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DATE: October 30, 1962

SUBJECT: Building 3019 Vessel Off-Gas Filter

TO: J. C. Bresee

FROM: B. B. Klima

ABSTRACT

A deep bed glass fiber filter has been designed, fabricated, and installed in the ten-inch vessel off-gas line as it leaves Bldg. 3019. The discharge from this filter goes to the 3039 stack.

The efficiency of this filter at normal gas flow rates is equivalent (99.96%) to the "absolute" type filters; however, it is capable of passing without damage to the filter many times the normal gas flow rate with a small reduction in efficiency.

This report describes the fabrication, test, and installation of the filter at Bldg. 3019. It also outlines a program of tests to be conducted periodically to establish feasibility and applicability of this type of filter to vessel off-gas service at ORNL.

This document has been approved for release to the public by:

David R Hamrin 10/24/95
Technical Information Officer Date
ORNL Site

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1.0 INTRODUCTION

Deep bed glass fiber filters have been used in off-gas service in installations at Savannah River (1) and Hanford (2). At Oak Ridge National Laboratory off-gas filters have been of the cartridge type; however, a deep bed glass fiber filter has been designed (3), fabricated, and installed in the vessel off-gas line of Bldg. 3019. The design of this filter followed closely the designs at Savannah River and Hanford and took advantage of their experience.

The deep bed glass fiber filter has the following advantages and disadvantages in comparison to the cartridge type"absolute"filters.

Advantages:
1. High capacity for dust
2. Undamaged by pressure waves
3. Unaffected by high humidity

Disadvantages:
1. High pressure drop
2. Low allowable superficial air velocity

The preliminary small scale testing and design of the filter (3) has been reported. The fabrication, installation, testing of the Bldg. 3019 off-gas filter is described in this report. A program of future instrumentation and testing to evaluate the performance of this filter to determine the feasibility and applicability of this type of filter to vessel off-gas use at ORNL is also outlined in this report.

2.0 SUMMARY

A deep bed glass fiber filter has been fabricated and installed (4) in the Bldg. 3019 vessel off-gas stream. This filter has been shielded with 12-in. of barytes concrete. This filter is easily replaceable.

The filter has been tested using D.O.P. Smoke (0.3-0.7 μ) and is equivalent at 50 cfm air flow to an "absolute" type filter (99.96%). The efficiency falls off as the air flow increases to 97.1% at the maximum allowable flow rate through the filter (500 cfm).

Instrumentation is being installed to monitor the filter. Additional instrumentation will be installed to aid in evaluation of the filter.

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(1) Savannah River Drawing: D-116068 - Off-Gas Filter.

(2) Hanford Drawing: H-2-56989 - Off-Gas Filter.

(3) B. B. Klima, "Bldg. 3019 Vessel Off-Gas Filter," ORNL-CF-62-5-83, May 28, 1962.

(4) List of Applicable Drawings - see Appendix A.

Tests will be periodically conducted to determine the suitability of this filter for vessel off-gas service at ORNL.

3.0 OFF-GAS FILTER DESCRIPTION

The off-gas filter (5) was fabricated from an existing 6-ft dia stainless steel tank (6) shell and head. An isometric sectional drawing of the filter is shown in Fig. 1. Tangential 10-in. lines are installed at the bottom and the top as gas entrance and exit lines. The bottom (entrance) line has a slope of 1-in. in 5 ft so that any condensate or other liquid will drain from the off-gas line down to the center of the tank where it can be drawn off by the 3/8-in. liquid scavenger line which is spot welded at the end of the line to the center of the tank bottom. The 3/8-in. line terminates in a 3/8-in. gate valve on the outside of the permanent barytes shielding.

The filter body and all internals are made from 304L stainless steel. The lower two grids are made from 1 in. x 3/16 in. stainless bars welded to form a 12-in. grid. The upper three grids are stainless steel grating (7).

A thermocouple well in the bottom of the filter is extended by means of an external pipe through the barytes concrete shielding.

The fiber glass is packed (8) inside the filter in four layers (see description of packing and supports in Section 4.0 of the report).

On the outside of the filter shell a 2-1/2-in. schedule 40 sleeve is welded. This sleeve will be normally filled with a barytes concrete plug and will be used to detect and monitor buildup of radioactivity on the filter bed. This monitoring hole is located six inches above the bottom grid.

An offset 1-in. schedule 40 pipe is installed four inches above the top internal grid. This pipe has a flanged closure outside the concrete and penetrates the tank horizontally six inches above the top grid and at right angles to the exit 10-in. off-gas line. This line will be used for test work to evaluate the filter.

Four lifting lugs, 1/2-in. thick by 6 in. wide, are welded to the tank. Seventy-eight 1/2-in. stainless steel nuts are welded to the tank into which mild steel "J" bolts are screwed. Angle iron re-inforcing rims at the top and

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(5) D-46051 - Vessel Off-Gas Filter Assembly and Shielding Details.

(6) EV-21202 - Recovered Acid Storage Tank - Assembly and Details.

(7) Kerrigan Iron Works, Inc., Nashville, Tennessee, Grating No. KS-300, made from 1-in. by 1/8-in. bearing bars 1 in. apart.

