total vary from 40 to 80% for 2 to 72 hours after shutdown.

Air sampling for iodine involves adsorption of gases and filtration of particles on a cylindrical canister(20). Readout requires the insertion of a shielded GM detector, hereafter termed a probe, into the axial suction hole in the canister, as shown on Figure 1.2. The energy response of the 6306, TGM, and OCD-D-103 probes within a canister with 4% by weight silver loaded on silica gel is shown on Figure 5.4. Calculations indicate that $\sim$ 50% of the adsorbed organic iodine will be in the first 0.4 cm of adsorber. To better account for photon attenuation a 0.4 cm void was placed in the periphery of the adsorber bed and orientated normal to the photon beam.

A sand shield was recommended(8) for canister measurement, Appendix A-5. Most of the effect of back scattered photons from sand to probe was included by irradiating the probes through a window in the shield. Results for the 3 probe types are summarized in Figure 5.5.

5.5 Discussion and Results

A least squares curve fitting program was used to obtain mathematical expressions for energy responses of all probes,

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inside a canister, and the probe canister assembly inside a sand shield. A listing of polynominals for the 6306, TGM, and OCD-D-103 probes is provided in Table 5.3. The polynominials were used to calculate probe responses for various combinations of fission products.

The normally filtered intensity of the x-ray machine used, was 4 to 5 orders of magnitude higher than the capability of the GM tubes. Heavy filtration reduced the intensity sufficiently for dead time correction to be used. The standard two isotope source method was used to determine dead time. The measured dead times were 275 μsec for the OCD-D-103, 555 μsec for the TGM, and 430 μsec for the 6306. In general, dead time corrections averaged less than 20% for the Victoreen and less for the other detectors due to fewer events per unit time.

GM detectors can be used to measure iodine levels in pasturage, water, milk, human and cow thyroids, as well as air sampling adsorbers. For all of the uses, except air sampling, noble gases should not be a problem; therefore, thinner GM detector shields could be used with increased sensitivity. Air sampling evaluation of iodine in the presence of noble gases were taken to be the most critical application for which the Victoreen 6306 GM shield was designed to reduce the xenon to iodine response ratio.

5.6 Summary

a. The critical GM detector requirement was taken to be the evaluation of air samples containing mixed fission products.

b. A filter was designed to attenuate the xenon decay photons more than ^{131}I photons.

c. Energy responses were measured for probes composed of filtered 6306 and TGM detectors. The determinations were made with probes in air, with probes in a 4% Ag - gel loaded canister, and with the probe - canisters inside a sand shield.

d. The experimental data were fitted to polynominials to permit response calculations for different radionuclides.

e. In general, the 6306 probe was more than 10 times as sensitive as the standard OCD-D-103 probe for photons from .25 to .5 MeV.

TABLE 5.1 DECAY CHARACTERISTICS OF SELECTED FISSION PRODUCTS

ISOTOPE	HALF LIFE Hours	CHARACTERISTIC GAMMA ENERGY keV, (γ/decay)
$^{131}\mathrm{I}$	193	370(.84)
$^{132}\mathrm{I}$	2	670(.99); .77(.79)
$^{133}\mathrm{I}$	21	530(.88)
$^{134}\mathrm{I}$	1	850(.95); .88(.65)
$^{135}\mathrm{I}$	7	1130(.21); 1.26(.28)
$^{131M}\mathrm{Xe}$	288	30(.48)
$^{133M}\mathrm{Xe}$	1	30(.65); .23(.10)
$^{133}\mathrm{Xe}$	127	80(.14)
$^{135}\mathrm{Xe}$	9	250(.85)
Solids		∿700

TABLE 5.2 X-RAY PARAMETERS AND ISOTOPE SOURCES

X-Ray Setting		Filter, mm			Effective Energy
kV	Isotope	Pb	Cu	Al	keV
78			11.8	4.2	74
100		.96	13.9	1.0	92
128		.80	15.5	1.0	110
170		3.18	14.8	4.2	155
218		8.52	6.6	3.2	200
	$^{131}\mathrm{I}$				365
	$^{137}\mathrm{Cs}$				662
	$^{60}\mathrm{Co}$				1250

TABLE 5.3 ENERGY RESPONSES EXPRESSED AS POLYNOMINALS FOR PROBE, CANISTER, AND CANISTER IN SAND EXPOSURES

	VICTOREEN PROBE			TGM PROBE			D103 PROBE		
Exposure Type	Probe Ci	Canister Ci	Sand Ci	Probe Ci	Canister Ci	Sand Ci	Probe Ci	Canister Ci	Sand Ci
T^0	.3051E3	.3176E3	.2443E3	.1820E3	.1619E3	.1279E3	-.3844E2	-.2618E2	-.5744E2
T^1	-.9968E4	-.1058E5	-.8193E4	-.5842E4	-.5242E4	-.4228E4	.1108E4	.6930E3	.1258E4
T^2	.1217E6	.1313E6	.1011E6	.6957E5	.6214E5	.5109E5	-.8753E4	-.4590E4	-.8437E4
T^3	-.6754E6	-.7694E6	-.5591E6	-.3798E6	-.3373E6	-.2789E6	.3418E5	.1433E5	.2669E5
T^4	.2071E7	.2572E7	.1707E7	.1146E7	.1013E7	.8423E6	-.7649E5	-.2392E5	-.4510E5
T^5	-.3805E7	-.5337E7	-.3125E7	-.2074E7	-.1827E7	-.1528E7	.1046E6	.2199E5	.4190E5
T^6	.4294E7	.7120E7	.3518E7	.2308E7	.2027E7	.1707E7	-.8861E5	-.1050E5	-.2018E5
T^7	-.2916E7	-.6119E7	-.2385E7	-.1548E7	-.1357E7	-.1150E7	.4554E5	.2035E4	.3959E4
T^8	.1093E7	.3275E7	.8933E6	.5737E6	.5020E6	.4284E6	-.1284E5		
T^9	-.1737E6	-.9933E6	-.1419E6	-.9029E5	-.7889E5	-.6774E5	.1518E4		
T^{10}		.1304E6							
Error (Max)%	+33	-21	+24	-19	+33	+28	+30	+54	+67
E(error m.) Mev	.115	.08	.115	.09	.07	.115	.09	.09	.09
Avg. Error %	<8	<5	<5	<5	<5	<5	<5	<5	<10

$$R(T) = C1 + C_2T^1 + C_3T^2 + C_4T^3 + \cdots\cdots$$

Where R(T) = Probe response in CPS/mr/hr @ T Mev

E x Number = 10^{Number}

All constants were derived by use of a least squares polynominal fitting code.

