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SAFETY AND ENVIRONMENTAL PROTECTION DIVISION

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HIGH EFFICIENCY MIXED SPECIES RADIOIODINE AIR
SAMPLING, READOUT, AND DOSE ASSESSMENT SYSTEM

C. Distenfeld and J. Klemish

May, 1976

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ABSTRACT

Reactor accidents require monitoring to assess the impact to persons in the environment. This implies methods and apparatus to accurately and economically sample and evaluate possible released activity.

In this regard the Defense Civil Preparedness Agency awarded a contract to the Safety and Environmental Protection Division. Among other specifications, the contract required the development of a prototype iodine air sampling system that could differentiate against noble gas activity and could be evaluated by standard Civil Defense instrumentation.

The apparatus developed can efficiently (95%) collect organic or inorganic, particulate or gaseous radioiodine in concentrations below stable atmospheric iodine, and under severe ambient conditions. Response to noble fission gases was reduced to $<4 \times 10^{-4}$ of an equal iodine airborne activity by heating the collector to approximately 100° C. Reliable sample size, $\pm 5\%$, was achieved by using a simple air flow regulator. Thyroid dose commitment was mathematically and graphically related to the iodine isotope distribution expected in the environment and to the response of the Civil Defense CDV-700 instrument used to evaluate the sample. Sensitivity of the method allows dose assessment of 1-2 rads to a child's thyroid.

I. INTRODUCTION

Accidental releases of radioactivity from fission reactors will consist of active vapors or ^{particulate} aerosols. Composition of the released plume or cloud will depend on the energy of release and fission product volatility. In accidents at Windscale (1) and SL-1 (2), ¹³¹I was the predominant isotope present in both the initial cloud and later release. Therefore noniodine particulates were assumed to be trivial and ignored.

Subsequent to the Windscale and SL-1 studies, gamma spectrometry, and environmental iodine chemistry were improved. In a recent reactor safety study (3) a variety of accidents were considered that would lead to releases from containment. The study group composed nine different pressurized water and five boiling water reactor accident scenarios. Both elemental and organic compounds of iodine are listed in their Table VI 2-1, Summary of Release Categories Representing Hypothetical Accidents. Considering the amount of organic to total iodine for the 15 study cases, the organic form varies from ~1 to 97%.

Collins (4) studied the removal efficiency of coal and coconut based activated charcoal for organic iodine. He concluded organic iodine was more difficult to trap and retain in a wet atmosphere. Humidity, >35%, increased penetration sharply thereby leading Collins to try various impregnants to improve the high humidity efficiency of activated charcoals. A third chemical species of iodine was studied by Keller (5). Hypoiodous acid, HOI, is claimed to have an airborne molecular half time of

approximately one day and to be the major inorganic iodine species after washout treatment of the contained fission products within a steam-air atmosphere.

Kovach (6), in his invited paper "Adsorbents: Review and Projection", postulated another charcoal efficiency modifying parameter, adsorbate concentration. He relates the concentration of the adsorbate to be inversely proportional to the length of the mass transfer zone in an activated charcoal bed.

In order to assess environmental radioiodine an appropriate sample must both be collected and evaluated. The CDV-700 instrument uses a G.M. detector affording a response to all iodine isotopes as well as the radioactive noble gases. Heating the charcoal bed to $\sim 100^{\circ}$ C prior to analysis releases most of the xenon and krypton leaving the iodine activity intact. The fission iodines 131 to 135 have different decay times and energies, thus the average energy per decay will change with time. The CDV-700 instrument response per unit activity and absorbed dose are isotope and, therefore, time dependent.

This study was directed toward developing an activated charcoal collector that maintains high efficiency for all chemical species of radioiodine, in any humidity or concentration. A cylindrical collector with an axial counter tube was selected for optimum counter geometry and collection characteristics. This relationship between counter sensitivity and environmental composition of iodine isotopes was studied to permit evaluation of personnel exposure based on postaccident time and CDV-700

counting rate. A collector heater and regulated air mover were developed to quantitatively remove the radioactive noble gases and to insure a reliable sample size.

II. ORGANIC IODINE GENERATOR

Calibration and determination of collection efficiency required an organic radioiodine source free of carrier compounds and with the isotopic distribution expected in the environment of a reactor involved in an accident.

To satisfy these needs a fission iodine generator coupled with a chemical reactor was constructed using $<3 \mu$ thick ^{235}U alloy foil positioned around a 10^8 neutron/sec AmBe source. Approximately 3 m^2 of foil, containing 16.2 g of ^{235}U was assmblled in a strip approximately 12 cm wide. The foil was positioned on a continuous strip of 0.1-0.2 cm thick by 12 cm wide polyethylene-polypropylene open mesh and wound on a form designed to contain the neutron source. The resulting ^{235}U foil moderator-separator mesh spool was 22 cm in diameter with a >7.6 cm source hole along the axis. The assembly was positioned in the centroid of an aluminum pressure vessel and voids were filled with paraffin.

Thermal neutron fluences average $\sim 7 \times 10^4$ neutron/cm² sec along an outside end of the spool. After a number of trials, 180 psig argon containing $<0.3\%$ CH_4 was used as the standard gas moderator to "range out" the fission fragments, and provide methane for iodine conversion to organic form. Iodine isotopes are formed directly by fission and more importantly (7) through decay of chain members. Generator operation

involves pressurizing the cell and delaying discharge until adequate buildup can take place. About eight days will provide 50% equilibrium for ^{131}I , 75% for ^{132}I , and near saturation for the remaining three isotopes. Considering ^{135}I , the calculated equilibrium activity was 2.9 μCi . Measurements indicated a CH_4 ^{135}I yield of 0.16 μCi , about 5.4% of the total ^{135}I saturation value. Postma (8) studied the conversion efficiency of elemental to organic iodine. His results showed that the conversion efficiency was inversely related to iodine concentration and directly related to container size. Postma calculated a value of approximately 4% for a minimum initial iodine concentration of 10^{-14} g/cc; a concentration about ten times larger than exists in the generator. Generator operation is considered to be reasonable in light of Postma work.

Chemical iodine species produced by the generator were determined by using the method outlined by Keller (5,9). Four 2.5 cm I.D. by 1.9 cm deep cylindrical cells were constructed (Fig. 1) to be used to differentiate the iodine into its different chemical species. In serial order a Hulingsworth and Vose type HV-70 particulate filter was mounted on the inlet side of the first cell. The cell was filled with cadmium iodide impregnated Chromosorb-P to a depth of 1.3 cm. The second cell contained a similar bed of P-iodophenol impregnated, acid washed, activated alumina, and the remaining cells were completely filled with 18 x 30 mesh triethylenediamine activated charcoal. According to Keller

the chromosorb and alumina filters are specific for elemental and HOI iodine, respectively. The remaining filter and backup collect the organic iodine activity and noble gases. NaI (Th) spectrometer scans were used to evaluate the five differentiator components. Results indicated that 95-99% of the iodine existed in organic form. On the HOI filter 1-5% was observed and nothing on the remaining filters.