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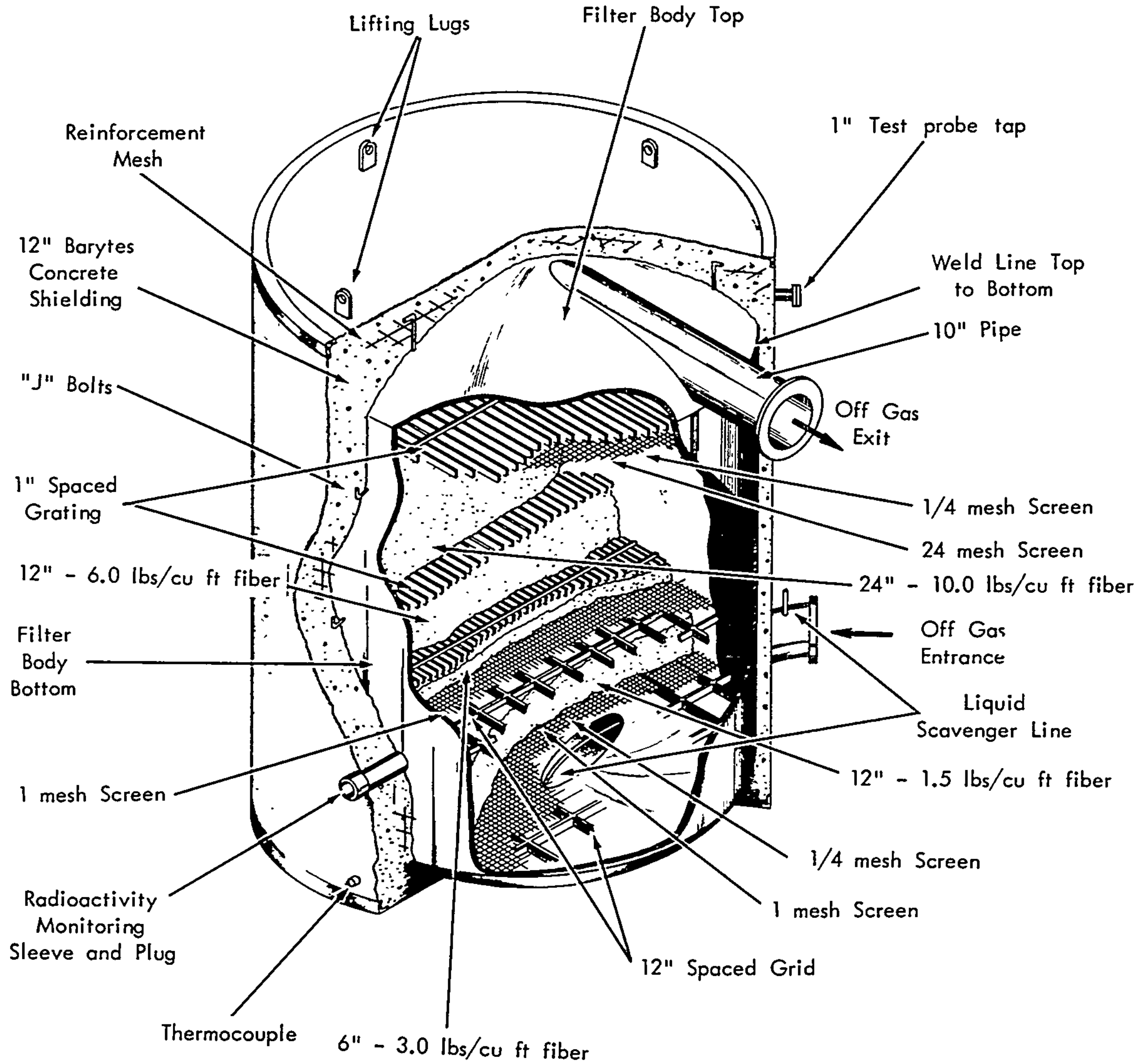

Fig. 1. Vessel off-gas filter, Building 3019.

bottom are tied to re-inforcing wire which is tied to the "J" bolts. After the filter was in place twelve inches of barytes concrete (8) was poured around the filter as permanent shielding. The complete shielded filter is estimated to weigh 31 tons.

The shielded off-gas filter rests on a re-inforced concrete pad (9) 10 ft square by 24 in. thick at the edges and 12 in. thick in the center.

4.0 OFF-GAS FILTER PACKING

The glass fiber packing for the filter is Owens-Corning Fiberglas Basic Fiber No. 115-K (10). It is a white "crinkly" lubricated glass fiber of random length in bulk form (11). The fiber diameter is nominally 0.00115 in. (12).

The off-gas filter body is shown ready for packing in Figs. 2 & 3. The bottom 12-in. grid is welded to the filter body and the 1-in. and 1/4-in. mesh screens are wired to the grid. The supports for the second grid were welded to the body before 42.4 lbs of the 115K bulk glass fiber was added to the body and compressed using the second 12-in. grid to a density of 1.5 lbs/cu ft. During the compression and welding steps, a 4-ft plywood disc (see Fig. 4) is placed on the grid to keep dirt out of the filter bed and to protect the grid. The packed first layer is shown in Fig. 5. The supports for the next grid are welded to the filter body before removal of the plywood disc preparatory to loading the second layer.

The second layer of the filter consists of 42.4 lbs of 115K fiber compressed using a 1-in. spaced grating to a density of 3.0 lbs/cu ft. The packed second layer with the grating above it secured is shown in Fig. 6.

The third layer of the filter consists of 169.6 lbs of 115K fiber compressed using a 1-in. spaced grating to a density of 6.0 lbs/cu ft. Figure 7 shows this quantity of fiber in the filter packed hand-tight. The compressed third layer with the grating above it secured is shown in Fig. 8.

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(8) D-46071 - Assembly, Filling, Testing, and Installation Procedures.

(9) C-46070 - Vessel Off-Gas Filter Support Pad.

(10) Made from type C-7 glass lubricated with 8-17 W lubricating oil (1.63% average, maximum 2.5%, minimum 0.75%).

(11) Similar to coarse, washed, and fluffed sheep's wool.

(12) Fiber diameter maximum 0.0013 in., minimum 0.0010 in.