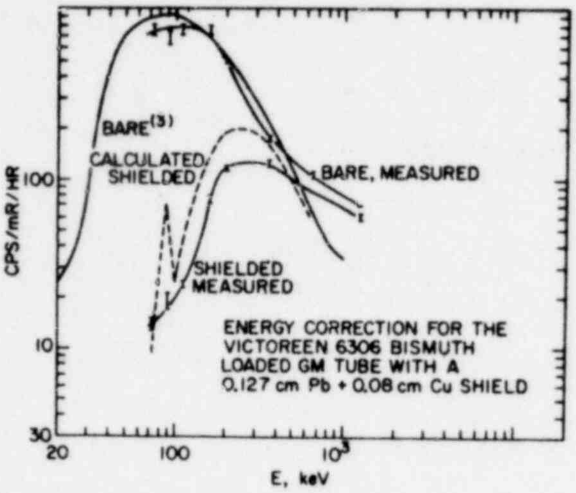

Figure 5.1 X-Ray Response of Bare and Shielded 6306 GM Detectors

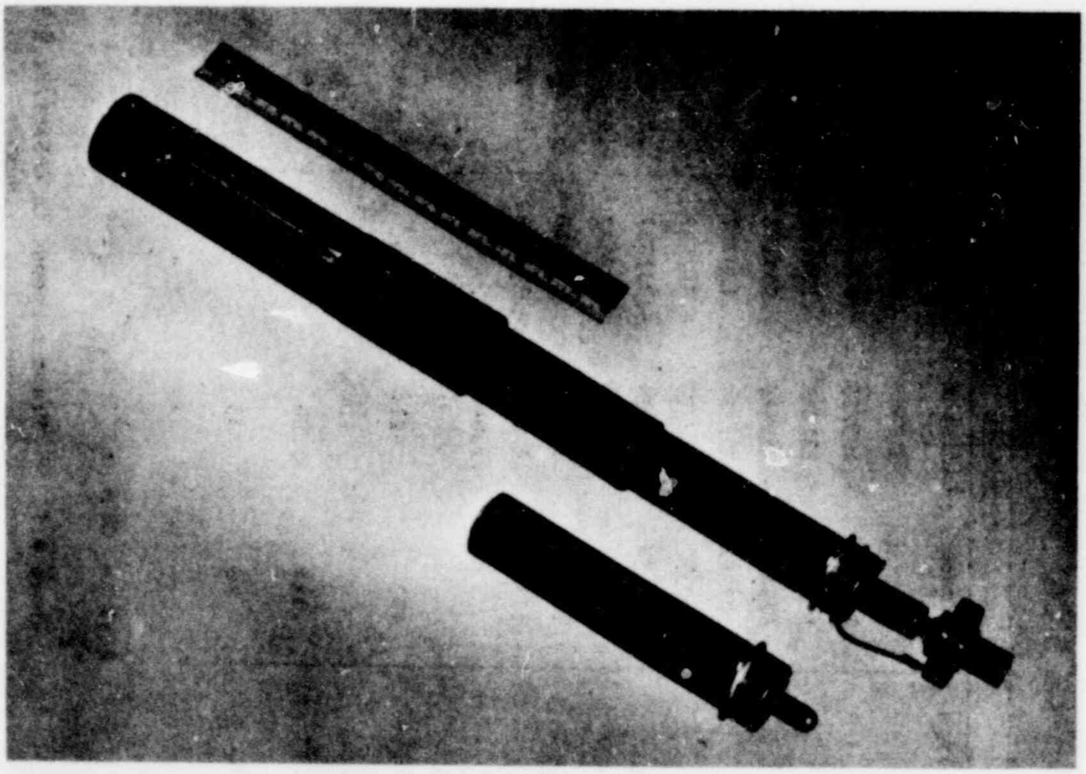

Figure 5.2 6306 GM Detector and Shield Assembly

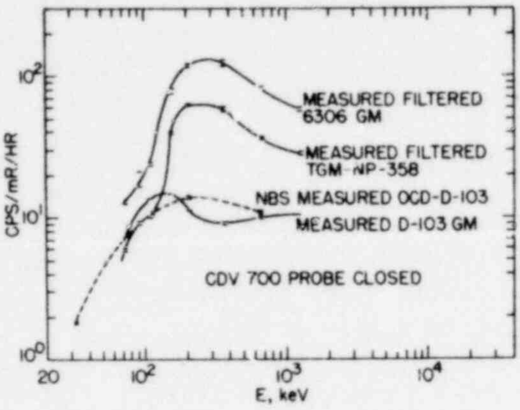

Figure 5.3 GM Detector Energy Response
Filter by .127 cm P_B + .08 cm C_U

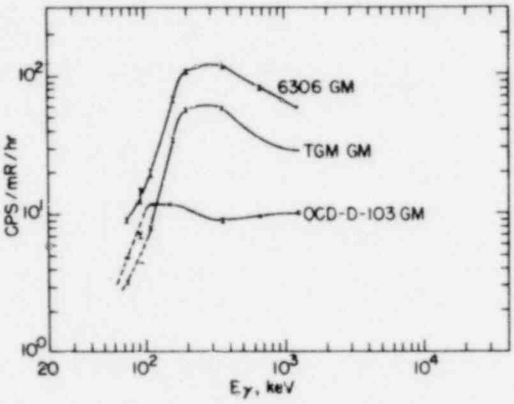

Figure 5.4 Shielded Probe Exposed in
4% AG-GEL Canisters

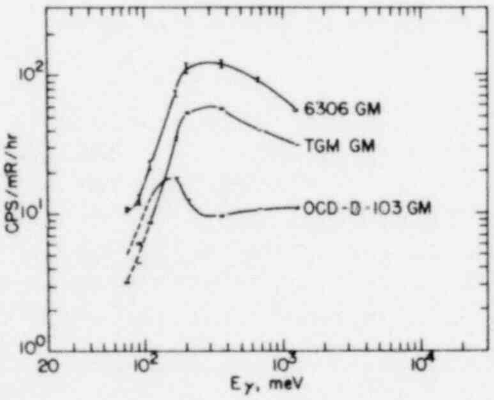

Figure 5.5 GM Probes Exposed
Through Collector and
within Sand Shield

6. AIR SAMPLING DOSE ASSESSMENT

6.1 Introduction

The air sampling system dose assessment was previously(8) based on a 15 minute sampling cycle and filter-adsorber evaluation with a standard CDV-700. The minimum detectable dose commitment, MDDC, of ~ 1.2 rem to a 5 year old child thyroid corresponded to a 10 hour inhalation starting 36 hours after shutdown.

Adoption of a 5 minute sampling cycle would require a greater MDDC or higher sampling rates or more efficient detectors. Table 6.1 contains a listing of the CDV-700 response to the fission iodines for a 15 minute, 75 ft^3 sample.

6.2 Dose Evaluation

An air sampling cannister containing adsorbed HOI labeled ^{131}I was used as a source to determine the relative sensitivity of the 6306 and the OCD-D-103 probe to ^{131}I. The improved sensitivity of 12.8 was reduced by 5/15 to 4.3 to account for the shorter sampling time. The resulting overall improvement factor of 4.3 was used to correct the CDV-700 sensitivity per unit dose commitment listed on Table 7 of reference (8), and appear on Table 6.1.

Employing the calibration results outlined on Table 6.1 and starting with the earlier work of Hull (21), thyroid uptake dosages can be calculated for various post reactor shutdown times and inhalation times. The fraction of inhaled stable iodine reaching the thyroid, f(t), as a function of time was interpolated from Berman (22), using

$$f(t) = .235e^{-.000453t} - .235e^{-.111t} \qquad (1)$$

where t = hours.

The first term reflects thyroid iodine input and the second term iodine leaving the gland. Maximum values for f(t) of 5, 15 and 25% were given by Berman. A linear interpolation of the constants was used to produce a maximum thyroid uptake of 23% which is in agreement with the ICRP II (23) recommended value for inhalation exposure.

Correcting for iodine isotope decay

$$f(t) = (.235^{-.000453t} - .235e^{-.111t})\, e^{-\lambda t} \qquad (2)$$

where λ = physical decay constant, hr^{-1}

and considering an initial instantaneous exposure of A_o, µCi/hr, the total iodine uptake is A, µCi for unit activity inhaled per hour.

$$A = .235\, A_o \int_{t_1}^{t_2} e^{-t(\lambda+.000453)}\, dt - \int_{t_1}^{t_2} e^{-t(\lambda+.111)}\, dt \qquad (2e)$$

Integrating from t = o to ∞

$$A = .235\, A_o \quad \frac{1}{\lambda+.000453} - \frac{1}{\lambda+.111} = A_o T_i \qquad (2b)$$

Realistically, protracted exposures are expected. The total protracted activity Ap µCi per hour of immersion

$$Ap = A_o T_i \int_o^b e^{-\lambda b}\, d\, b \qquad (3)$$

where b is the exposure time in hours.

Isotope	Phy.t½, hr	λi^{-1} hr	T_i hr	Initial Air Activity µCi m^{-3}	Initial Exposure A_o µCi·hr^{-1}
^{131}I	193.56	.003581	56.20	.0485	.01938
^{132}I	2.284	.30347	.21	.0465	.0166
^{133}I	20.8	.03332	5.33	.0848	.03392
^{134}I	.872	.7952	.04	.0896	.03585
^{135}I	6.7	.10345	1.17	.07752	.0310

A_o was calculated as the product of air activity and the breathing rate of a standard 5 year old (1).

Referring to Table 6.2 from reference (1), the ratio of breathing rate to thyroid mass indicates that the 5 year old child will receive the maximum uptake per gram of thyroid tissue. The infinite dose can be calculated as follows:

$$D_\infty = Ap \times \frac{.5928 \text{ rad}}{\mu\text{CixMeVxhr}} \times \Sigma\, E\ (RBE)\ MeV = rem \qquad (4)$$

The following parameters were used to calculate D_∞:

	Σ E(RBE) MeV		.5928 Σ E(RBE).T_i
Isotope	Stand. Man	Stand. 5 yr old	$Rad_\infty \cdot \mu Ci^{-1}$ inhaled
^{131}I	.19 (ref.24)	.18 (ref.24)	5.997
^{132}I	.50 (ref.22)	.47 (ref. 22*)	0.0575
^{133}I	.42 (ref.24)	.40 (ref.24)	1.264
^{134}I	.66 (ref.23*)	.62 (ref. 23*)	0.0132
^{135}I	.42 (ref.23*)	.40 (ref. 23*)	0.2765

*Interpolation from the indicated reference.

The 6306 probe response to fission iodines can be calculated for time t, after reactor shutdown, by summing the decay adjusted initial values listed on table 6.1 over the iodine isotopes.

$$CPM = \sum_{i}^{1-5} CPM_i(t_o)\, e^{-\lambda t} \qquad (5)$$

The ratio CPM(t) to thyroid dose commitment D_∞ (t,t_1) is desired for various coupled start of immersion and air-sampling times after reactor shutdown. Results are shown on Table 6.4 for immersion times $(t_1 - t) = b$ for 1 to 72 hours, and on Figure A-4.2 for a 2 hour exposure.

The tabular values can be used directly interpolated, or adjusted to provide more compact format. A condensation was made by calculating ratios of (CPM/D_∞) for 2 hour reference immersions to (CPM/D_∞) for other immersion times. The results are listed on Table 6.4 and on Figure 6.1. The ratios vary with immersion time but were nearly constant for the decay times considered and for immersion times up to about 18 hours. Longer immersion times resulted in increasing differences in the ratio with increasing decay time. The largest and still acceptable difference was about 15% for 1 to 48 hours of decay and for 72 hours of immersion. Thus the product of a single ratio, for a given immersion time from 1 to 72 hours, and the 2 hours immersion reference data translates the reference data to the given immersion time. Solutions for the 6306 probe response per unit thyroid dose commitment are reduced to two graphs. One containing the 2 hour immersion data shown on Figure A-4.2 and the other correction ratios shown on

Figure 6.1.

6.3 Summary

Figure A-4.2 can be used to predict thyroid dose commitments for 5 year old children immersed in a plume for 2 hours. Figure 6.1 provides correction values to be applied to Figure A-4.2 for immersion times from 2 to 72 hours.

Referring to Figure A-4.2 and Appendix A-4, the MDDC is about 0.13 rem for a 5 year old child thyroid for a 2 hour immersion starting 36 hours after shutdown. The ^{131}I MDDC for a 10 hour inhalation can be determined as the product of 0.13 rem and the 10 hour immersion correction value of 4.8 found on Figure 6.1. Thus the MDDC for a 10 hour inhalation starting 36 hours after shutdown is 0.62 rem. In all cases, cannister evaluation must be made in an undisturbed background. Use of a previously recommended sand shield (8) installed in a basement would significantly reduce background from fission products. The shield configuration is included as Appendix A-5.