Isotopes produced by this generator were identified with a 5 cm Ge (Li) detector. The lines displayed on Figure 2 represent magnitudes of the maximum channels for all of the peaks observed. Vertical peak lines were coded as ¹³¹I, 2, 3, 4, and 5, and represent identification of each peak produced by the designated isotope. Identification criteria required the correct energy ± 1 KeV, and the proper family yield relationship. One peak, 918 KeV, could not be attributed to the iodines. However, the peak intensity was comparable to background suggesting a statistical artifact. Table 1 lists some of the common volatile fission products. The spectrum (Fig. 2) was searched for gamma signatures of the volatile products listed in Table 1, and they could not be confirmed. If present, the maximum individual product concentration must be <5% of the iodine lines observed. Noble fission gases are inefficiently adsorbed on activated charcoal at ambient temperatures. Calculations (Appendix 1) indicate that about one-sixth of the Xe activity will be retained. Unfortunately the noble gases may exceed (3) radioiodine activity by a factor >10, requiring quantitative removal by heating (see Appendix 1 and Part 2).

III. COLLECTOR, AIR MOVER AND HEATER

A. Collector

The air sample collector is a cylindrical structure measuring 7 cm in diameter x 9 cm in length with a blind hole along the axis. The outer collector shell is constructed of 0.89 mm aluminum sheet perforated by 3 mm holes comprising about 35% of the surface. The same material is used to form the hollow center that provides a path for the exit filter air and later a guide to insert a CDV-700 counter probe for evaluation. Collector dimensions were determined by calculations, Part IV calibrations, and verified by measurements (see Table 2). In keeping with the stated aims of high efficiency for any condition, either the 2 cm thick CDV-700 or 1.7 cm CDV-700M collector could be used.

Approximately 133 g of 18 to 30 mesh activated charcoal (10) impregnated with triethylenediamine (TEDA) is packed into the 2 cm thick annular space between the outer shell and counter tube. Other adsorbers were considered and eliminated as too expensive or not as efficient (see Appendix 2).

Glass fiber mat, 0.8 mm thick, is used to line the interior of the outer shell and the exterior of the inner tube. Refer to Appendix 3 for engineering drawings.

B. Air Mover

A conventional shop vacuum cleaner motor is mounted over perforations in the bottom of a standard 5 gallon metal paint pail. Metal legs are used to establish a 2.5 cm discharge air diffusion space below the can.

The pail lid supports the power cord, switch, collector seal, heater power plug, and air flow controller. Flow control is achieved by balancing the vacuum head within the tank against an adjustable spring loaded relief valve. Increases in line voltage will increase both motor speed and unregulated vacuum by a maximum of about 35%. Controlling the head across the collector provides fairly precise flow, $5 \pm 3\%$ SCFM, through the filter since dust loading is discounted by the short design sampling time. Engineering drawings are available in Appendix 3.

C. Heater

The heater assembly is a glass wool insulated double wall cylindrical container with one open end. The open end is designed to fit over the air sampler collector, and seal to the air mover lid. Air is drawn through perforations in the top of the heater, and heated by a wire wrapped ceramic heater. Temperature control is achieved by a thermostat positioned in the hot air stream. The heated air reaches about 100°C in 1 min and stabilizes at about 120°C in 4-5 min. Thermocouple measurements (Fig. 3) made in the exit air stream of the sample collector indicate a thermal lag of 2-3 min requiring a 7 min heating cycle. A neon lamp is mounted on the top of the heater. The indicator is electrically connected across the thermostat so that on-off operation of the lamp indicates thermostat operation. Timing of the heating operation is started with the first turn on of the neon light. Heater power is unplugged after 7 min while the air movement continues for an additional 4 min. This insures the collector will exceed 95°C for about 4 min.

Adsorbed xenon removal was determined by measuring the heat induced reduction of the 81 KeV ^{133}Xe and 250 KeV ^{135}Xe lines. Gamma measurements were made using a Ge (Li) detector before and after the standard heating cycle mentioned above. Integral peak attenuation values of 141 and 151 reflect minimum values since the postheating peak values were near background. Katz (Appendix 1) calculated a xenon adsorption efficiency of about 5.5% relative to airborne iodine for a 75 ft³ sample. Thus the heating cycle can reduce the overall xenon response to $<3.8 \times 10^{-4}$ of that for iodine.

Adsorbed iodine peaks were also observed before and after the standard heating cycle. No significant change was observed. Mechanical details of the heater assembly are contained in Appendix 3.

IV. CALIBRATION

Radioiodine collector calibration was accomplished by slowly discharging the generator into a treated air stream that passed through the collector. Air treatment was limited to heating approximately 200 ft³ of clean air to $>95^{\circ}\text{F}$, and evaporating distilled water to humidify the air to $>90\%$ RH (see Fig. 4). The air was circulated by fan within the 200 ft³ polyethylene lined steel tank. Glass wool insulation, on the tank exterior, reduced heater power needs and allowed higher humidity by reducing condensation within the tank.

Collectors were tested in an external 19.5 cm diameter x 22 cm high polyethylene test chamber. Vacuum applied to the collector caused the

treated air to flow at a controlled $5 \text{ ft}^3/\text{min}$ rate from the 200 ft^3 tank, through an insulated and heated line to the testing chamber and collector under test. Flow rate was measured in the discharge stream of a sealed oil-less vacuum pump and the air then returned to the 200 ft^3 tank.

Filter testing was accomplished by mounting an experimental and back up collector in the chamber, sealing, and pumping down the entire apparatus to ~ 0.2 psi below atmospheric pressure. Flow was adjusted to $5 \text{ ft}^3/\text{min}$ and test chamber temperature was monitored to observe thermal equilibrium, always a few degrees less than the tank air temperature. The iodine sample was introduced into the flowing inlet air stream with a small flow rate, $0.4 \text{ ft}^3/\text{min}$. This reduced the organic iodine concentration to $< 4 \times 10^{-19} \text{ g/cc}$ and slightly modified the temperature, $< 0.1^\circ \text{ C}$, and humidity of the inlet air.

After exhausting the generator, about 6 min, the test collector and back up filter were removed and heated to 100° C to remove noble gases. The collector was counted with CDV-700 or 700M instruments for ~ 1 hr postcollection. After opening the collector and removing, mixing, and weighing the charcoal, a 15 cc weighted sample was taken. The back up filter consisted of two serial 15 cc 18 x 30 mesh TEDA impregnated charcoal beds. All three samples were counted with a 5 cm Ge (Li) detector to determine collection efficiency and isotopic concentration.

Pence (11) described charcoal adsorption characteristics for organic iodine in terms of the log decontamination factor where

decontamination factor DF is $= (1 - \text{adsorption efficiency})^{-1}$, and bed depth, for a constant flow rate. Changing this relationship slightly to penetration $p = DF^{-1}$ or

$$\ln p = -kB \quad (1)$$

where B = bed depth and k = constant;

$$p = e^{-kB} \quad (2)$$

Considering an initial concentration, A_0 , the concentration, A, for any bed thickness is

$$A = A_0 e^{-kB} \quad (3)$$

Efficiency of a test collector was the trapped activity on the collector, A_c , divided by the sum of the collected and untrapped activity, A_z . Since two backup filters were used with collected activities, A_1 and A_2 , the efficiency, ϵ , was

$$\epsilon = \frac{A_c}{A_c + A_1 + A_2 + A_z} = \frac{A_c}{A_t + A_c} \quad (4)$$

where $A_t = A_1 + A_2 + A_z$.