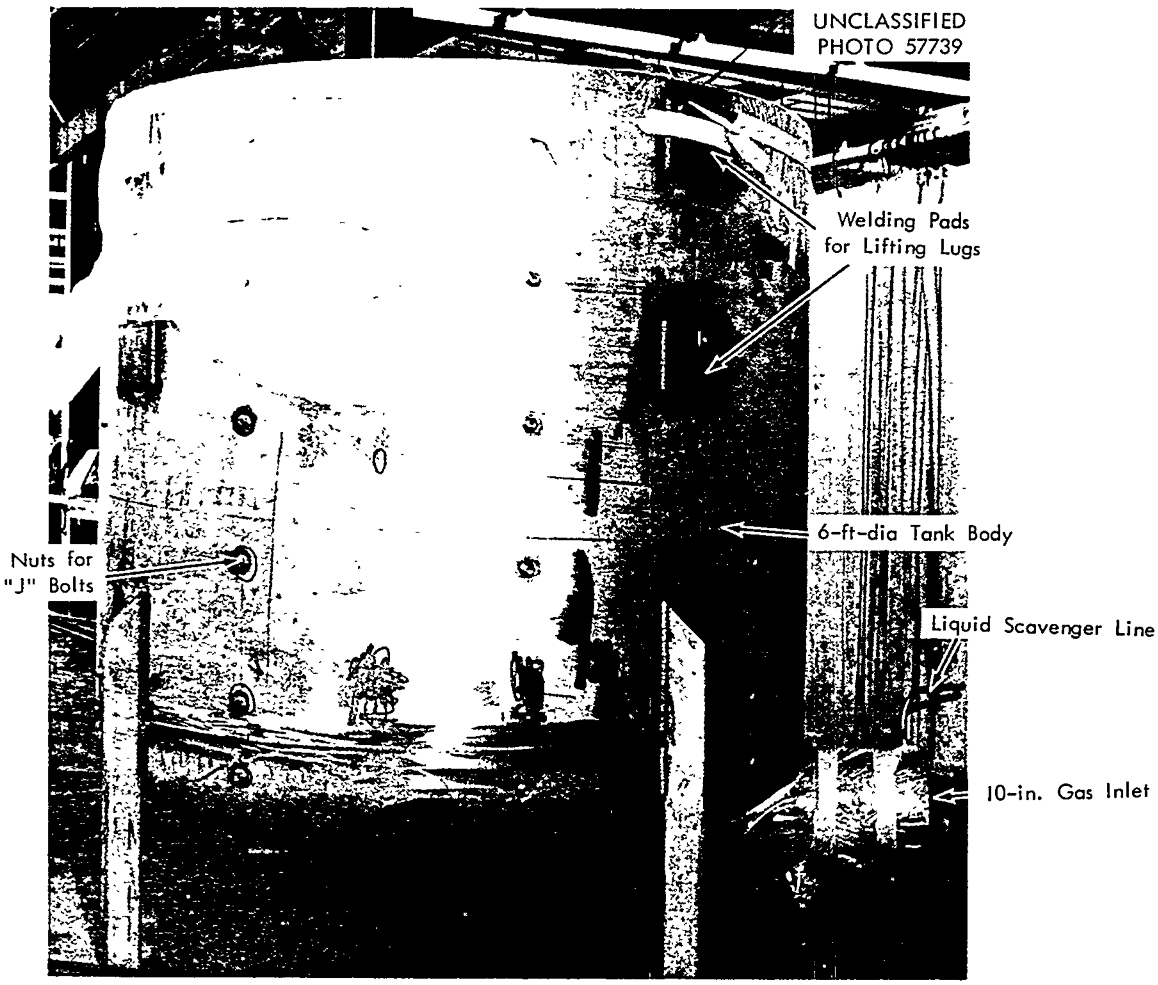

Fig. 2. External view of filter body bottom, ready for filling.

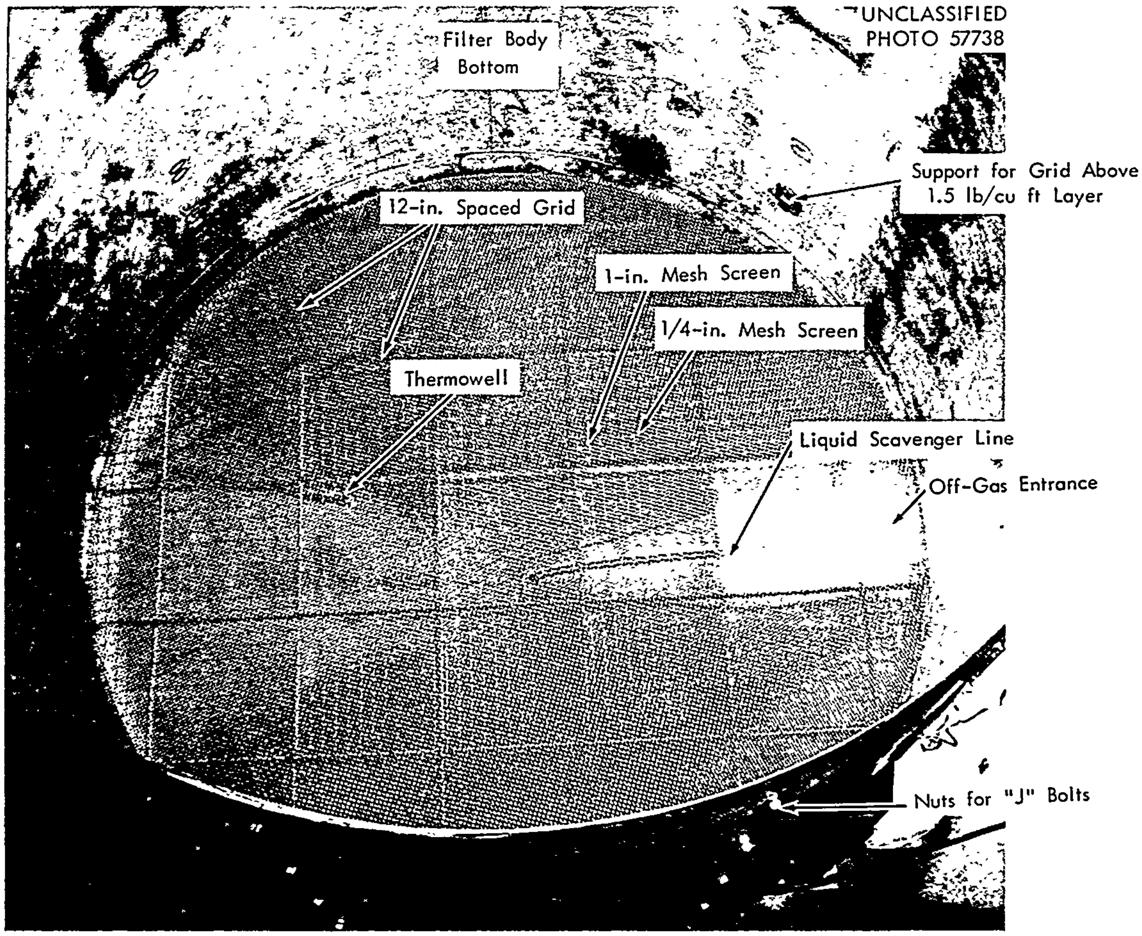

Fig. 3. Internal view of filter body bottom, ready for filling.

