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Iodine Filter Tests at the NRL Nuclear Reactor

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ABSTRACT

Efficiency tests were performed on the iodine filters in the emergency air cleanup system of the NRL nuclear reactor. The filters were found to transmit approximately 0.2% of the iodine incident upon them.

PROBLEM STATUS

This is an interim report; work on this problem is continuing.

AUTHORIZATION

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IODINE FILTER TESTS
AT THE NRL NUCLEAR REACTOR

INTRODUCTION

An air scrubber system is installed at the NRL reactor facility to be used in the event of a fission product release inside the reactor building. The system is designed to remove particulate matter and certain gases from the building air before it is exhausted to the atmosphere.

A series of tests has been performed to determine the removal efficiency of the entire cleanup system, i.e., with all operational filters in place. In earlier tests (1) the efficiency of the air filtration system for particulate removal was tested using a method (2) developed at NRL for testing naval filter installations. In this test an aerosol of dioctylphthalate (DOP) was generated upstream of the filter system. The concentrations of the aerosol upstream and downstream of the filter were measured by a forward light scattering photometer. With an average particle size of 0.7 μm, the upper filter transmitted 0.01%. The measurement on the lower filter was inconclusive; more refined tests are planned in the future.

In the present report the results of tests to determine the efficiency for iodine removal by the system are presented.

THE NRL REACTOR AIR-CLEANUP SYSTEM

The system consists of two gas-particulate filter units, associated ductwork, and an 85-ft stack. The equipment is located in a small building (called the Scrubber House) adjacent to the north wall of the reactor building. Each filter unit is connected to the reactor building by a 20-in.-diam duct passing through the reactor building north wall. The system is shown schematically in Fig. 1.

The gas-particulate filter units are manufactured to Army specifications (3). An Army technical manual (4) gives a detailed description of this filter. Several modifications have been made at NRL to the original filter units, as follows: (a) the axial blower has been replaced by an American Blower industrial fan Series 106, (b) a prefilter and an absolute filter have been added to the input end, and (c) flexible transition pieces were replaced with sheet-metal transitions.

Since the filter units are rated at 5000 cfm each, a damper in the line of each is used to control the flow. When the units are in operation, air from the reactor building passes through the two filter units and is exhausted through the 85-ft stack.

Each filter unit is monitored for flow. A stainless steel pitot tube is installed in the duct leading to each filter unit. The pitot tube is connected to a Dwyer Series 25 Flex-tube manometer with flexible plastic tubing. The pitot tube and manometer are utilized to show the difference between the total and static pressures. This reading indicates the velocity pressure of the moving stream of air, and the flow is measured as a pressure drop in inches of water. A Dwyer Air Velocity calculator (slide rule) is used to convert this reading to flow in cubic feet per minute.