Ignoring the input activity and thereby avoiding apparatus upstream of the collector and plate out, the only unmeasurable quantity in equation (4) was A_z . The observed activity on the back up filters was:

$$A_1 = A \int_0^1 e^{-kB} dB \quad (5)$$

for a bed 0-1 thick

$$A_1 = \frac{A}{k} (e^{-k} - 1)$$

$$A_2 = A \int_1^2 e^{-kB} dB \quad (6)$$

for a bed 1-2 thick

$$A_2 = \frac{A}{k} (e^{-2k} - e^{-k}) = \frac{A}{k} e^{-k} (e^{-k} - 1)$$

$$\frac{A_1}{A_2} = \frac{1}{e^{-k}} = e^k \quad (7)$$

$$k = \ln (A_1/A_2)$$

The total activity available to the back up filter was A_t

$$A_t = A \int_0^{\infty} e^{-kB} dB \quad (8)$$

$$A_t = \frac{A}{k}$$

from eq. (5)

$$A = \frac{k \cdot A_1}{(e^{-k} - 1)}$$

Finally,

$$A_t = \frac{A_1}{(e^{-k} - 1)} \quad (9)$$

Deriving k from eq. (7) and A_t from eq. (9), the collector efficiency was determined as:

$$\epsilon = \frac{A_c}{A_c + A_t} \quad (10)$$

According to Collins (12) the methyl iodide trapping efficiency is directly related to the depth of bed and inversely related to the gas velocity through the bed. Collins combined the two variables in terms of stay time, T , which was the result of dividing the bed volume by the volumetric flow rate of the gas. He experimentally determined that the

log of the decontamination factor was nearly proportional to stay time. The relationship appears to hold for more than three decades of decontamination factor. The proportionality constant, $\log_{10} DF \div \text{stay time}$, was a characteristic of temperature, humidity, grain size, type of charcoal, and impregnant. Collins determined the constant to be 9.35 for 12 x 16 mesh American coconut charcoal impregnated with 5% TEDA, a material that was nearly free from temperature-humidity dependence. His value was adjusted for our grain size, 18 x 30 mesh, by applying the same improvement Collins observed between 12 x 16 and 18 x 30 mesh on 0.5% KI loaded 207B charcoal. The relationship was

$$\text{Log}_{10} DF = 13.6 T \quad (11)$$

Using our measurements for stay times of 0.06 and 0.106 sec, and corresponding efficiencies of 0.87 and 0.96, the resulting constant was 14.0 ± 0.7 . This is in good agreement with the adjusted Collins value permitting simple engineering adjustment of collector parameters for flow rate and bed size.

Basically a collector for all chemical species should have a high and constant efficiency. Particulate iodine activity would present a source near the outer shell of the collector. According to Keller (Allied Chemical Corp.), HOI species will be as readily adsorbed on TEDA impregnated charcoals as elemental species. Organic iodine would undergo exponential adsorption according to eq. (11). For a cylindrical collector, stay time should vary with the square of the radius. Calculations

indicate that particulate or gaseous elemental activity would be detected with about 86% of the value of the same airborne organic iodine activity. Assuming 50% elemental iodine vapor or particulate activity, the reported value would be an acceptable 93% of a pure organic iodine source.

Kovach (6) raised the question of concentration dependence on collection efficiency. It was instructive to consider the naturally occurring stable environmental iodine concentration. Lininger (13) reported measurements of 0.2 to 1×10^{-14} g/cc of particulate iodine in Massachusetts. He compared his work to a Hawaiian determination of $\sim 2 \times 10^{-15}$ g/cc. Applying Postma (8) predictions would suggest an environmental organic iodine concentration $> 8 \times 10^{-17}$ g/cc. This value is approximately 10^2 larger than the organic iodine concentration produced by our generator and dispersed into the test air stream so that a concentration dependence was not inferred by measurement.

Breakthrough corresponds to saturation of a charcoal bed for iodine under stay time conditions adjusted for high efficiency. Nelson measured the methyl iodide required to produce 1% breakthrough in the charcoal used in the American Optical cartridges. A value of 0.06 g $\text{CH}_3\text{I/g}$ of charcoal equivalent to an activity of $\sim 7 \times 10^5$ Ci at 1% loss; more than the total iodine released from the Windscale accident (1).

Field use of the collector requires evaluation by standard CDV-700 type instruments. Evaluation time is expected to vary widely so readout was performed over 24 hr (see Fig. 5). The time dependent response was calculated by converting the assayed iodines to their equivalent counting rates. This was accomplished by adjusting all of the assayed

radioiodine gamma lines of >1% (15) per decay to their equivalent air dose rate (16), and CDV-700 energy dependence (17) (Fig. 6). Results are listed per unit decay as follows:

Isotope	^{131}I	^{132}I	^{133}I	^{134}I	^{135}I
$\frac{\mu\text{R}\cdot\text{cm}^2\cdot\text{sec}}{\text{hr}}$	.813	3.97	1.15	4.39	3.55

Considering the above table an assayed activity, d/s, and the geometry factor, cm^2 , are needed to complete the calculation. Geometry was studied with 2.52 μCi ^{131}I source on a strip of filter paper 1.0 x 7.3 cm. The strip was oriented along the length of the cylindrical collector. GM measurements were made with the collector empty and charcoal filled, and with the strip adjacent to the outside shell and probe housing tube (Fig. 7). Photon attenuation for the 2 cm thick bed followed the published (16) mass attenuation value, $0.1 \text{ cm}^2/\text{g}$, for a measured charcoal density of 0.53.

Simple geometry correction was not expected since the detector source was neither a line nor a point. The measured CDV-700 response to the ^{131}I step adjacent to the probe tube was 0.95 mr/hr. This value was normalized to the standard ^{137}Cs calibration of 600 c/m per mr/hr. The geometry correlation found through the use of ^{131}I activity, the calculated dose rate due to ^{131}I (see above table) and the measured CDV-700 response was 80.3 cm^2 . The distance dependent correction was

$$\text{area} = k R^x \quad (12)$$

where area = cm^2 , R = radius, cm from ϕ , k = 55.16 and x = 1.25.

Expression (12) was used to calculate the geometry dependence shown in Figure 7.

Finally CDV-700 response could be calculated from the assayed iodines, geometry, attenuation, tabulated air dose rate, and the organic iodine adsorption dependence described by equation (2). Results are shown in Figure 8 and as the solid lines in Figure 5.