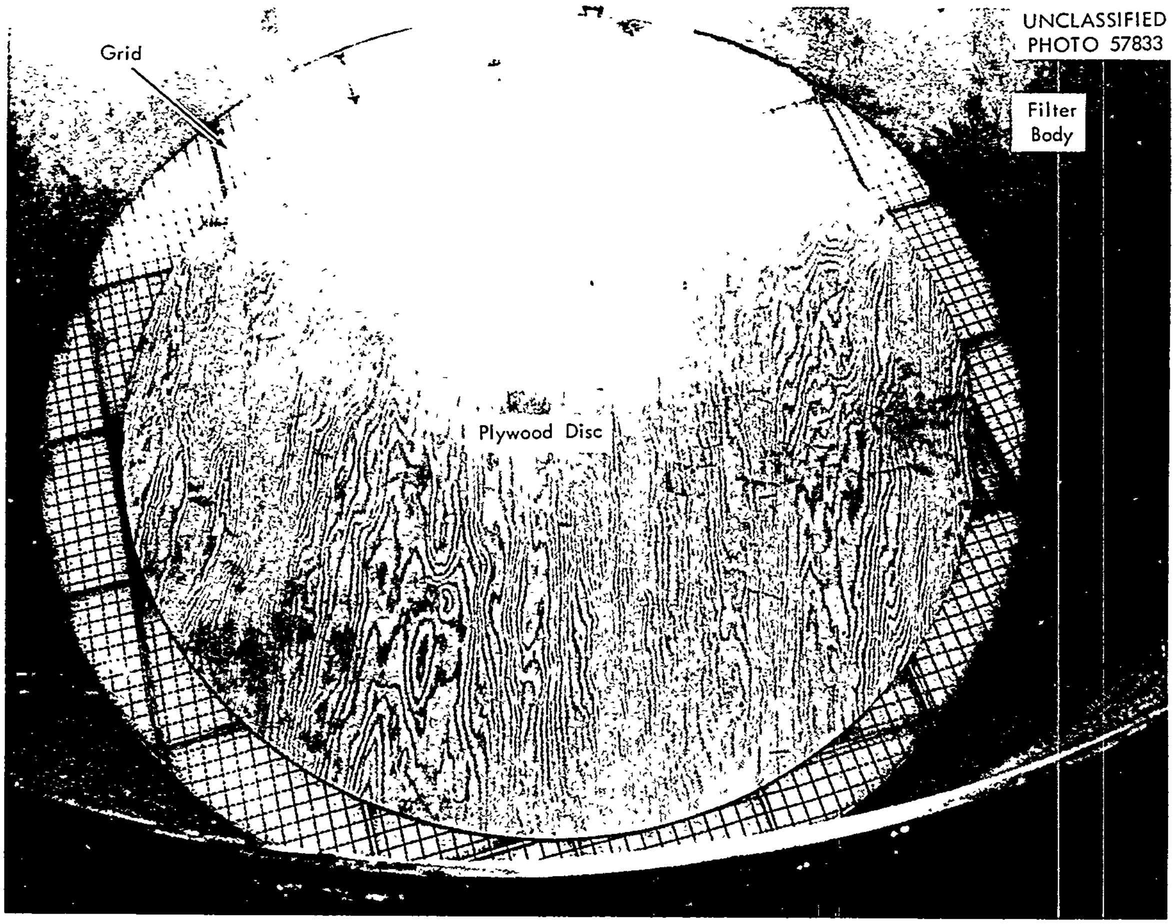

Fig. 4. Plywood grid protector and dirt catcher.