Table 6.1 CDV-700 and 6306 PROBE RESPONSE TO AN ADSORBER WITH FRESH* FISSION IODINE

Isotope	CDV 700, 75 ft^3 Sample µCi (to)	±%	Cnts/Min	6306 PROBE, 25 ft^3 Sample µCi (to)	±%	Cnts/Min
^{131}I	.103	2.0	8.04	.034	2.0	34.3
^{132}I	.099	45.8	37.7	.033	45.8	157.9
^{133}I	.180	31.4	20.0	.060	31.4	85.2
^{134}I	.190	30.0	80.6	.063	30.0	343.8
^{135}I	.165	37.5	56.2	.055	37.5	239.9

* Corrected for decay

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Table 6.2 Standard Person Parameters*

Parameter	Age (years) 0 (Newborn)	1	5	10	20 (Adult)
Total body mass (kg)	3.5	10	19	33	70
Thyroid mass (g)	1	1.8	3.6	7.4	16
Surface area of total body (m^2)	0.21	0.39	0.75	0.96	1.7
Breathing rate (10^4 liter/day)	0.08	0.38	0.96	1.5	2.3
Ratio of breathing rate to total body mass	0.023	0.038	0.051	0.045	0.033
Ratio of breathing rate to thyroid mass	0.08	0.21	0.27	0.20	0.14

* WASH 1400

Table 6.3 6306 Probe Sensitivity
Net Counts (Min. $\text{Rem}_{\infty})^{-1}$

Immersion Time	Start of Inhalation After Reactor Shutdown								
HOURS	1	2	4	8	12	16	24	36	48 Hours
1	3719	2907	2114	1480	1163	1004	719	541	453
2	1875	1465	1064	744	585	483	361	271.3	227.3
3	1260	984	714	499	392	323	242	181	151.9
4	952	743	539.5	377	295	244	182	137	114.3
6	644	503	364	254	199	164	122	91.7	76.6
8	490	382	277	193	151	124	92.5	69.2	57.8
10	397	309	224	156	122	100	74.5	55.7	46.5
18	231	180	130	90.0	70.1	57.6	42.6	31.7	26.4
24	179	139	100	69.3	53.9	44.2	32.6	24.2	20.1
36	126	97.8	70.4	48.5	37.6	30.7	22.6	16.7	13.8
48	99.0	76.9	55.2	37.9	29.3	23.9	17.5	12.9	10.6
60	82.6	64.1	46.0	31.5	24.3	19.8	14.5	10.6	8.74
72	71.5	55.4	38.9	27.2	20.9	17.0	12.4	9.08	7.47

Table 6.4 **Ratio of 6306 Probe Sensitivity per Unit Thyroid Dose Commitment for 2 Hour Immersion to OTHER Immersion Times**

Immersion Time Hours	START OF EXPOSURE AFTER REACTOR SHUTDOWN HOURS				
	1	2	12	24	48
1	.5	.5	.5	.5	.5
2	1.0	1.0	1.0	1.0	1.0
3	1.5	1.5	1.5	1.5	1.5
4	2.0	2.0	2.0	2.0	2.0
6	2.9	2.9	2.9	2.9	2.9
8	3.8	3.8	3.8	3.8	4.0
10	4.8	4.8	4.8	4.8	5.0
18	8.3	8.3	8.3	8.3	8.5
24	10.5	10.5	10.9	11.1	11.4
36	14.9	14.9	15.6	16.1	16.4
48	18.9	19.2	20.0	20.8	21.3
60	22.7	22.7	23.8	25.6	26.3
72	26.3	26.3	27.8	29.4	30.3

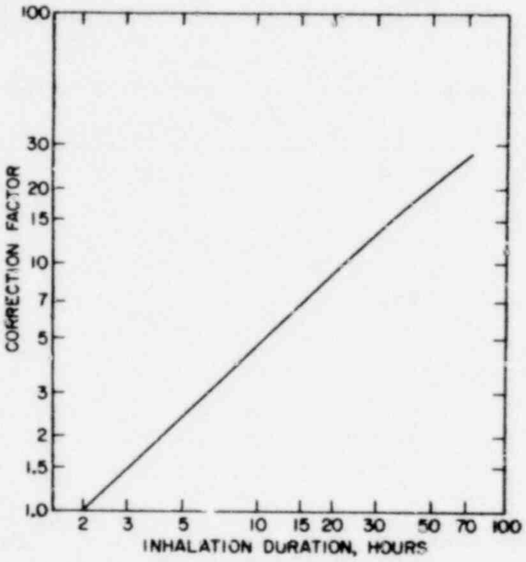

Figure 6.1 Correction Factors for Cloud Immersion Times Longer Than 2 Hours

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7. TEST OF TRIAL PROCEDURES FOR OPERATION OF THE AIR SAMPLING SYSTEM

7.1 Introduction

Many measurement systems are a composite of apparatus and user developed skills. The low probability of a release from containment power reactor accident, require users to train and drill rather than do. Training can be aided by properly written procedures; so that complete procedures could serve as reminders and instructions during an accident.

Operating personnel will require a general orientation on what to expect, on how to control their exposure, and on the operating details of the sampling system.

Air monitoring can be divided into three phases. They are: first, take one or more air samples; second, measure the activity of the air samples and third, predict thyroid dose commitments from the measured samples. The three functions are better performed by different groups of individuals. This is clearly evident with the evaluation phase where an overview of all measurements is required. The province of remedial action or staff guidance belongs to an emergency coordinator. Sample evaluation at too low a level may result in a splintered chaotic response. Due to the limited number of test personnel available and the trial nature of the procedure, the parts were integrated into one document. The trial air sampling procedure, containing all of the parts mentioned, is included in Appendix A-4.

7.2 Test and Evaluation

Six groups of two to four summer students each, were given copies of the trial procedure and asked to read and perform the procedure without any indoctrination. They were informed that the procedure was being tested and their comments were requested.

A trial problem was given to the students after they had read through the orientation and sample collection portions. The following is a typical trial problem:

Team - Air Sample

Go to location "A" in the Apartment Area located
and collect an air sample. Return and measure the activity.

Individual - Evaluation

Start of hypothetical HFBR (PWR) fission product release was

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1400 hours. Wind was stable from the NE at 1 m/s. Estimate H_∞ for the public for a 2 hour immersion.

7.3 Results

A composite of observer and student comments follow and are given in the order of the procedure.

Relatively minor reading problems persisted throughout the step by step instructions, resulting in omitted steps. Different omitted steps for different teams suggest the procedure requires drill for a high level of performance.

Evaluation of the dose commitment was well done for these rather involved instructions. One problem persisted. About half of the evaluations were made for the air sampling team rather than the public.

Certain problem words and sentences were located and are corrected in the procedure included in the Appendix.

All of the teams were able to take the desired air sample, measure the filter-canister and partially evaluate the dose commitment without prior instruction. For this reason, it was concluded that the trial procedure was a successful start toward final, <u>separate</u> procedures for air sample collection, filter-adsorber measurement and evaluation of the dose commitment.

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APPENDIX A-1

ASSESSMENT OF THE IODINE FRACTION ON THE PARTICULATE FILTER

A. Condensation Nuclei Retention Efficiency

Particulate fission products are assumed to have been released from the core in a vapor state. Cooling produces condensation particles that grow or coagulate by Brownian motion into a selfpreserving distribution(1). Particle size measurements made at an altitude of 9 km of weapons test fallout indicated that > 90% of the activity was carried by particles with $r < .15$ micron. Drevinsky(2) specified that most of the radioactivity was on particles $0.02 < r < 0.15$ microns.

Wilkening(3) used natural atmospheric radioactivity in tracer studies of particles above about .001 microns. He found 97% of natural radioactivity to be on particles smaller than 0.025 microns. Because of the similarity between Wilkening's results and expected fission produced particles, collection efficiency measurements were made with natural background. The method allows a comparison of Millipore type A, 0.2 micron pore size, to HV 9-33-FD-RI(4) glass-Remay laminated filter paper. The glass-Remay laminate was developed to replace HV-70, an asbestos based filter. Hollingsworth & Vose specifications list a DOP penetration of 0.001% as compared to 2% for HV 70.

The experiment was performed by drawing two separate streams of air, 5 CFM, through two standard adsorbers covered with the glass laminate filter media. One of the streams passed through a heater which raised the air temperature to > 100° C before filtering. A third sampler drew about 9.8 CFM through the reference millipore filter. Analysis was based on the 294 and 351 keV ^{214}Pb gamma lines. This isotope is the first gamma daughter of Radon, produced by alpha decay of 3.05 minute ^{218}Po. ^{214}Pb has a short half-life, 26.8 minutes, so that coagulation is assumed to be minimal. Particulate ages of < 1 hour are considered to be a good approximation of the resulting particle size distribution of early fission products from a containment release accident. Results indicated that both the heated and room temperature glass laminate media collected 93% of the ^{214}Pb found on the millipore reference filter.

B. Effects of Other Fission Products on Iodine Discrimination

Time dependent predictions were made of the iodine to total fission product vapor and aerosol activity released from containment. The WASH 1400 fractional release data were converted to activities by way of their core inventory. The activities of the more volatile radionuclides (except the actinides) were transformed to values proportional to CDV 700 instrument response, Figure A1.1.