V. PROJECTED FIELD USAGE

Conversion of collector readings to potential thyroid dose depends on a CDV-700 evaluation of the iodine isotopes expected in the environment. Table 3 lists isotope yield measurements made at release points around power reactors (18,19), standard fission yield data (7), and the results of the BNL generator, corrected for build up (t_0). In all cases the data were normalized to unit activity for ^{131}I . These data reflect variable amounts of elemental, HOI, and organic iodine species. Significant differences in chemical reactivity of the different isotopes are expected and verified through the courtesy of C. Pelletier, staff member of Science Applications (20). Page 80 of their data is included as Table 4, and indicates a marked reduction in the organic ^{132}I yield compared with ^{131}I . Thus it is suggested that uncertainties listed in Table 3 are due to differences in chemical species. Figure 9 graphically presents the data listed on Table 3. Numbers 1 to 5 refer to power reactor measurements, M-R represents a recent tabulation of elemental

fission yield (7), and BNL refers to our measured organic fission yield. Considering ^{133}I and ^{134}I , most of the power reactor yield data are, as expected, between the elemental and organic yield limits. Oyster Creek yields are consistently low, suggesting the measurements may not have been made under equilibrium conditions. High ^{132}I yields measured at reactors 3 and 4 are thought to reflect spectrometry problems.

In general the BNL organic yields are below the elemental yield except for ^{135}I where an excess exists. Radioiodine is derived directly as a fission fragment and through decay of a parent isotope. A tabulation (7) of the direct or incident yield and the total or cumulative yield suggests

Isotope	Percent				
	^{131}I	^{132}I	^{133}I	^{134}I	^{135}I
Incident	0.3	0.5	6.2	12.3	48.1
Cumulative	99.7	99.5	93.8	87.7	51.9

that most of ^{131}I to ^{135}I are decay products while the direct fission yield increases significantly with iodine mass number. Figure 10 indicates an organic yield dependence with direct fission. Methane gas labeling is a kinetic process, so organic iodine formed in the light tight generator takes place either during Te decay or near the end of the path for ^{133}I to ^{135}I fragments. Some of the Te must be adsorbed on the generator walls. During decay a fraction of the newly formed iodine is trapped on the generator walls suggesting that the decay mode will yield less organic iodine than the direct fission mode.

An understanding of the yield is important since the CDV-700 will have about four times the response to ^{135}I as compared to ^{131}I (see section IV. Calibrations). Iodine formed in a power reactor will be trapped by the fuel cladding in an organic free environment. Melt down will terminate fission so that organic iodine ultimately formed should not be due to fission labeling. For this reason the organic ^{135}I yield value was reduced to the dotted line in Figure 9. A range of field values are expected (3) requiring the use of mean values. The magnitude of the uncertainty varies from 30 to 46% leading independently to uncertainty in evaluating the expected thyroid dose and CDV-700 reading.

Employing the methods and results outlined in section IV. Calibrations, and starting with the earlier work of Hull (21), thyroid uptake dosages were calculated for several 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), where

$$f(t) = .235e^{-.000453t} - .235e^{-.111t} \quad (13)$$

where t = hours

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

Correcting for iodine isotope decay

$$f(t) = (.235^{-.000453t} - .235e^{-.111t}) e^{-\lambda t} \quad (14)$$

where λ = physical decay constant

and considering an instantaneous exposure of A_o , $\mu\text{Ci/hr}$, the total iodine uptake is A , $\mu\text{Ci/unit inhaled activity/hour}$.

$$A = .235 A_o \int_{t_1}^{t_2} e^{-t(\lambda+.000453)} dt - \int_{t_1}^{t_2} e^{-t(\lambda+.111)} dt \quad (14a)$$

Integrating from $t = 0$ to ∞

$$A = .235 A_o \left[\frac{1}{\lambda+.000453} - \frac{1}{\lambda+.111} \right] = A_o T_i \quad (14b)$$

Realistically, protracted exposures are expected. The total protracted activity A_p $\mu\text{Ci/hr}$ is

$$A_p = A_o T_i \int_0^b e^{-\lambda b} d h \quad (15)$$

where Δb is the exposure time in hours.

Isotope	Phy. $t_{1/2}$, hr	λ , hr^{-1}	T_i , hr	$\mu\text{Ci/m}^3$	$A_o = \mu\text{Ci/hr}^1$
^{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 (3) 5 year old child.

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

Clearly the ratio of breathing rate to thyroid mass indicate that the 5 year old child will receive the maximum uptake per gram of thyroid tissue. The infinite dose was calculated

$$D_{\infty} = A_p \times \frac{.5928 \text{ radxd}}{\mu\text{Ci x MeV x hr}} \times \sum E(\text{RBE}) \text{ MeV} = \text{rads} \quad (16)$$

and listed below.

Isotope	$\sum E(\text{RBE}) \text{ MeV}$		$.5928 \sum E(\text{RBE}) \cdot T_i$ Rad _∞ · μCi ⁻¹
	Stand. Man	Stand. 5 yr old	
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 dose results are shown in Table 5 for inhalation times from 0.5 to 10 hr and exposure starting times of 1 hr to infinity. CDV-700 response (Table 6) was used to determine the net reading per unit infinite thyroid dose listed on Tables 7 and on Figure 11. Dose uncertainty was generally less than 11% with a maximum approximately 17%. CDV-700 uncertainty varied inversely with time from 35 to 10%. The overall error in CDV-700 response per unit dose was the difference between meter and dose uncertainty since they compensate (i.e., shifts to larger organic fractions reduce both dose commitment and meter response). An overall uncertainty of approximately 25% was attributed to the expected iodine isotope yield variation.

Evaluation of field samples requires a heating operation prior to measurement. Since this must be done in clean air free of the plume or cloud, significant time differences may exist between the required exposure starting time and the collector evaluation time. Figure 12 was constructed from Table 6 to permit collector evaluation to be adjusted to the exposure starting time. Use may then be made of Figure 11 to determine the infinite dose.

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. 13) 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 $1.05 \pm .009$ over an open evaluation on a wooden table. The small increase was certainly due to backscattered photons and helped to offset the approximately 8% efficiency loss attendant with a particulate sample.

VII. SUMMARY

A. Organic iodine was efficiently, $>95\%$, adsorbed by 18 x 30 mesh TEDA impregnated charcoal in concentrations of $<4 \times 10^{-19}$ g/cc, at temperatures of 33°C and at relative humidities of 95%. The cylindrical collector was designed to draw air, 75 ft^3 in 15 min, through the curved outer wall, a charcoal bed, and into an axial discharge tube.

B. Model CDV-700 GM counters have adequate sensitivity to easily detect 1-2 rad infinite dose to a child thyroid. This response is achieved by inserting a GM probe into the axial discharge tube after heating.

C. Heating the collector to 100° C with flowing hot air reduces adsorbed noble gas activity to $\sim 3.8 \times 10^{-4}$ compared to an equal iodine airborne activity.

D. An air mover was designed to provide a regulated flow of $5 \pm 3\%$ ft³/min.

E. Field distribution of the five iodine isotopes is uncertain, 30-46%, and probably depends on differences in conversion from elemental to organic iodine. Since the ratio of organic to elemental iodine released from containment varies with postulated accidents, mean isotope distribution values were adopted. Power reactor measurements, fission yield data, and experimental values were used to derive the mean values.

F. Infinite thyroid dose can be evaluated with an uncertainty of $\pm 25\%$ due to uncertainties in the iodine isotope distribution.

G. The response of CDV-700 counters were predicted by calculations and compared with measurements. The calculational method can be used for any hypothetical reactor accident involving significant loss of containment of radioiodine.

H. An exponential adsorption dependence for organic iodine tends to move the point of mean activity slightly closer to the GM counter compared with particulate or gaseous elemental iodine. The latter would be reported as 0.86 of an organic iodine assessment.