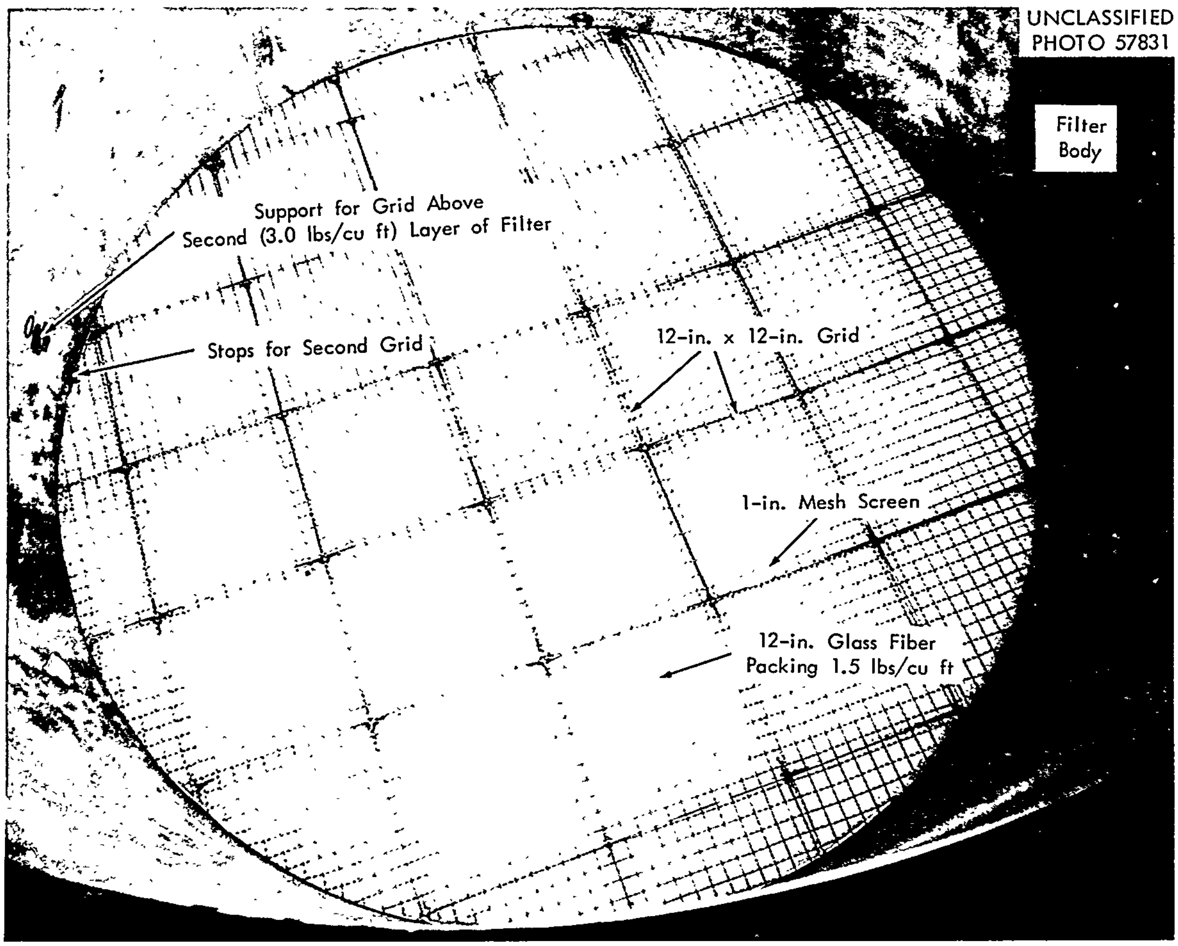

Fig. 5. First layer of filter.

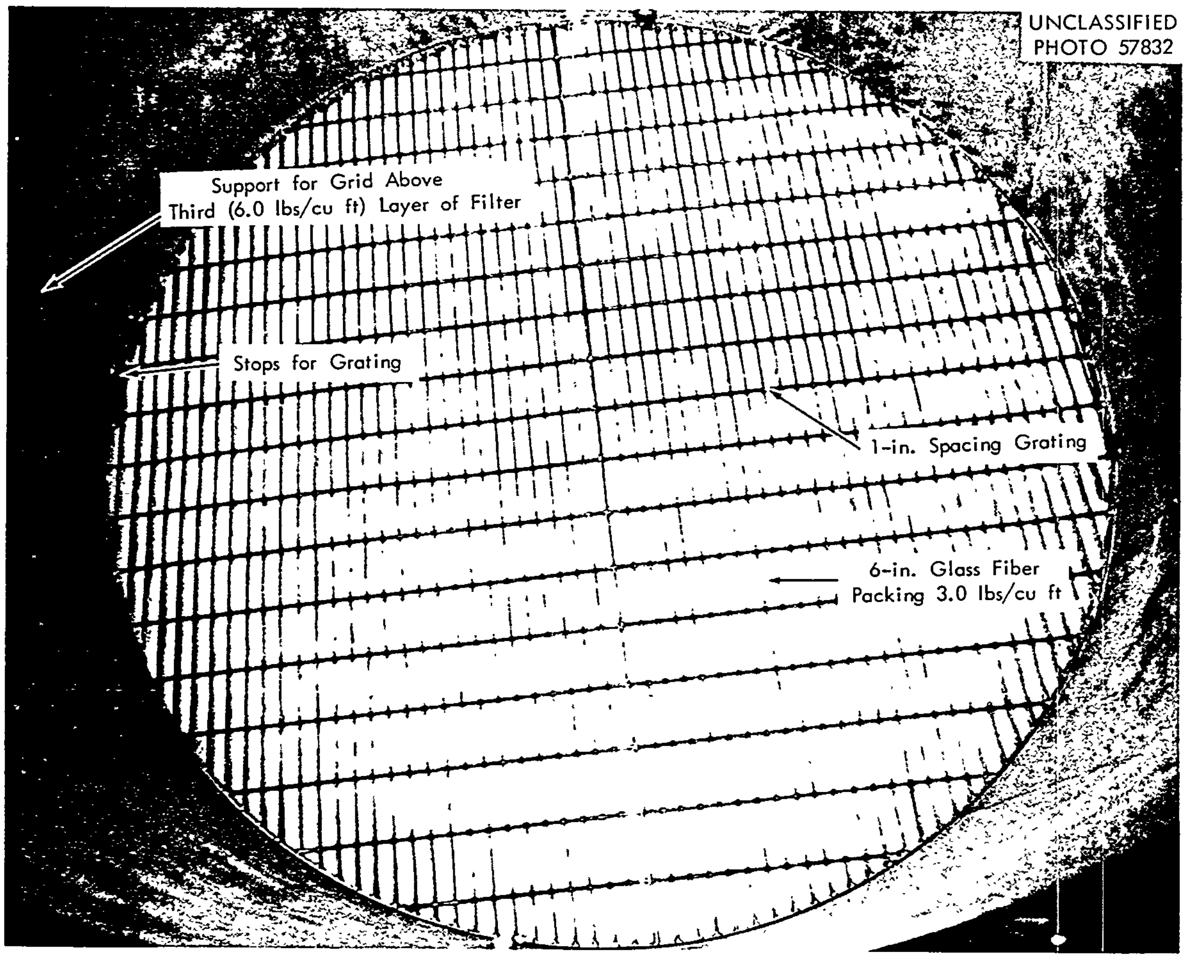

Fig. 6. Second layer of filter.

Fig. 7. 115 K fiber packed hand-tight.