Iodine to total volatile fission product intensity decreases with increasing time, Figure A1.1. All nine PWR cases are contained within the dashed lines which vary from .92 to .64 for 2 hours decay and .64 and .21 for 70 hours decay. A single line between limiting cases is the probability weighted ratio for all 9 PWR cases. Adopting WASH 1400 probabilities, the most probable ratio varies from .82 at 2 hours to .39 at 70 hours.

The BWR ratios start at a lower value and decline slightly faster with increasing time. The most probable iodine to total volatile fission products ratio declines from .58 at 2 hours to .19 at 70 hours. Neglecting BWR 5 as a trivial release, the BWR release cases vary more widely than the PWR cases.

C. Correction Method

Readings must be corrected for the presence of other fission products. Two correction systems can be used. First, the composite adsorber-filter counting rate can be corrected by the most probable iodine to total volatile fission product ratio for a PWR or BWR accident case. Second, and probably more accurate, two readings can be taken. The first with the adsorber-filter assembly and the second, immediately after, with the filter stripped off. The second reading of the stripped adsorber container is due mainly to iodine activity. The difference between first and second readings must be due to particulate activity. The iodine fraction of the particulates must be added to the adsorber reading. This can be done by correcting the particulate reading by an appropriate particulate iodine to particulate total ratio similar to Figure A1.1. Under the terms defined in WASH 1400 elemental iodine can exist in particulate, hypoiodous acid, and gaseous elemental forms. The particulate filter would be efficient for the first fraction but not the remaining elemental forms which would be stopped by the adsorber. For this reason, a rigorous correction could not be made by method 2, since the particulate fraction would not be known. A reasonable correction for the activity present on the particulate filter could be made by applying Figure A1.1,

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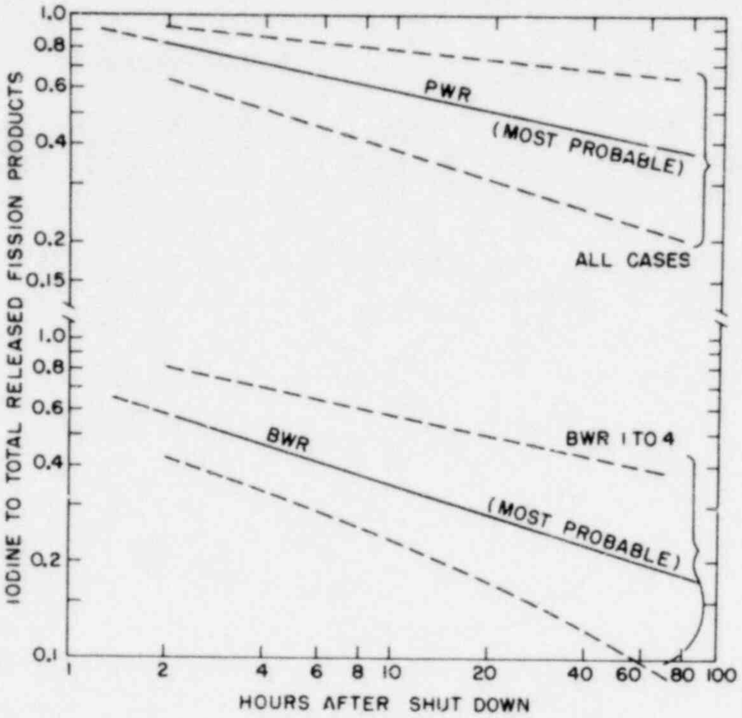

Figure A-1.1 Shield CDV 700 Response Exclusive of Noble Gases

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APPENDIX A-2

ASSEMBLY DRAWINGS

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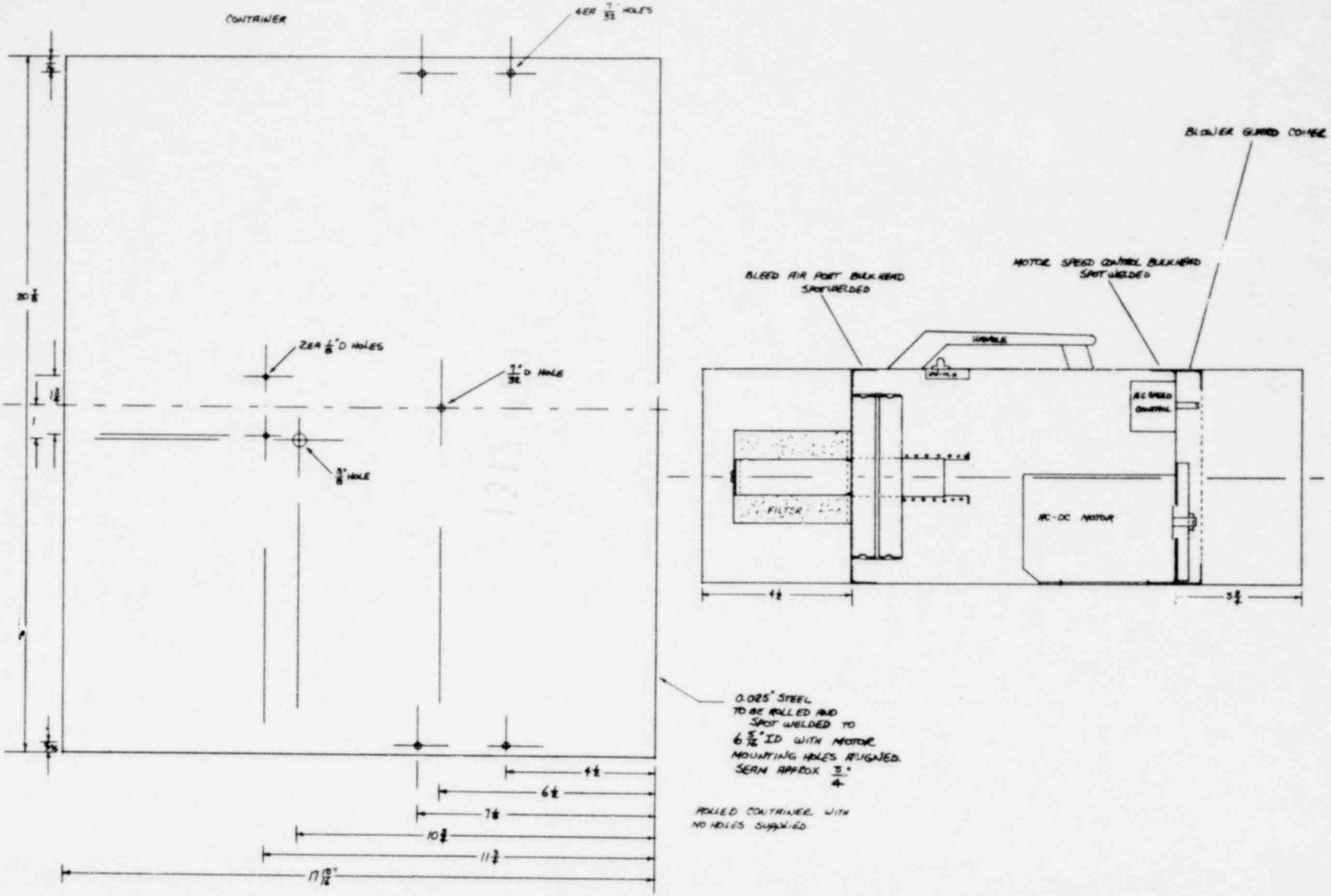

Figure 1. Radioiodine air sampling system container and assembly.