I. An ultra low cost shield made of four cardboard boxes, plastic bags, and a used one pound coffee can can attenuate ¹³⁷Cs gamma rays

by more than seven. Placing the shield assembly against an outside cellar wall should increase the attenuation value to 10 to 20.

ACKNOWLEDGEMENTS

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TABLE 1

OTHER VOLATILE FISSION PRODUCTS

	<u>T_{1/2}</u>	<u>Yield %</u>	<u>γ, Energy (Intensity,%)</u>
⁸³ Br	2.5h	0.51	.530 (1.4%)
⁸⁴ Br	31.8m	0.90	.81 (9%), .88 (51%), 1.01 (10%), 1.21 (4%), 1.90 (10%), 2.47 (0%), 3.93 (13%)
⁸⁴ Br	6m	0.02	.44 (68%), .88 (75%), 1.46 (75%)
⁸⁵ Br	3m	1.10	None
⁸⁹ Sr	52.7d	4.8	.91 (.009%)
⁹⁰ Sr	27.7y	5.8	None
¹⁰⁶ Ru- ¹⁰⁶ Rh	368d	0.38	.512 (21%), .622 (11%), 1.05 (1.5%)
¹³⁷ Cs	30g	5.9	.662 (85%)
¹⁴⁴ Ce- ¹⁴⁴ Pr	284d	6.1	.134 (11%), .695 (1.5%)

TABLE 2

MEASURED COLLECTION EFFICIENCY OF SEVERAL CHARCOAL FILTERS

<u>Note</u>	<u>Adsorber</u>	<u>Type</u>	<u>Flow ft³/min</u>	<u>Stay Time Secs.</u>	<u>Temp. °C</u>	<u>Humidity %RH</u>	<u>Collector Efficiency(%)</u>
(1)	MSA #2133	-	0.76	-	35.0	44	~ 1.0
(2)	R-51	G215	4.3	.04	36.2	88	75
	2cm CDV 700	TEDA	5.0	.106	33.0	95	96
	1.7cm CDV 700M	TEDA	5.0	.113	32.0	80	95
	1.0cm CDV 700M	TEDA	5.0	.06	34.8	75	87

Notes:

- (1) MSA #2133 Mine Safety Appliance Company, Pittsburgh, Pennsylvania.
- (2) R-51 American Optical Corporation, Southbridge, Massachusetts,
G-215 North American Carbon Spec. No.

TABLE 3

YIELD OF IODINE ISOTOPES

Log Number Fig. 9	Plant	$\frac{131}{I}$	$\frac{132}{I}$	$\frac{133}{I}$	$\frac{134}{I}$	$\frac{135}{I}$
1	Oyster Creek (ref 16)	1	.35	.75	.60	.43
2	Millstone Point (ref 16)	1	1.34	1.38	1.62	1.16
3	Monticello (ref 16)	1	2.81	2.20	1.79	1.71
	Dresden 2 (ref 16)					
4	Dresden 3 (ref 16)	1	1.84	1.60	1.94	1.34
5	Pickering G.S. (ref 17)	1		2.06		2.17
	BNL Generator	1	.51	1.19	1.29	2.60
	Meek-Rider (ref 7)	1	1.40	2.30	2.40	2.20
	Relative Mean Activities (Fig. 9)	1	.96 $\pm$ 46%	1.75 $\pm$ 31%	1.85 $\pm$ 30%	1.60 $\pm$ 38%
	Relative Mean Activities (1 hour decay)	.996	.71 $\pm$ 46%	1.70 $\pm$ 31%	.85 $\pm$ 30%	2.16 $\pm$ 38%

Table 4[†]

OYSTER CREEK IODINE MOLECULAR SPECIES (% of total)

2/22 - 2/27/75

	TURBINE FLOOR	1	2	HEATER BAY		5	6	CHUTE	TOTAL TURBINE BLDG DUCT	REACTOR BUILDING	RADWASTE BUILDING
		3	4								
<u>131_I</u>											
P	32	17	16	17	17	27	25	25	27	49	<2
I ₂	43	60	56	55	55	47	50	50	47	17	20
HOI	21	20	23	23	23	20	19	20	19	<2	30
CH ₃ I	4	3	5	5	5	6	6	5	7	34	50
<u>132_I</u>											
P	31	16	17	24	19	33	34	25	28	*	*
I ₂	58	71	71	61	68	60	57	65	51	*	*
HOI	11	13	12	15	13	7	9	10	21	*	*
CH ₃ I	<1	<1	<1	<1	<1	<1	<1	<1	<1	*	*
<u>133_I</u>											
P	25	15	15	16	19	24	22	20	21	*	<1
I ₂	53	65	64	62	59	57	60	62	54	*	21
HOI	18	18	20	20	19	16	15	18	22	*	45
CH ₃ I	4	2	1	2	3	3	3	<1	3	*	34
<u>134_I</u>											
P	41	18	22	30	**	33	45	30	**	*	*
I ₂	48	71	68	55	**	60	45	63	**	*	*
HOI	11	11	10	15	**	7	10	7	**	*	*
CH ₃ I	<1	<1	<1	<1	**	<1	<1	<1	**	*	*
<u>135_I</u>											
P	27	10	18	17	22	31	24	22	24	*	<1
I ₂	54	72	65	64	59	54	65	65	55	*	21
HOI	16	16	17	19	19	15	11	13	21	*	35
CH ₃ I	3	2	<1	<1	<1	<1	<1	<1	<1	*	44

* Insufficient concentration for adequate measurements

** Activity decayed before sample was completely analyzed

† Taken from reference 20

Table 5

Thyroid Dose Commitment* for Several Inhalation Starting Times

Inhale Time (hr)	Time After Reactor Shutdown								
	1	2	4	8	12	16	24	36	∞
	Rads								
0.5	.083	.081 $\pm$ 11%	.079	.075	.071	.068	.063	.058	.051
1	.165	.162 $\pm$ 17%	.157	.149	.142	.136	.126	.115	.102
2	.326	.312 $\pm$ 11%	.321 $\pm$ 10%	.296 $\pm$ 9%	.282 $\pm$ 8%	.270 $\pm$ 8%	.251 $\pm$ 7%	.229 $\pm$ 5%	.204 $\pm$ 2%
3	.486	.478 $\pm$ 10%	.464	.441	.421	.404	.375	.342	.305
4	.643	.642 $\pm$ 10%	.615	.584	.558	.536	.498	.455	.406
6	.950	.936 $\pm$ 10%	.920	.866	.828	.759	.741	.677	.606
8	1.250	1.233 $\pm$ 10%	1.200	1.143	1.093	1.051	.981	.897	.806
10	1.541	1.520 $\pm$ 10%	1.481	1.412	1.354	1.302	1.217	1.115	1.004