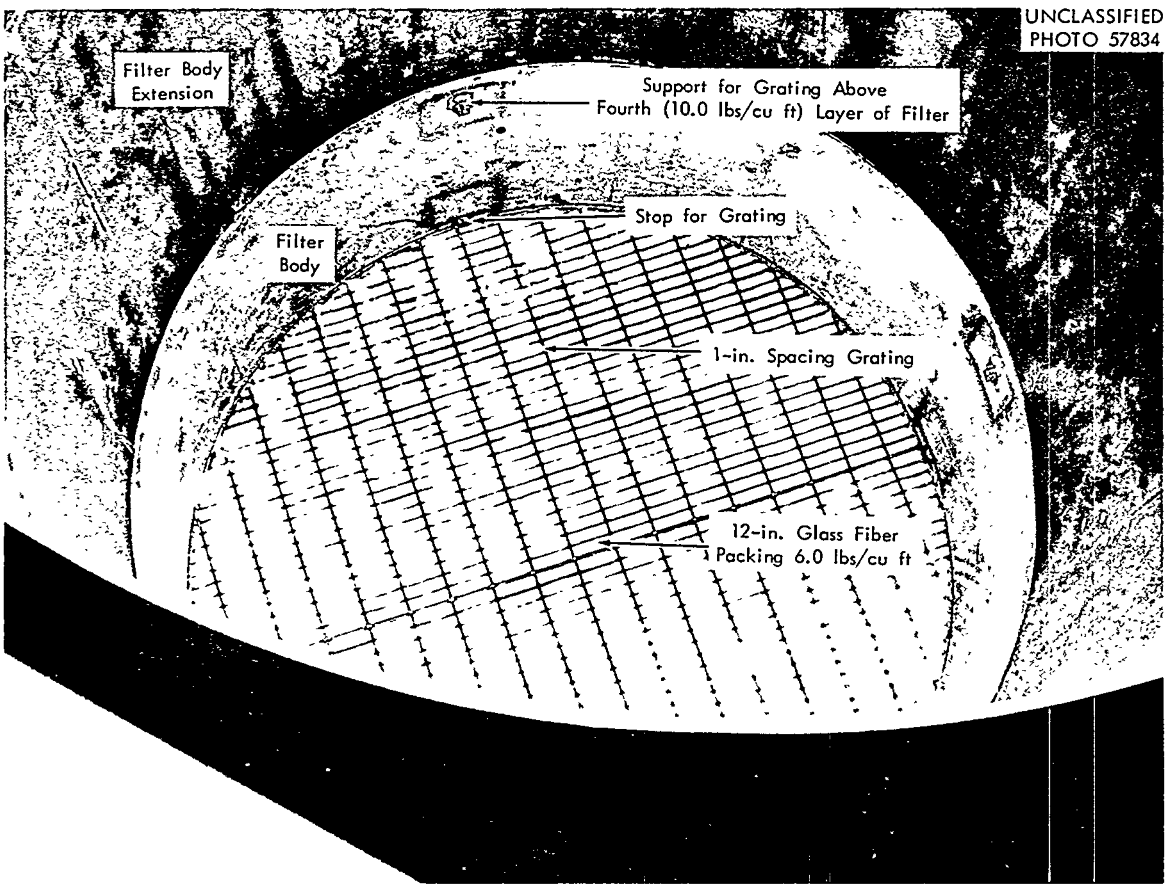

Fig. 8. Third layer of filter.

Since the glass fiber cannot be packed very much by hand, it was necessary to attach an extension to the filter body (see Figs. 8 & 9) before the fourth fiber layer was added. The fourth layer of the filter consists of 565.2 lbs of 115K fiber compressed, using a one-inch spaced grating, a one-quarter inch mesh and a 24 mesh screen, to a density of 10 lbs/cu ft. The packed fourth layer with the grating above it secured is shown in Fig. 10.

5.0 OFF-GAS FILTER ACCEPTANCE TEST

After completion of packing of the filter the top of the filter was placed on top of the body and taped (using masking tape) in place. The top was not welded on at this time since, for this test, it was more convenient to rotate the head 90°. The filter test set up is shown in Fig. 11. The quantity of air through the filter was controlled by a damper on the inlet of the fan which drew air through the filter. Ten-in. inlet and exhaust pipes conducted the air in and out and each permitted over ten pipe lengths of gas mixing before sampling of the gases in and out of the filter. A hot wire anemometer (13) was used to measure the gas velocity, determine the over-all gas flow, and set the damper for each test.

Di-octyl phthalate (D.O.P.) aerosol was generated using standard procedures and standard generators to produce an aerosol with 0.3-0.7 μ particulate size range. The generators were installed in a funnel shaped adapter on the inlet pipe. A wire screen was installed between the funnel and the inlet pipe to further promote mixing.

After the air flow rate was set, the rate of production of aerosol was checked and set to give an optimum reading on the instrument. The air and aerosol flows were then allowed to proceed for a time equivalent to at least ten filter body volume changes to pass through the filter before the concentration of the aerosol in the exhaust gases was determined.

Seven tests were run on the filter at from 50 to 855 cfm (see Table 1). After Test No. 5 the unit was shut down, and the pulley on the fan was changed to speed up the fan to get sufficient air flow to conduct the high flow (855 cfm) test. Five hundred cfm is the maximum (14) air flow to be permitted for this off-gas filter.

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(13) A hot wire anemometer is accurate and usable at gas velocities down to 10 ft/min.

(14) Limited by 3039 stack capacity and allotment.