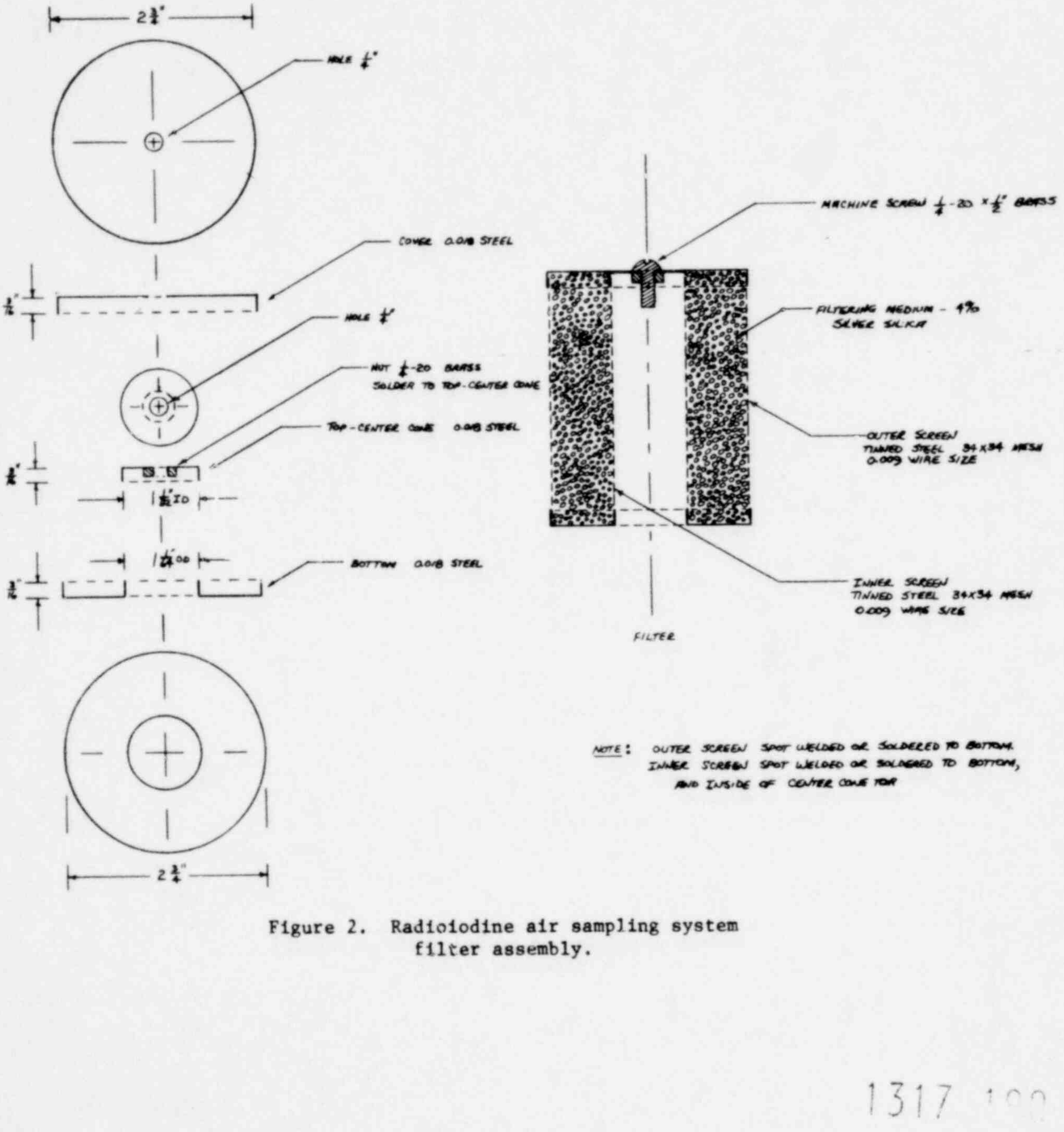

Figure 2. Radioiodine air sampling system filter assembly.

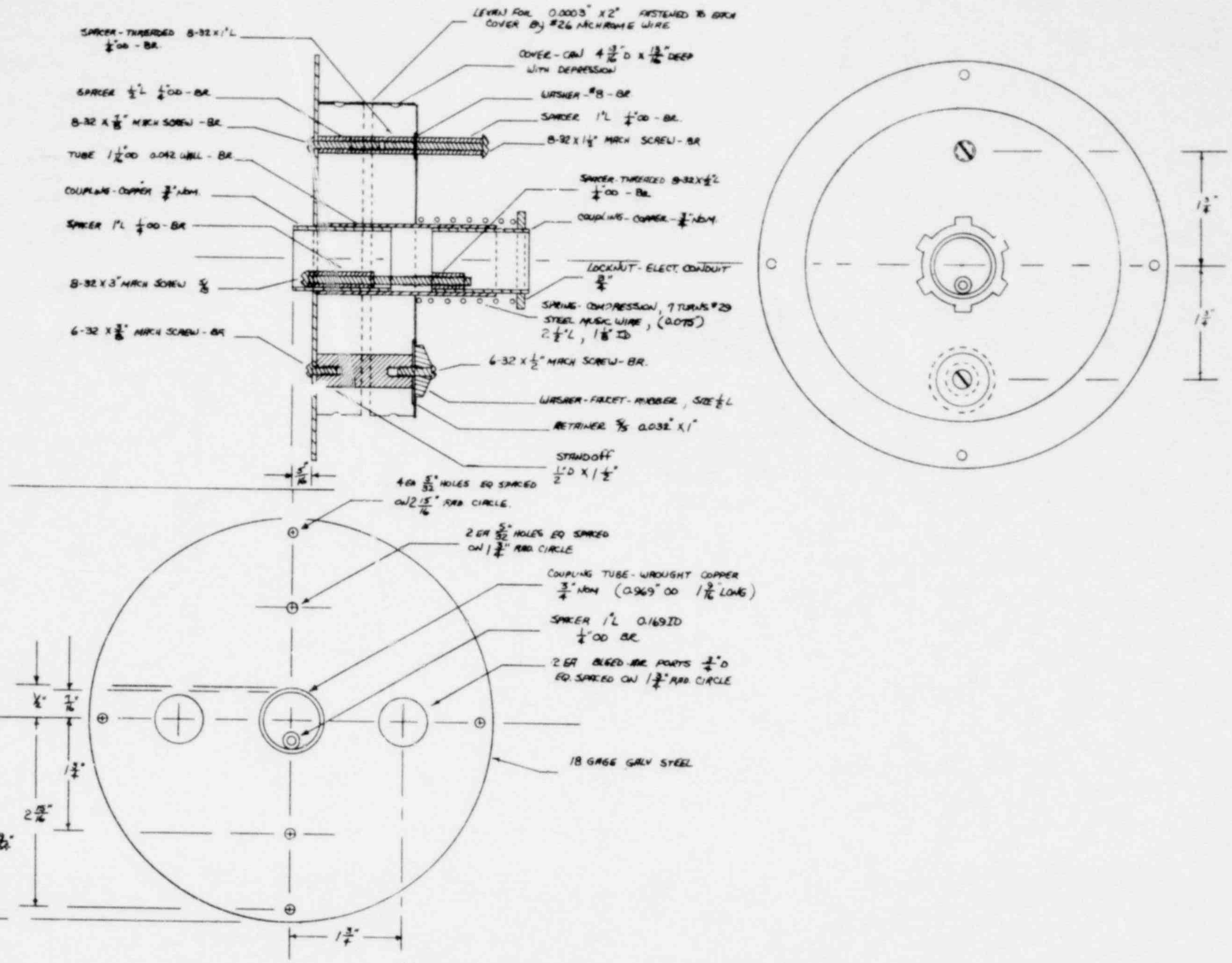

Figure 3. Radioiodine air sampling system bleed air port air flow regulator assembly.

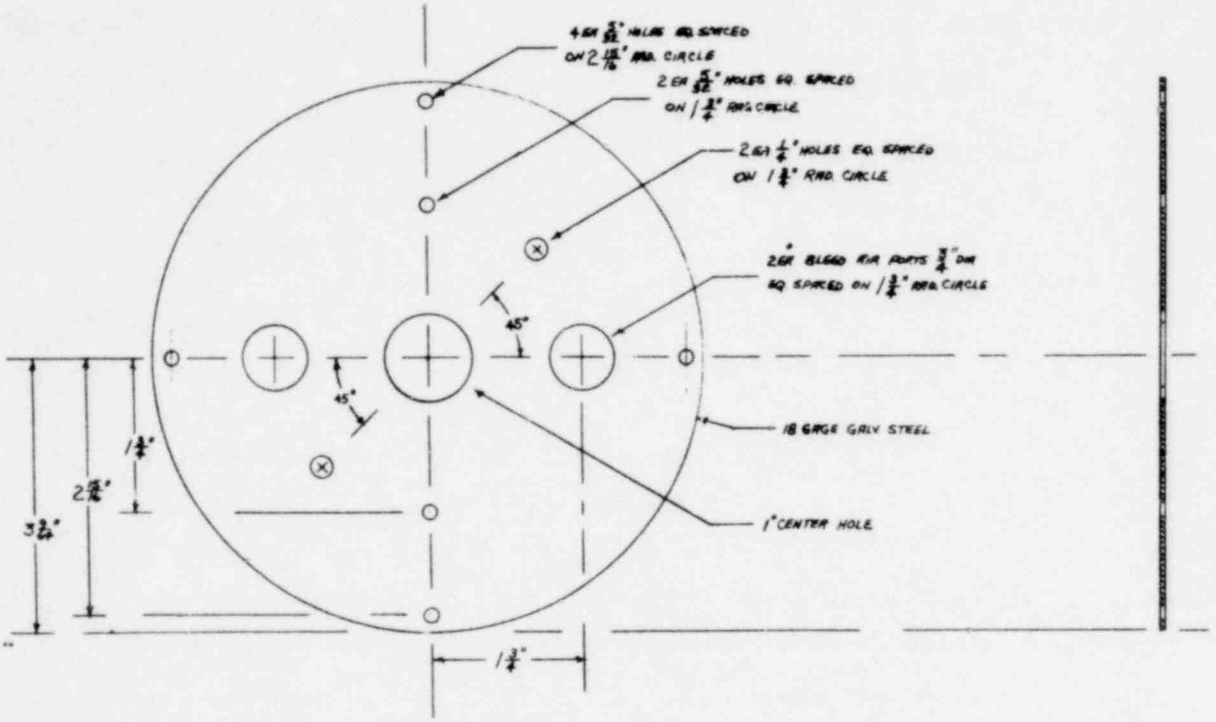

Figure 4. Radioiodine air sampling system bleed air port air flow regulator mounting end plate.