^{131}I ^{132}I ^{133}I ^{134}I ^{135}I

A_0
Initial Activity
Inhalation Rate

$\mu\text{Ci/hr}$ .0194 .0166 .0339 .0359 .0310

* 5 year old child

TABLE 6
Predicted CDV-700 Response

Time After Reactor Shutdown (hr)		^{131}I	^{132}I	^{133}I	^{134}I	^{135}I	Σ CDV 700 Response
0	t_0 μCi	.103	.099	.180	.190	.165	
	$\pm$ % Act.	2.000	45.800	31.400	30.000	37.500	
	c/m	8.040	37.710	19.980	80.580	56.220	
1	c/m	8.010	27.840	19.350	36.900	50.700	142.80
	$\pm$ c/m	.160	12.250	6.080	11.070	19.010	49.08
	$\pm$ %						34.40
2	c/m	7.980	20.520	18.690	17.640	45.720	110.55
	$\pm$ c/m	.160	9.400	5.870	5.290	17.150	37.83
	$\pm$ %						34.20
4	c/m	7.920	11.190	17.490	3.540	36.600	76.74
	$\pm$ c/m	.160	5.130	5.490	1.060	13.730	25.56
	$\pm$ %						33.30
8	c/m	7.800	3.300	15.230	.150	24.570	51.15
	$\pm$ c/m	.160	1.510	4.810	.050	9.210	15.75
	$\pm$ %						30.10
12	c/m	7.710	.990	13.440	.000	16.260	38.40
	$\pm$ c/m	.150	.450	4.220		6.100	10.92
	$\pm$ %						28.40
16	c/m	7.590	.300	11.790	.000	10.740	30.42
	$\pm$ c/m	.150	.140	3.700		4.030	8.01
	$\pm$ %						26.30
24	c/m	7.380	.030	9.050	.000	4.680	21.15
	$\pm$ c/m	.150	.010	2.840		1.760	4.77
	$\pm$ %						22.60
36	c/m	7.080	.000	6.090	.000	1.350	14.52
	$\pm$ c/m	.140		1.910		.510	2.56
	$\pm$ %						17.70
^{131}I	c/m	7.080					7.08
	$\pm$ c/m	.140					.14
	$\pm$ %						2.00

TABLE 7

CDV 700 Sensitivity Per Unit Dose Commitment

Net Counts $\cdot (\text{min} \cdot \text{RAD}_{00})^{-1}$

Start of Inhalation After Reactor Shutdown

Inhale Time (hr)	1	2	4	8	12	16	24	36	∞
0.5	1727	1360	974	686	540	446	335	252	139
1	865	684	489	344	271	224	168	126	69
2	438	344	246	173	136	113	84	63	35
3	293	231	165	116	91	75	56	42	23
4	222	175	125	88	69	57	42	32	17
6	150	118	84	59	46	40	29	21	12
8	114	90	64	45	35	29	22	16	9
10	93	73	52	36	28	23	17	13	7

APPENDIX 1

Retention of Noble Gases

C. Distenfeld and S. Katz

Considerations of radioactive krypton and xenon trapping in the filter was evaluated. The approach (A) was a theoretical prediction of total gas adsorbed onto the filter. It is first necessary to determine the concentrations of noble gas that we expect. At the danger level the amount of noble gas that would be sampled would be thirty times the iodine activity of 10 d/min cc. For a 15 min 5 CFM sample the noble gas activity is:

$$\text{Noble gas activity} = \frac{30 \times 10 \text{ d}}{\text{min cc}} \times \frac{2.1 \times 10^6}{\text{sample l}} \times \frac{1}{60} \times \frac{1 \text{ Ci sec}}{3.7 \times 10^{10} \text{ d}} = 2.9 \times 10^{-4} \text{ Ci}$$

Since the adsorption rate for xenon is almost twenty times as great as that of krypton, we will consider all the noble gas to be xenon.

The concentration of ^{133}Xe in the air is:

$$(2.9 \times 10^{-4} \text{ Ci}) \times \left(\frac{1 \text{ g}}{1.87 \times 10^5 \text{ Ci}} \right) = 1.5 \times 10^{-9} \text{ g}$$

$$\text{Xe volume} = \frac{22.4 \times 10^3 \frac{\text{cc}}{\text{mole}}}{133 \frac{\text{gm}}{\text{mole}}} \times 1.5 \times 10^{-9} \text{ g} = 2.6 \times 10^{-7} \text{ cc}$$

Since the total sample was 2.1×10^6 cc, the concentration of xenon is

$$\frac{2.6 \times 10^{-7}}{2.1 \times 10^6} = 1.2 \times 10^{-13} \text{ cc Xe/cc air.}$$

Taking advantage of the symmetry of xenon breakthrough curves, the method (A) predicts the equilibrium volume of xenon trapped in the charcoal to be as follows:

$$V_{\text{equi}} = K_d MC$$

where K_d = adsorption coefficient for xenon, 900 cc/g, M = mass of charcoal, 133 g, C = relative concentration of xenon to air.

$$V_{\text{equi}} = (900 \text{ cc/g}) (133 \text{ g}) (1.2 \times 10^{-13}) = 1.4 \times 10^{-8} \text{ cc}$$

$$\begin{aligned} \text{Trapped } ^{133}\text{Xe} &= (1.4 \times 10^{-8}) \left(\frac{133 \text{ g/mole}}{22.4 \times 10^3 \text{ cc/mole}} \right) (1.87 \times 10^5 \text{ Ci/g}) \\ &= 1.6 \times 10^{-5} \text{ Ci.} \end{aligned}$$

The trapped iodine is on the order of 9.6×10^{-6} Ci.

The noble gas activity that will remain on the filter appears great enough to interfere with our readings so some method must be found to purge them. So far, 25°C is not a great enough temperature for a carrier gas to purge these gases, 50°C is great enough for krypton and 100°C (B) is great enough for xenon. Whether these are minimum purging temperatures will have to be experimentally determined. At this time, 68°C is the highest purge gas temperature that will be convenient for usage with a minimally modified vacuum system.

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APPENDIX 2

Study and Selection of an Adsorbing Material for Environmental Organic Iodine Collection

C. Distenfeld and D. Sanders

Adsorption efficiency is known to vary with temperature, humidity, and chemical form of the radioiodine. Setting a standard of greater than 90% efficiency for the worst environmental conditions will insure system stability. Additionally, the charcoal must be heated to 212° F for approximately 5 min post collection in order to remove noble gases.

Literature Search

Table A represents a significant sample of all known adsorber performance data. Considering the English made S.S. charcoal, the unimpregnated 207B material seriously loses organic iodine adsorption efficiency with high humidity. Impregnation with KI or triethylenediamine, TEDA, maintains 90% efficiency for 100% relative humidity conditions. MSA 85851 and BC727 are impregnated with KI-I₂. Considering this data, performance above the 90% collection efficiency criteria requires a shift to TEDA impregnated charcoal or silver zeolite clays.

Silver zeolite is prepared commercially by CTi-Nuclear, Inc., Denver, Colorado. According to D. Porrey (personal communication, 1975) their standard material is 10 x 16 mesh beads. Improving the surface and collection efficiency requires gridding larger stock to 10 x 16 mesh grains.

This will add \$5 to \$10 per pound for 100 pound quantities. Clearly this material is too expensive for our need as a single collector loading would cost about \$30.

TEDA impregnated charcoal is available locally from at least three manufacturers. North American charcoal type G618 was recommended by J. Keller (Allied Chemical Corporation). He indicated that his measurements agreed with the findings of other investigators. Heating to 212° F should not be a problem, since Adams (A) was able to collect organic iodine moderately efficiently at 232° F. F. Schwartz (North American Carbon Inc.) quoted a price of \$2.28 per pound (200 pound lots) in June 1975.