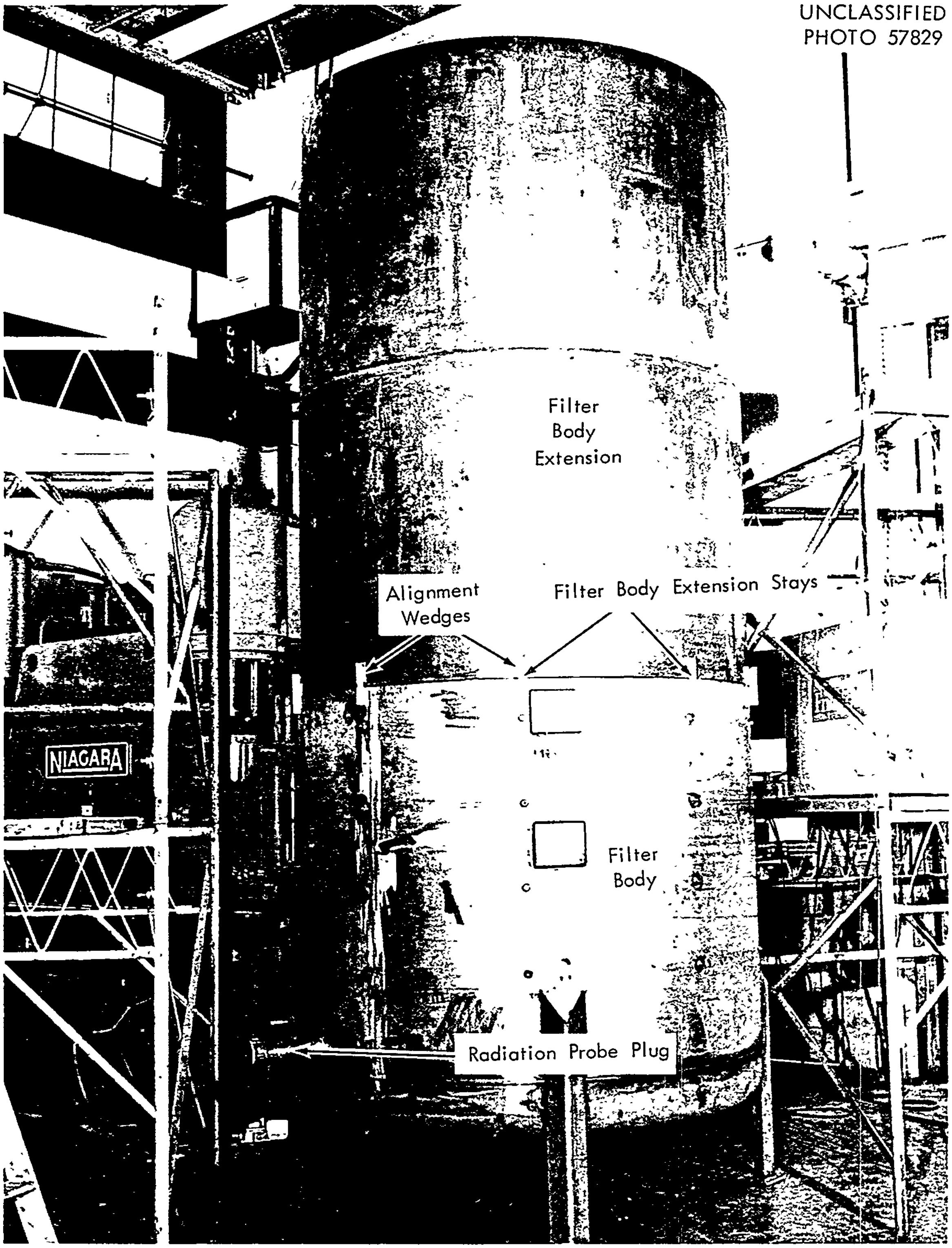

Fig. 9. Filter body extended.

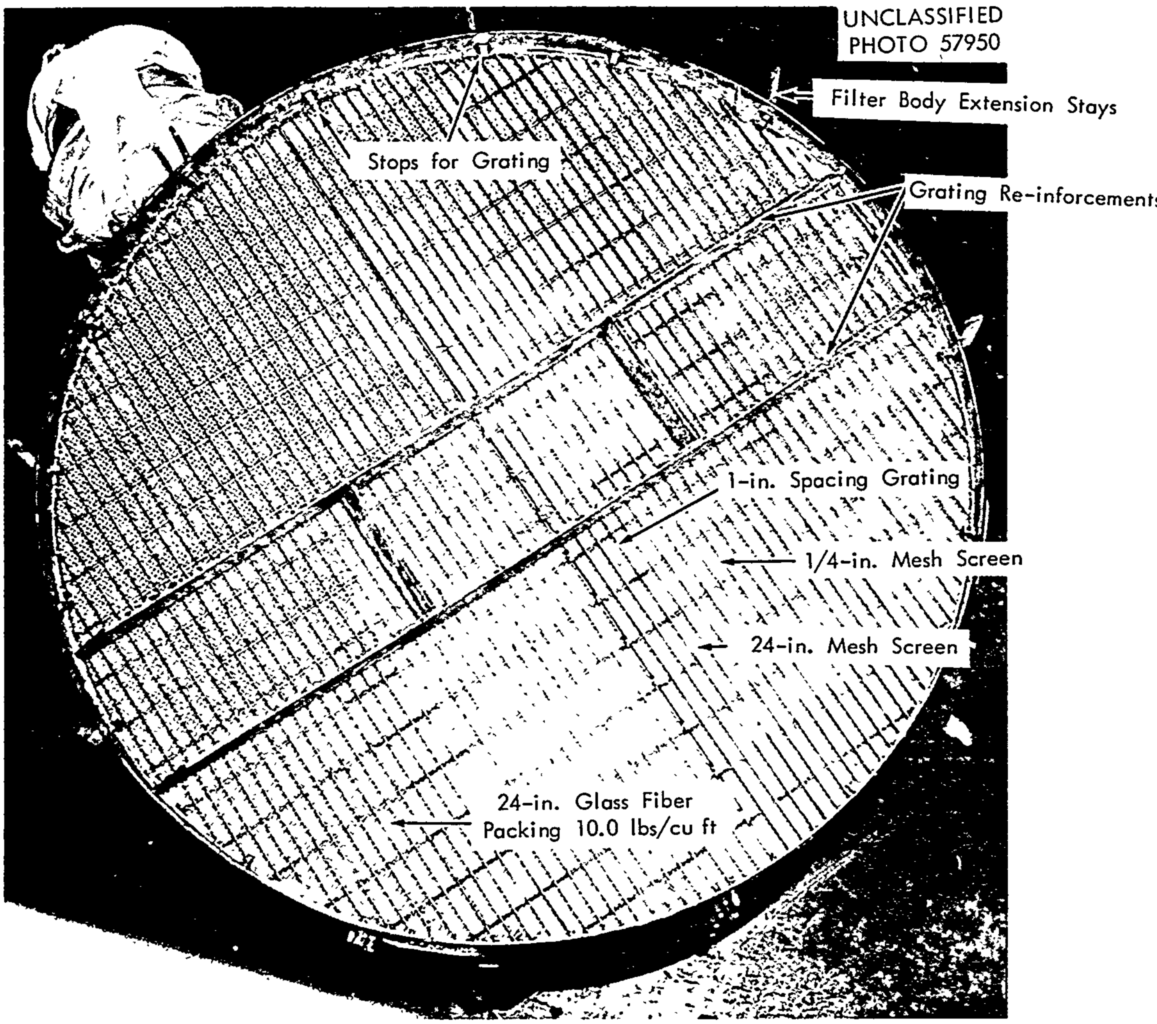

Fig. 10. Fourth layer of filter.