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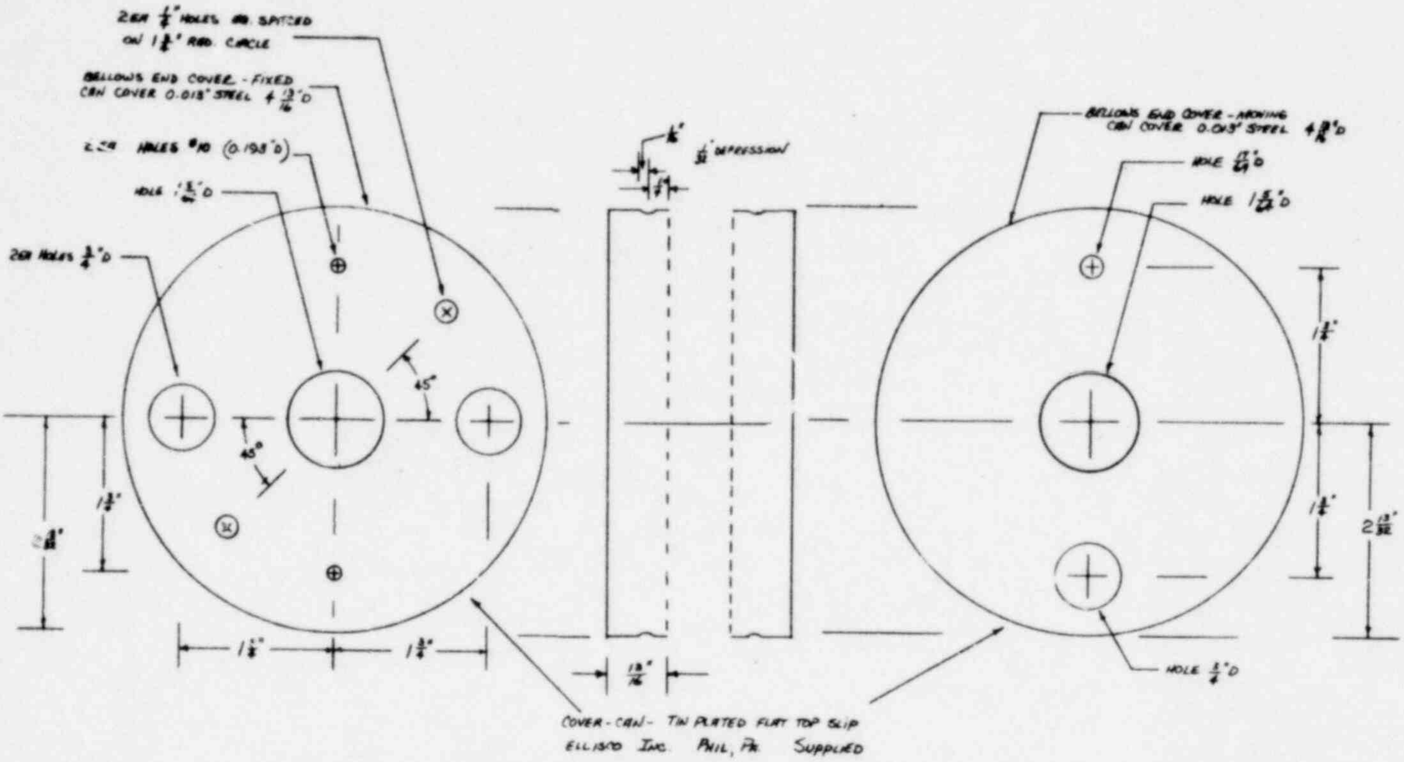

Figure 5. Radioiodine air sampling system bleed air port air flow regulator bellows end covers.

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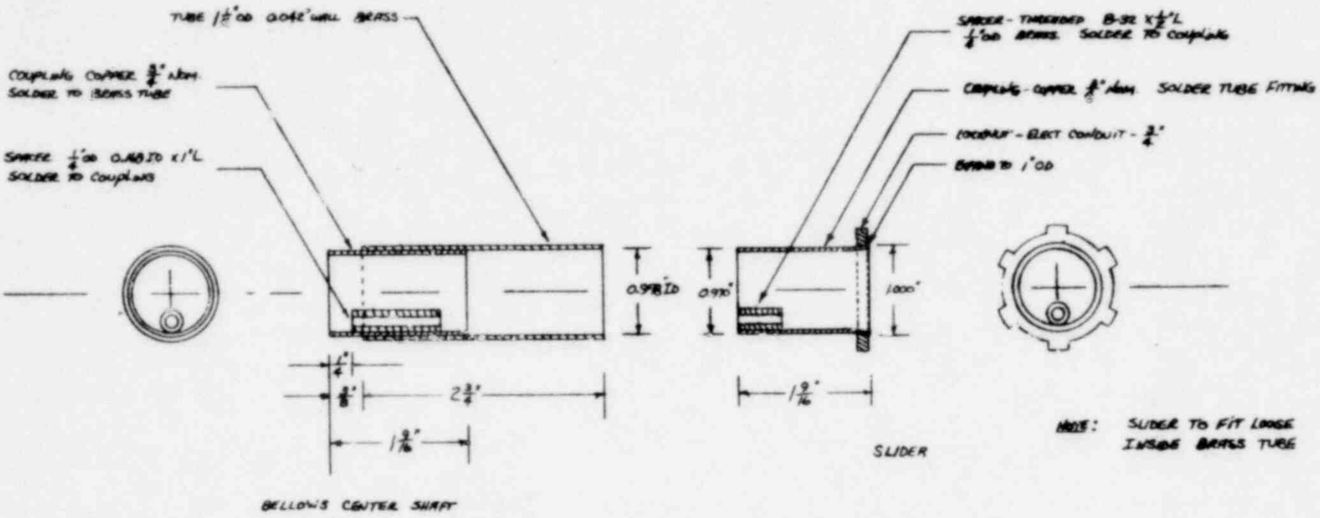

Figure 6. Radioiodine air sampling system bleed air port air flow regulator bellows center shaft and slider.

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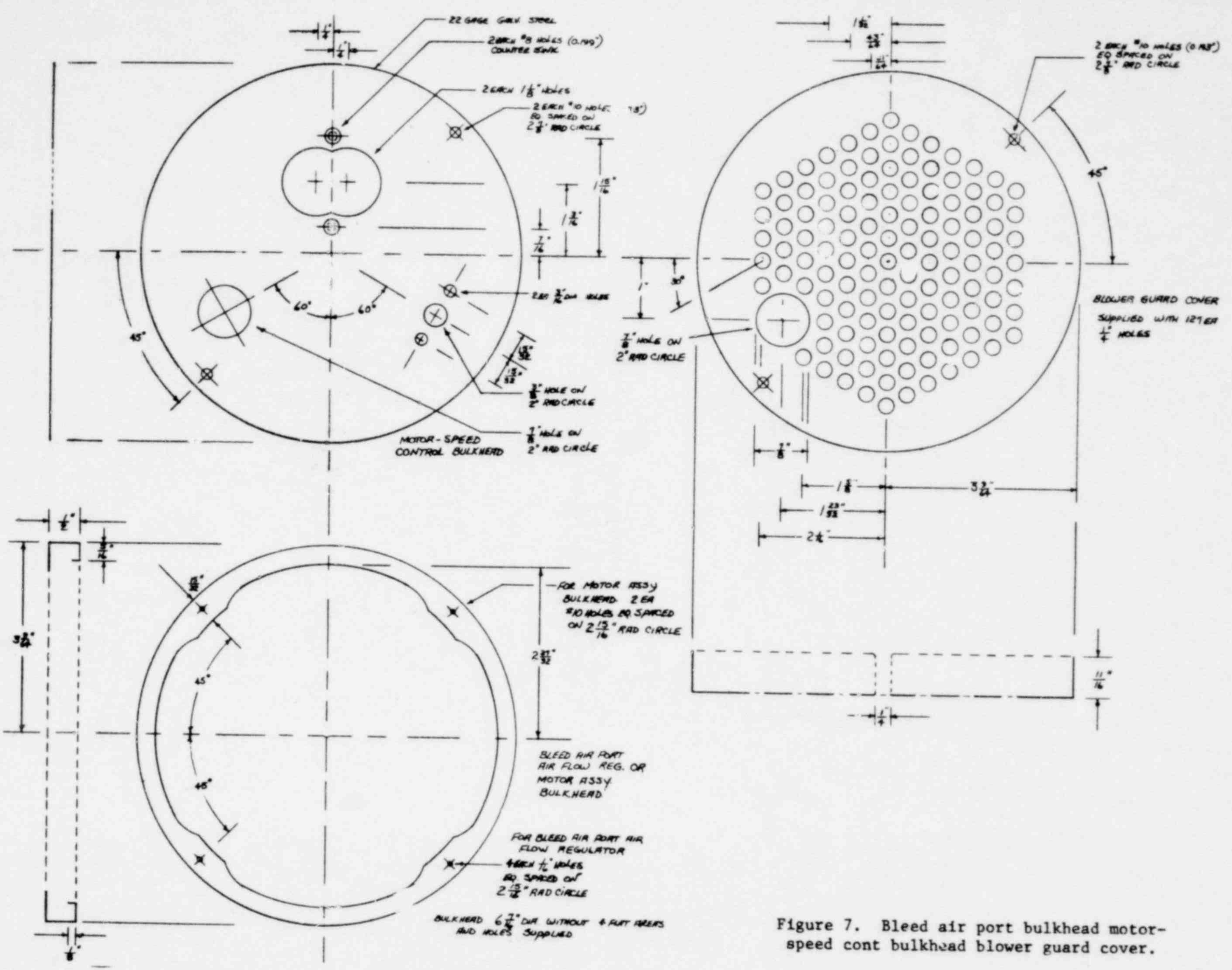

Figure 7. Bleed air port bulkhead motor-speed cont bulkhead blower guard cover.