Elemental iodine is easier to adsorb as evidenced by Gelman AC-1 charcoal coated paper. This material has an efficiency of 99% for elemental, but less than 3% for organic iodine.

Retention of collected organic iodine was measured by Davis (I) on G618 charcoal. He passed air through pre-load filters (0.14 sec stay time) and measured much less than 1% CH₃I loss after 600 hr.

Poisoning of TEDA material was considered by Collins (H). He concluded no apparent change in adsorption ability with 10⁷ air changes. This would be equivalent to sampling at 5 ft³/min for 5 hr, about 20 times longer than the design value of 75 ft³.

Finally Pence (G) measured the adsorption characteristics of G618 charcoal for two largely different organic iodine concentrations. TEDA charcoal provided an efficiency of approximately 95% for a stay time of

0.1 sec at 90% R.H. and 194° F. The efficiency did not appear to change with adsorbant concentrations of 0.1 to 10×10^{-12} g/cc and 0.1 to 1×10^{-16} g/cc. Ritzman (J) studied the literature and the theoretical basis for a concentration dependent effect. He concluded that no experimental or theoretical basis existed (1972) for a concentration dependent isotherm in the range 10^{-20} to 10^{-9} g/cc.

Recommendations

North American Carbon type G618 TEDA impregnated coconut shell charcoal is a suitable material for the adsorption studies.

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Table A
CH₃¹³¹I Removal Efficiency

Designation	Type	Impreg.	Mesh (US)	Reference	Stay time (sec)	Temp. (°F)	Relative humidity (%)	ε ₁ (%)
MSA 85851	MSA25725	KI-I ₂	8-16	a	.05	212	~.1	92
MSA 85851	MSA25725	KI-I ₂	8-16	a	.11	208	82	82
MSA 85851	MSA25725	KI-I ₂	8-16	a	.11	284	82	92
MSA 85851	MSA25725	KI-I ₂	8-16	a	.19	262	100	52
MSA 85851	MSA25725	KI-I ₂	8-16	b	.13	70	90	71
Linde Sieve	13 x		60-80	h+k	.1	77	100	54
BC-727	BC-513	KI-I ₂	8-16	a	.12	278	95	72
BC-727	BC-513	KI-I ₂	8-16	b	.13	77	90	75
G-618	coconut	TEDA	6 x 18	a	.12	282	82	72
G-618	coconut	TEDA	6 x 18	a	.12	274	100	14
S.S. 207B	coal	none	12 x 16	h	.1	77*	dry	99.4
S.S. 207B	coal	none	12 x 16	h	.1	77*	100	4
S.S. 207B	coal	.5% KI	8 x 12	c	.13	77	90	89
S.S. 207B	coal	.5% KI	12 x 16	h	.1	77*	100	99.4
S.S. 207B	coal	5% TEDA	12 x 16	h	.1	77*	100	97.8
Witco 19 or 36	petroleum	5% TEDA		e	.13	77*	90	99.7
MSA 21104	coconut	5% TEDA		e	.13	77	90	99.2
BC 371	coconut	5% TEDA		e	.13	77	90	97.2
G 601	coconut	I ₂	12 x 16	d	.13	277	82	93
G 615	coconut	2.5% I ₂ + 2.5% TEDA		e	.13	77	90	99.4
G 618	coconut	5% TEDA	8 x 16	g	.10	194	90	95.0
G 618	coconut	5% TEDA		e	.13	77	90	99.5
Silver zeolite	(Agx)	silver	12 x 14	g	.10	194	90	97
	(Agx)	silver	10 x 20	g	.10	194	90	90
			(beads)					
Gelman AC-1	paper	none		f	25.4 cm/ sec	77*	75	~.2
<u>Elemental Iodine Removal Efficiency</u>								
MSA 85851				c	.13	77	98	99
BC-727				c	.13	77	98	99
Gelman AC-1	paper	none		f	102 cm/ sec	77*	75	99

MSA = Mine Safety Appliance Co., Pittsburgh, Pa; BC = Barneby - Cheney, Columbus, O; SS = Sutcliffe, Speakman and Co., England; G = North American Carbon, Inc., Columbus, O; Witco = Witco Chemical Co., New York, N. Y.; Gelman = Gelman Instrument Co., Ann Arbor, Mich.

* Temperature quoted as ambient.

APPENDIX 3

Mechanical Aspects of the Air Mover, Sample Collector,
and Air Heater

1. Air mover
2. Air mover bottom
3. Bleed air port air flow reg. assy
4. Heater assy
5. Iodine collector mounting assy
6. Heater mounting assy
7. 700 filter
8. 700-M filter
9. Air mover and heater wiring diagram

SCALE: 1" = 4"

				SSEP			
NO. REQ.	ACCT. NO.	I. L. R. NO.	ORDER NO.	DEPT.	JOB NUMBER	USED ON DWG. NO.	NO. PER ASST.
DEC. $\pm$		ANG. $\pm$		MAX.	MIN.		
TOLERANCE		BREAK SHARP EDGES					
0-20°		20°-60°		OVER 60°		FINISH	
FRACTIONAL TOLERANCE		1" = 4"		✓			
DATE		MATERIAL		SCALE		WEIGHT	
J. KLEMISH							
DRAWN BY		CHECKED BY		ENG. APP.		SUPVR. APP.	
					1		-1
					DRAWING NUMBER		REV.

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.
UPTON, N. Y. 11973

RADIO IODINE AIR SAMPLING SYSTEM
AIR MOVER

1

-1

DRILL 4 HOLES
 $\frac{3}{16}$ " EQ. SPACED ON
 $3\frac{1}{4}$ " DIA. CIRCLE

$2\frac{3}{4}$ " PUNCHED HOLE,

DRILL 4 HOLES
 $\frac{5}{16}$ " EQ. SPACED ON
 $4\frac{3}{4}$ " DIA. CIRCLE

MOTOR BOLTS
 4 EACH

$\frac{1}{2}$ " DIA X 1" ALUMINUM
 10-24 THREADED
 STAND-OFF 4 EACH

10-24 X $\frac{3}{8}$ " MACH SCREW - BR.