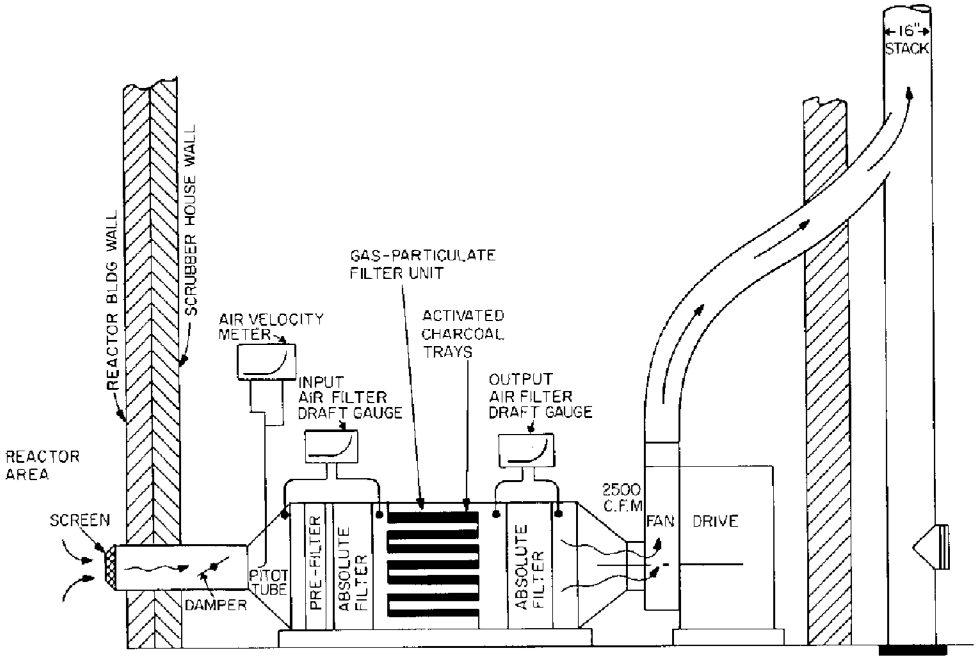


Fig. 1 - Schematic of typical scrubber unit

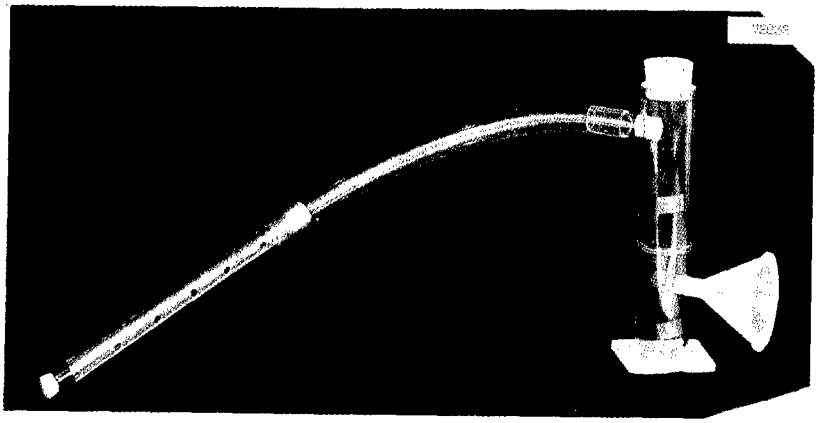
On the inlet side one gauge measures the drop across both the prefilter and the absolute filter. On the exhaust side a gauge measures the pressure drop across the particulate filter banks. These readings show the result of dirt accumulation in the particulate filters. The reading will increase as more dirt obstructs the filter. A Dwyer Series 25 Flex-tube manometer is used, and the pressure drop is given directly in inches of water.

EXPERIMENTAL METHOD

The iodine filter system was put into operation and iodine vapor introduced into the ducts ahead of the input to the filter. For the purposes of this test the ductwork through the reactor building wall shown in Fig. 1 was extended an additional 11 ft into the reactor area. This was done to extend the straight-line run from the point at which the iodine was introduced to the point at which the air was sampled on the intake side of the filters. Probes in the ductwork at the input and output of the filter then sampled the air at the rate of 25 cfm and collected samples of iodine in activated charcoal. The amount of iodine collected in the charcoal was determined by neutron activation analysis utilizing the 441-keV gamma ray associated with the 25-min beta decay of ^{128}I, and the fraction of iodine transmitted through the system was computed from the amounts of iodine collected simultaneously at the input and output.

Sampling Apparatus

Figure 2 shows one of two identical probes used to sample the iodine in the air passing through the ductwork. Each probe is an iodine filter in itself. The input end is a Lucite tube 14 in. long by 7/8 in. ID with six holes, each 3/8 in. in diameter, spaced 2 in. apart along one side. The end of the tube is plugged with a two-holed rubber stopper. When the probes were in use the Lucite tubes were inserted through rubber diaphragms into the ductwork with the holes facing upstream. Separate measurements were made with the probes vertical and horizontal in the ducts. The Lucite tube is attached to a