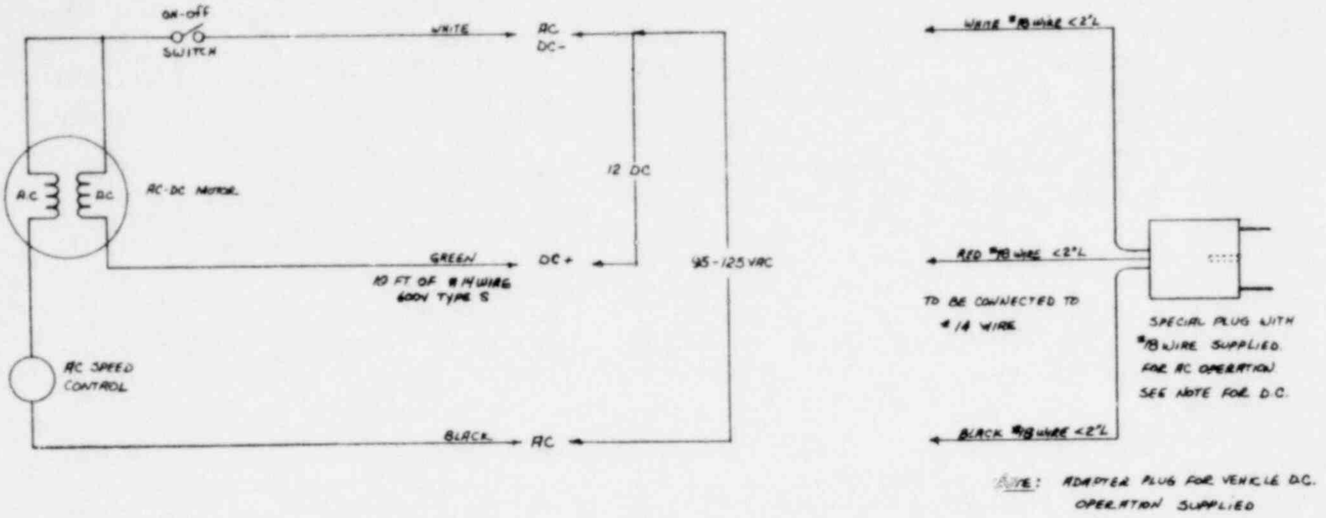

Figure 8. AC DC air mover wiring diagram.

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Appendix A-3

Itemized Component and Material Cost
(in 1978 Dollars)

Item	Price	Basis	Price 1 Each	# Required	Unit
Case	$2250.00	1000	$2.25	1	$2.25
Plastic Handle	500.00	1000	0.50	1	0.50
Bulk Heads	600.00	1000	0.60	2	0.60
3/8" Br. Washer	2.22	100	0.022	1	0.022
"O" Ring 3/8" ID (Buna 'N')	3.15	50	0.063	1	0.063
1/8" x 1/8" Rivots	1.25	50	0.025	2	0.050
#10 x 1/2 Sheet Metal Screw	1.10	100	0.011	1	0.011
				Total	3.50

Bellows

Item	Price	Basis	Price 1 Each	# Required	Unit
8-32 x 2 1/2" s/s Blunt Head Machine Screw	5.70	144	0.04	1	0.04
3/4" Conduit Nut	0.031	1	0.031	1	0.031
3/4" Copper Swet Coupling	0.12	1	0.12	2	0.24
Heyco(SB-875-11) Bushing	3.00	100	0.03	1	0.03
Spring	0.25	1	0.25	1	0.25
#8 Brass Washers	3.19	1000	0.003	2	0.006
#8 Phosphor Bronze Lock Washer	2.54	1000	0.0025	1	0.0025
#6 Phosphor Bronze Lock Washer	1.95	1000	0.002	1	0.002
#8 x 1 1/4" Br. Machine Screw (Blunt Head)	4.56	144	0.032	2	0.065
#6 x 3/8" Br. Machine Screw (Blunt Head)	1.69	144	0.012	1	0.012
#6 x 1/2 Br. Machine Screw (Blunt Head)	2.10	144	0.015	1	0.015
1/2 L. Bev. Faucet Washer	0.15	1	0.15	1	0.15
Spacer Non-insulating 1" (Not Threaded)	13.50	100	0.135	3	0.405
Spacer Non-insulating 1/2" (8-32 Threaded)	8.95	100	0.09	2	0.18
Steatite Pillar 1 1/2" x 1/2" (6-32 Threaded)	4.47	12	0.373	1	0.373
s/s Backing Washer 1" (W/#6 Hole)	2.28	100	0.028	1	0.028
Spring Cord 1/4" D x 10" L	0.25	FT.	0.21	1	0.21
Bellows Covers 4 3/4" D	0.25	1	0.25	2	0.50

Appendix A-3 cont'd.

Item	Price	Basis	Price 1 Each	# Required	Unit
Felt 3" Square	4.00	YD^2	0.003	1	0.03
Lexan Plastic 2"D x 30"L	0.25	YD	0.25	1	0.02
#26 Nichrome Wire 20"L	0.014	FT	0.023	2	0.046
"O" Ring 1/8"ID x 6 1/4" OD (Duna 'N')	1.61	2	0.81	1	0.81
Sheet Metal Screws #6 B.H. 3/8"L	0.57	144	0.004	4	0.016
Tube Brass 1 1/16" OD x .042" wall x 2 3/4"L	0.097	IN	0.27	1	0.27
Bellows Mounting Plate	0.52	FT^2	0.15	1	0.15
				Total	3.88
Motor Assy					
AC-DC Motor (W/Mounting Bracket and Screws	9000.00	1000	9.00	1	9.00
Switch (8A-120V) (W/Nut)	450.00	1000	0.45	1	0.45
Motor Speed Control (600 watt)	3.00	1	3.00	1	3.00
1/2" Conduit Bushing and Nut	0.36	1	0.36	1	0.36
Standard Cable Ties (1 3/4")	2.19	100	0.022	2	0.044
Cord #14, 600V 10 ft. long	0.138	FT	1.38	1	1.38
AC-DC Cord and Adapter Plug	1950.00	1000	1.95	1	1.95
8-32 x 1/2 Flathead Mach. Scr. s/s	1.70	144	0.012	2	0.024
10-32 x 3/8" B.H. Mach Scr. Brass	3.05	144	0.021	4	0.085
10-32 x 3/4" Br. Standoff	12.50	100	0.125	2	0.25
1/4" Brass Washer	2.69	200	0.013	2	0.026
1/4" External Lock Washer (Phosphor Bronze)	2.56	1000	0.0026	2	0.005
1/4-28 Nut (Steel)	0.30	144	0.002	1	0.002
Rev. Blower Assy	500.00	1000	0.50	1	0.50
"O" Ring 1/4" ID 3/8" OD	3.00	50	0.06	1	0.06
Splice Conductor (for Awg.12-18)	0.50	100	0.005	3	0.015
22 Gage Galv. Steel 6½" x 6½" (Motor Mounting Plate)	0.38	FT^2	0.11	1	0.11
Impeller Guard Cover	650.00	1000	0.65	1	0.65
Adhesive RTV-102	1.58	1	1.58	1/8	0.20

Appendix A-3 cont'd.

Item	Price	Basis	Price 1 Each	# Required	Unit
Epoxy Elmers (2 part)	0.49	1	0.49	1/100	0.005
				Total	18.12
Filter					
Steel 0.018" 1 pc 1½ x 1½ 2 pcs 3½ x 3½ }.19sq.ft.	0.25	FT^2	0.05	1	0.05
Screen Wire 34 x 34 mesh 1 pc 3½ x 3½ 1 pc 8 3/4 x 3 1/2 }.3sq.ft.	2.28	FT^2	0.68	1	0.68
Filter Paper H-933-FD-21 (9"L)	.10	FT	0.075	1	0.075
Mach Screw-Br. 1/4 x 20 x 5/16"	9.12	144	0.063	1	0.063
4% Ag-Silica Gel	2.70	1	2.70		2.70
				Total	3.57

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APPENDIX A-4

AIR SAMPLING PROCEDURE

Procedures are given for 3 phases of the task. They are equipment check and field air sampling, evaluation of the exposed filter-adsorber canisters, and internal thyroid dose equivalent predictions for the people living in the measured area. In order they are:

I. Equipment Check and Field Air Sampling

A. The air sampling system

1. Air mover, similar to a vacuum cleaner.

2. Automobile, 12 volt cigar lighter adapter.

3. One or more quart cans each containing one filter-adsorber canister. Take one can for each location you are to measure <u>and one spare</u>.

4. CDV-700 G-M counter.

5. Pocket ionization chamber.

6. Screwdriver or 25 cent coin to open the quart can lids (<u>immediately before use</u>).

7. Pocket or wristwatch to time the 5 minute ±6 second sampling period.

8. Respirator, one per person, optional.

B. Equipment checkout

1. Turn on the CDV-700 and test for an on-scale meter deflection of about 10 to 30 counts per minute on the times 1 range with probe shield closed. The meter will jitter around on an average reading. Read the midpoint value within the jitter band. Reject an instrument for zero reading or too high a reading in place where other CDV-700's read much lower. Twist metal shield open on probe and move toward the test spot on right side of instrument. Meter should go upscale as probe moves toward spot. Close the probe shield and allow the instrument to remain on.

2. Test the air sampler for operation with normal household AC electric power. Plug cord into a wall outlet and push the start switch near the handle. For proper operation, the sampler will sound and feel like a small vacuum cleaner.

3. Rezero pocket ionization chamber.

4. Take all of the 7 items of part A plus a map and/or route instructions to a car or truck that has a working cigar lighter.

5. Plug the DC adapter on the end of the sampler power cord and test for sampler operation using the car electrical system with the engine running. Turn the sampler off.

C. Air sampling procedure

1. Keeping vehicle windows closed, drive to the first location.

2. Arriving at the first location, leave engine running, open the first quart can, and remove the filter-adsorber canister.

3. Mount filter-adsorber canister over central suction hole and stretch rubber retainer over the outer end of the canister.

4. Check to see that the air sampler is plugged into the cigar lighter socket and step out of the vehicle to the relaxed extent of the power cord.

5. Turn on the sampler for exactly 5 minutes ±6 seconds.

6. During this period, the other team member will measure the general area outside of the vehicle with the CDV-700 and will record the time of day, location, and general area reading on the empty quart can top label similar to Figure A -4.

7. When the air sample is finished, remove the canister, replace in its quart can, and reseal can. Note: The canister may be warm to hot due to adsorption of moisture from the air, NOT radioactivity.