$\frac{1}{8}$ " $5\frac{1}{2}$ "
 $2\frac{1}{4}$ " $2\frac{3}{4}$ " $2\frac{3}{8}$ "

AIR
 FLOW

AIR MOVER - BOTTOM

$\frac{5}{16}$ " X 2" STEEL
 CARRIAGE
 BOLT
 4 EACH

				S E P					
NO. REQ.	ACCT. NO.	I. L. R. NO.	ORDER NO.	DEPT.	JOB NUMBER	USED ON DWG. NO.	NO. PER ASST.		
DEC. $\pm$		ANG. $\pm$		MAX.	MIN.		BROOKHAVEN NATIONAL LABORATORY ASSOCIATED UNIVERSITIES, INC. UPTON, N. Y. 11973 RADIO IODINE AIR SAMPLING SYSTEM AIR MOVER - BOTTOM		
TOLERANCE		BREAK SHARP EDGES		FINISH					
0-20° $\frac{1}{64}$ "		20°-60°		OVER 60°					
DATE		MATERIAL		SCALE	WEIGHT				
J. KLEMISH									
DRAWN BY		CHECKED BY		ENG. APP.	SUPVR. APP.		REV.		
							2 -1		
							DRAWING NUMBER		

BLEED AIR PORT AIR FLOW
REGULATOR ASSEMBLY

NO. REQ.		ACCT. NO.	I. L. R. NO.	ORDER NO.	DEPT.	JOB NUMBER	USED ON DWG. NO.	NO. PER ASSY.
DEC. ±		ANG. ±		MAX. MIN.		BROOKHAVEN NATIONAL LABORATORY		
TOLERANCE		BREAK SHARP EDGES		FINISH		ASSOCIATED UNIVERSITIES, INC.		
0-20° $\frac{1}{64}$		20°-60°		OVER 60°		UPTON, N. Y. 11973		
FRACTIONAL TOLERANCE		DATE		MATERIAL		RADIO IODINE AIR SAMPLING SYSTEM		
MAY 1976		AS SPECIFIED		1" = 1"		BLEED AIR PORT AIR FLOW		
J. KLEMISH		SCALE		WEIGHT		REGULATOR ASSEMBLY		
DRAWN BY		CHECKED BY		ENG. APP.		SUPVR. APP.		REV.
						3 -1		
						DRAWING NUMBER		

				SEEP			
NO. REQ.	ACCT. NO.	I. L. R. NO.	ORDER NO.	DEPT.	JOB NUMBER	USED ON DWG. NO.	NO. PER ASSY.
DEC. ±		ANG. ±		MAX.	BROOKHAVEN NATIONAL LABORATORY		
TOLERANCE		BREAK SHARP EDGES		MIN.	ASSOCIATED UNIVERSITIES, INC.		
0-20°		20°-60°		OVER 60°	UPTON, N. Y. 11973		
FRACTIONAL TOLERANCE		FINISH		✓	RADIO IODINE AIR SAMPLING SYSTEM		
MAY 1976		1"=1"			HEATER ASSEMBLY		
DATE	MATERIAL	SCALE	WEIGHT				
J. KLEIMISH							
DRAWN BY	CHECKED BY	ENG. APP.	SUPVR. APP.				
					4		-1
					DRAWING NUMBER		REV.

IODINE COLLECTOR MOUNTING ASSEMBLY

NO. REQ.		ACCT. NO.		I.L.R. NO.		ORDER NO.		SEEP		JOB NUMBER		USED ON DWG. NO.		NO. PER ASSY.	
DEC. ±		ANG. ±		MAX.		MIN.		BROOKHAVEN NATIONAL LABORATORY ASSOCIATED UNIVERSITIES, INC. UPTON, N. Y. 11973 RADIO IODINE AIR SAMPLING SYSTEM IODINE COLLECTOR MOUNTING ASSEMBLY							
TOLERANCE		BREAK SHARP EDGES		FINISH		✓									
0-20° $\frac{1}{64}$		20°-60°		OVER 60°											
DATE		MATERIAL		SCALE		WEIGHT									
MAY 1976		MYCARTA		1" = 1"											
DRAWN BY		CHECKED BY		ENG. APP.		SUPVR. APP.									
J. KLEMISH															
DRAWING NUMBER		5		-1		REV.									

HEATER MOUNTING ASSEMBLY

				S E P			
NO. REQ.	ACCT. NO.	I. L. R. NO.	ORDER NO.	DEPT.	JOB NUMBER	USED ON DWG. NO.	NO. PER ASSY.
DEC. $\pm$		ANG. $\pm$		MAX.	BROOKHAVEN NATIONAL LABORATORY		
TOLERANCE		BREAK SHARP EDGES		MIN.	ASSOCIATED UNIVERSITIES, INC.		
0-20° $\frac{1}{64}$		20°-60°		OVER 60°	UPTON, N. Y. 11973		
FRACTIONAL TOLERANCE		FINISH		✓	RADIO IODINE AIR SAMPLING SYSTEM		
MAY 1976		AS SPECIFIED		1" = 1"	HEATER MOUNTING ASSEMBLY		
DATE	MATERIAL	SCALE	WEIGHT				
J. KLEMISH				6 -1			
DRAWN BY	CHECKED BY	ENG. APP.	SUPVR. APP.	DRAWING NUMBER			REV.

NO. REQ.		ACCT. NO.	I. L. R. NO.	ORDER NO.	SEEP	JOB NUMBER	USED ON DWG. NO.	NO. PER ASST.
DEC. ±		ANG. ±		MAX. MIN.		BROOKHAVEN NATIONAL LABORATORY		
TOLERANCE		BREAK SHARP EDGES		ASSOCIATED UNIVERSITIES, INC.				
0-20° 1/4"		20°-60°		OVER 60°		UPTON, N. Y. 11973		
FRACTIONAL TOLERANCE		FINISH		RADIO IODINE AIR SAMPLING SYSTEM				
MAY 1976		HS SPECIFIED		1" = 1"		700 FILTER		
DATE		MATERIAL		SCALE		7 -1		
J. KLEMISH		DRAWN BY		CHECKED BY		DRAWING NUMBER		REV.
				ENG. APP.				
				SUPR. APP.				

NO. REQ.	ACCT. NO.	I. L. R. NO.	ORDER NO.	SEEP	JOB NUMBER	USED ON DWG. NO.	NO. PER ASST.	
DEC. ±				ANG. ±	MAX.			MIN.
TOLERANCE				BREAK SHARP EDGES				
0-20° 1/4"				20°-60°		OVER 60°		
FRACTIONAL TOLERANCE				FINISH				
MAY 1976		FS SPECIFIED		1"=1"		✓		
DATE		MATERIAL		SCALE		WEIGHT		
J. KLEMIS								
DRAWN BY		CHECKED BY		ENG. APP.		SUPVR. APP.		
				8				
				-1				
				DRAWING NUMBER				
				REV.				

NO. REQ.	ACCT. NO.	I. L. R. NO.	ORDER NO.	DEPT.	SHEP
Q.C. #	ANG. #.	MAX.	MIN.		
TOLERANCE		BREAK SHARP EDGES			
0-30°	30°-40°	OVER 60°	FINISH		✓
FRACTIONAL TOLERANCE					
MAY 1976					
DATE	MATERIAL	SCALE	WEIGHT		
J. KLEMISH					
DRAWN BY	CHECKED BY	ENG. APP.	SUPV. APP.		
JOB NUMBER					USED ON DWG. NO.
BROOKHAVEN NATIONAL LABORATORY					NO. PER ASST.
ASSOCIATED UNIVERSITIES, INC.					
UPTON, N. Y. 11973					
RADIO IODINE AIR SAMPLING SYSTEM					
AIR MOVER & HEATER WIRING DIAGRAM					
9				-1	
DRAWING NUMBER				REV.	

ENL IODINE GENERATOR SAMPLE

FIG. 2

FIG 3

FIG. 4

FIG. 5

FIG. 7

FIG 8

FIG. 9

FIG. 10

FIG. 11

SAND SHIELD CONFIGURATION

FIG. 13