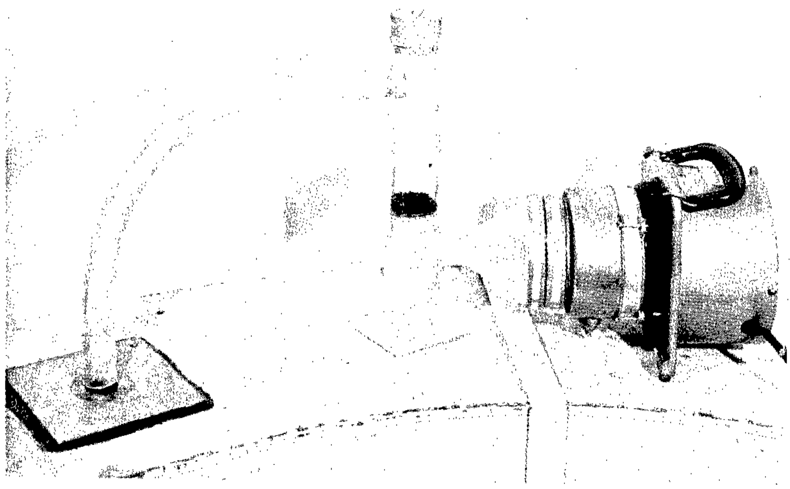


Fig. 3 - Iodine probe mounted in ductwork

Tygon tube, which was situated outside the ductwork when the probe was in use (Fig. 3). The Tygon tube enters the body of the probe, which is another Lucite tube 2 in. ID and 12 in. long, with the cylindrical axis oriented in the vertical direction when in use. A 40-mesh stainless steel screen held by a Lucite ring cemented to the inside wall of the probe body supported the 10-g charge of activated charcoal used to collect the iodine sample. A polyethylene funnel couples the output to a blower which moves air through the completely assembled probe at a nominal rate of 25 cfm.

To estimate the amount of iodine passing through the ducts it is necessary to know the relative flow rates and efficiencies of the two probes. The air velocity was measured at the intake end of each probe after the perforated Lucite tube had been removed. The velocity was measured under identical conditions for both probes with a hot-wire anemometer. A cylindrical tube 21 in. long by 3-1/2 in. ID was coupled to the input end of the Tygon tubing with a polyethylene funnel, and the anemometer probe was centered in the cylindrical tube near the funnel end. Measurements of the air velocity were made with three loadings of charcoal in each probe. The measured velocity was between the limits of 500 and 600 ft/min. With the simplest assumptions, 500 ft/min corresponds to a volume of air of 33 cfm, in rough agreement with the indicators on the blowers which showed about 25 cfm when the probes were in operation.

The fraction of the iodine introduced into the probe which could be collected by the charcoal was determined by the introduction of a known amount of iodine into the intake end of the Tygon tubing. The amount collected in the charcoal was measured by neutron activation analysis. Three determinations with probe No. 1 gave 0.67 ± 0.02 for the fraction of iodine collected and two determinations with probe No. 2 gave 0.72 ± 0.02.

In view of the flow rate and collection efficiency measurements, we conclude that the two probes have approximately the same overall sampling efficiency. However, to cancel out the effect of any differences, the probes were interchanged in different measurements as described in the results.

The Neutron Activation Analysis System

One gram of iodine vapor, obtained by heating solid iodine, was released into the filter systems during each run. The probes and filter system were operated for about 5 min. The charcoal was then removed from the probes and folded in polyethylene envelopes into cylindrical packages 3 in. long by 5/8 in. in diameter. Samples from the input side of the filter were irradiated for 10 sec at a thermal neutron flux of 6×10^{11} n $cm^{-2} sec^{-1}$ and from the output side for 2 min. The samples were allowed to decay for 10 min after the irradiation, and the intensity of the 441-keV gamma ray associated with the decay of ^{128}I was determined. The radiation was detected by a 30-cm^3 Ge(Li) detector and its associated equipment. The peak of interest in the spectrum was selected and recorded with a biased amplifier and a 512-channel analyzer. The irradiated charcoal* produced no interfering peaks in the spectrum. To observe whether the charcoal retains the iodine, a sample was irradiated twice with a 9-day interval between irradiation; no loss of iodine was observed.