8. Go to the next location and use a new canister.

9. After the last measurement return promptly to the center for analysis of the filter-adsorber canisters.

II. Evaluation of the Filter-Adsorber Canisters

A. Filter-adsorber readout can be accomplished by the measurement team or by another designated person.

1. First check out a special modified CDV-700 instrument for operation. This instrument should have a background reading of 50 to 100 cpm on the times 1X range. The probe does not open so the instrument will not respond to the test spot. Reject instruments that do not have on-scale readings.

2. Locate a measurement place where the modified CDV-700 will have a background reading of 50 to 70 cpm. A basement location near the floor and in a corner may be suitable. If the recommended sand shield was constructed, use this device for all measurements including background.

3. Stack used canister assemblies within their quart cans several yards away from the measurement point.

4. Open the first quart can and take the filter-adsorber out with a paper towel or kleenex.

5. Insert the special CDV-700 probe into the air suction hole of the filter-adsorber.

6. Record the time of day, background reading, and the filter-adsorber reading on the quart can label.

7. Locate the rip cord-like thread on the outside of the canister and pull to remove the glass fiber filter cloth. Using kleenex for handling, return the filter into its quart can at the storage point.

8. Read the bare adsorber canister and record this final entry and date on the label.

9. Return the canister to its quart can, containing the filter cloth and reseal with the correct lid.

10. Start on the next measurement.

B. Upon conclusion of the measurements, mark the location code on each can with a felt marking pen and remove the peel-away labels. The labels should be mounted on pages of a school notebook, composition book, in measurement sequence for each team. The location information should be checked and supplemented if necessary with additional information. The data should then be taken or phoned to the local emergency coordination center.

III. Internal Dose Predictions

A. Glass filter cloth evaluation

1. Use Figure A-4.1 to account for the radioiodine on the glass filter cloth for a set of measurements noted on a transfer label. Enter the curve for the type of reactor and the number of hours between shutdown and time of measurement.

2. Find the iodine to total fission products correction factor, CF, above the vertical axis and calculate the difference in filter-adsorber and adsorber readings. This difference, F, is due to total fission product activity on the filter. The product CF x F is the corrected filter reading due to iodine at the time of the measurement.

B. Filter-adsorber evaluation

1. The adsorber net counting rate is determined by subtracting background from the bare adsorber measurement.

2. Add the corrected filter reading, step A2, to the net adsorber reading.

3. Select the appropriate curve that corresponds to the total inhalation time in the clouds for the people in the area.

4. Enter Figure A-4.2 with the total iodine counting rate found in step B2. Follow a vertical to the number of hours after reactor shutdown that the bare reading was made. The ordinate is the predicted thyroid dose commitment to a 5 year old child at the site of the air sample.

5. Correct the dose commitment for thepart that could have

been received prior to the time of the prediction. Figure A-4.3 can be used to make the correction by following instruction included on the Figure.

6. Multiply the correction factor obtained on step 3 by the dose commitment found earlier on step 4.

C. Evaluation of results

The projected dose commitment values can be posted on a map corresponding to their locations. If sufficient measurements were made, the path of the cloud should appear as significantly higher readings.

Predictions can be made of the dose commitment along the cloud track. This should improve the data base so that decisions can be made about stable iodine feeding, evacuation of exposed persons to reduce exposure to resuspended radioactive particles, and designations of contaminated pasturage.

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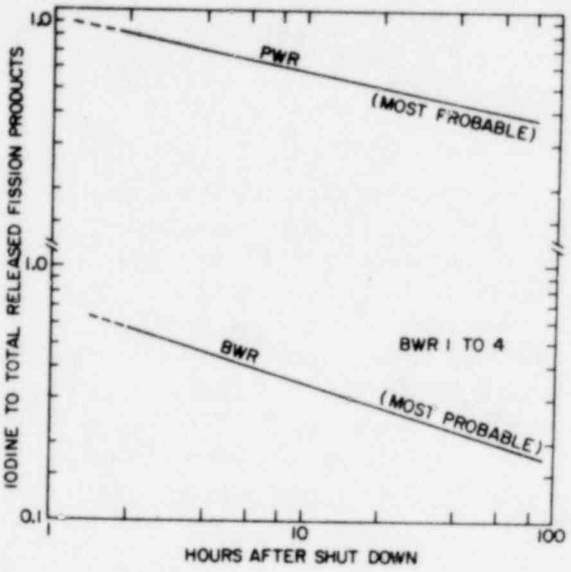


Figure A-4.1 Iodine to Total Fission Products Correction Factor for Shielded CDV-700 Instruments

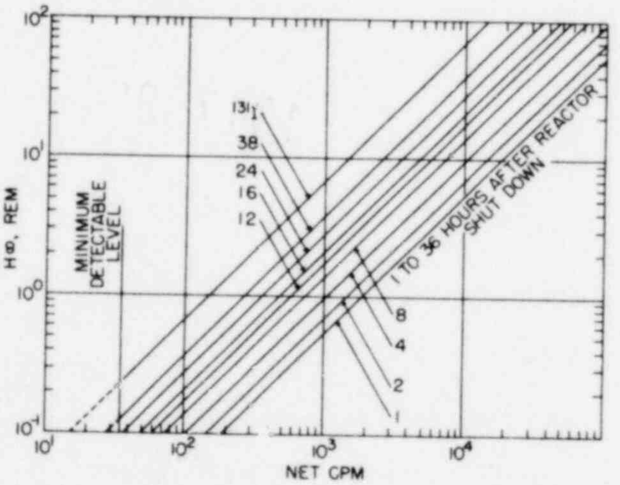
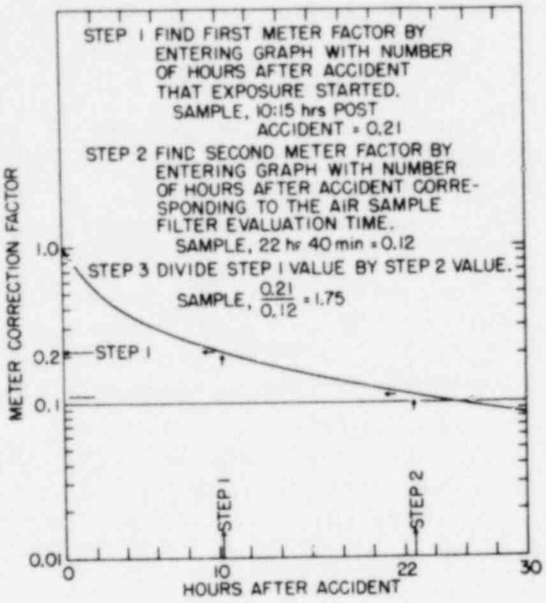


Figure A-4.2 Conversion of 6306 Probe Response to 5 Year Old Child Thyroid Dose Commitment for 2 Hr Immersion



STEP 1 FIND FIRST METER FACTOR BY ENTERING GRAPH WITH NUMBER OF HOURS AFTER ACCIDENT THAT EXPOSURE STARTED.
SAMPLE, 10:15 hrs POST ACCIDENT = 0.21

STEP 2 FIND SECOND METER FACTOR BY ENTERING GRAPH WITH NUMBER OF HOURS AFTER ACCIDENT CORRESPONDING TO THE AIR SAMPLE FILTER EVALUATION TIME.
SAMPLE, 22 hr 40 min = 0.12

STEP 3 DIVIDE STEP 1 VALUE BY STEP 2 VALUE.
SAMPLE, $\frac{0.21}{0.12} = 1.75$

Figure A-4.3 Correction for Iodine Isotope Composition

Location_______________

____

____ ______________

___ ______________

____

Time(Air Sample)_______

Date__________________

Area Reading_________cpm

EVALUATION

Background___________cpm

Filter-Adsorber______cpm

Adsorber_____________cpm

Time__________________

Date__________________

Figure A-4.4 Sample Filter-Adsorber Canister Label

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Appendix A-5

An Economical Sand Shield

CDV-700 counting rate within the collector, less an appropriate background rate, yields the net counting rate. Low activity samples or the presence of the radioactive plume or cloud may interfere with measurements. A simple sand filled shield (Fig. A-5.1) can significantly reduce cloud shine effects. The shield consists of four CDV-777-1 cardboard boxes labeled V3$_c$ and an empty one pound coffee can. Approximately 75 pounds of sand was placed in plastic bag lined 40 x 25 x 23 cm cardboard boxes. The coffee can counting chamber was positioned in the corner of a lower box. Configuration "A" was designed to be placed against an outside corner basement wall while "B" can be used anywhere. Measurements with a ^{137}Cs source indicated a minimum attenuation "A" type ∿7 and "B" type of ∿3.

Use of the shield slightly increased the sensitivity of a trial collector evaluation by 1.05 ± .009 over an open evaluation on a wooden table. The small increase was certainly due to backscattered photons.

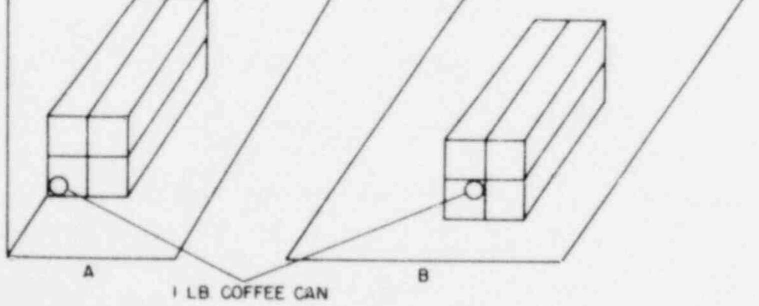

Figure A-5.1 Sand Shield Configuration

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