The samples were counted with the cylindrical axis in the vertical direction at a distance of 3 in. from the detector window. During counting, the samples were rotated about the vertical axis to average any inhomogeneities in the distribution of the iodine in the charcoal. Some of the characteristics of the probes and counting system are listed below.

1. Air flow through each iodine filter: 2500 cfm
2. Air flow through each probe: 25 cfm
3. Amount of iodine released into ductwork per run: 1 g released in 2 min
4. Duration of sampling by probes per run: 5 min
5. Amount of charcoal used in probe per run: 10 g
6. Irradiation of contents of probe at input: 10 sec at 6×10^{11} n cm^{-2} sec^{-1}
7. Irradiation of contents of probe at output: 2 min at 6×10^{11} n cm^{-2} sec^{-1}
8. Fraction of iodine collected by probes: approximately 0.70

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*6-14 mesh activated cocoanut charcoal obtained from the Fischer Scientific Company.

9. Radiation detector: Ge(Li) detector nominally 30 cm^3 with resolution of 3.9 keV for ^{60}Co and efficiency 3.8% (compared to 3- by 3-in. NaI at 25 cm)

10. Amount of iodine collected at input of filter: about 5 mg

11. Amount of iodine collected at output of filter: about 5 to 10 μg.

RESULTS AND DISCUSSION

It is assumed that the amount of iodine collected during a run is proportional to the product: (Efficiency of probe) × (Average concentration of iodine vapor in duct). The preliminary measurements showed the efficiency of the two probes to be approximately the same. It follows that the average concentration of iodine vapor in the ducts is proportional to the amount of iodine collected by the probes (to within a few percent). The most important limiting factor is the amount of iodine that can be detected by the output probe. The 2-min irradiation of the charcoal from the output probe increases the background count rate so that the standard deviation in the background counts under the 441-keV peak is about 400 counts. The number of counts under the peak corresponding to a microgram of iodine is 125, so that a determination of about 7 μg of iodine has a standard deviation of about 50%. The results of three runs on each of the two iodine filters are shown in Table 1. Note that the probes were interchanged to reveal any differences in their efficiencies. However, the amount of iodine collected by the output probes was near the lower limit of detectability determined by the counting statistics, thereby limiting the accuracy of the results to about 50%. This obscured any differences which might have been observed by interchanging the probes. The last column of Table 1 shows that the amount of iodine transmitted through either iodine filter is approximately 0.2% with an error of about 50%. Results to this precision show no difference between the two filters or between vertical and horizontal orientations of the probes but are sufficient to show that the iodine filters are much better in performance than their prescribed limits of 1% transmission (5).

Table 1

Fraction of Iodine Transmitted Through the Filters, $\frac{I(\text{Output})}{I(\text{Input})}$

Probe Orientation	I collected		Iodine Filter	Probe Number		$\frac{I(\text{Output})}{I(\text{Input})}$
	Input (mg)	Output (μg)		Input	Output	
Horizontal	4.0	7	Lower	1	2	1.8×10^{-3}
Vertical	4.5	10	Lower	1	2	2.2×10^{-3}
Horizontal	3.7	5	Lower	2	1	1.4×10^{-3}
Horizontal	4.5	7	Upper	1	2	1.6×10^{-3}
Vertical	5.6	7	Upper	1	2	1.3×10^{-3}
Horizontal	4.6	9	Upper	2	1	2.0×10^{-3}

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2. Echols, W.H., and Young, J.A., "Studies of Portable Air-Operated Aerosol Generators," NRL Report 5929, July 1963

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4. Army Technical Manual TM-3-4240-211-12

5. DiMeglio, A.F., and Elliot, J.O., NRL Report 5358 (1959) p. 23.

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13. ABSTRACT

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