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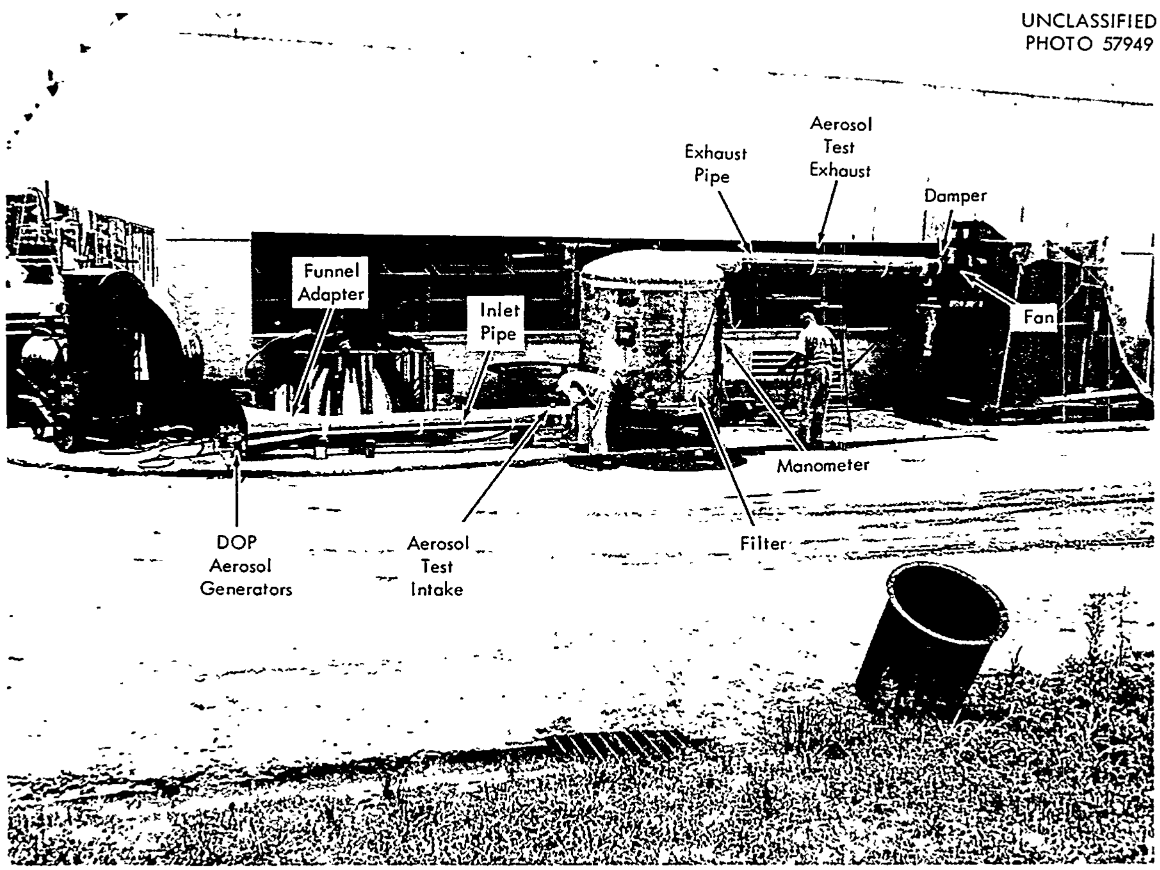

Fig. 11. Filter test set-up.

TABLE I

Off-Gas Filter Acceptance Test Data

Test No.	Gas Flow Rate, cfm	Pressure Drop Across Filter, in. H_2O	Time Allowed for Aerosol to Reach Equilibrium in Filter, min	Aerosol (DOP) Concentration		Eff., %
				Upstream, Units	Downstream, Units	
1	370	3.5	~1	40	0.57	98.58
2	370	3.5	5.5	40	0.90	97.75
3	200	1.9	10	60	0.68	98.87
4	50	1.0	40	50	0.02	99.96
5	500	4.8	4	40	1.0	97.50
6	855	9.6	~1	19	1.0	94.74
7	370	3.8	~1	26	0.7	97.31

A plot of the filter efficiency vs air flow, see Fig. 12 (round points), shows that at the air flows expected in Bldg. 3019 the filter is as efficient as the "absolute" type filter. The dashed line shown on the figure is a least squares line (15) based on all of the acceptance test values. The efficiency of the filter falls off as the air flow increases.

A plot of the pressure drop across the filter vs air flow is shown in Fig. 13. The pressure drop varies linearly with air flow. The lowest and highest point do not fall on the line. This is probably due to difficulty of accurately determining the air flow.

The efficiency of the filter was equivalent to an absolute filter at 50 cfm. At what is considered to be a very high flow rate, 300 cfm, the efficiency is 98.4%. The top was welded onto the body with a single pass of weld metal. The filter was now ready to install at Bldg. 3019.

6.0 OFF-GAS FILTER INSTALLATION

The vessel off-gas filter is installed southeast of Bldg. 3019 inside the building perimeter fence. The filter with its attendant piping is shown schematically in Fig. 14. A photograph of the installation of the filter is shown

(15) $y = 100.26 - 0.00629\ X.$

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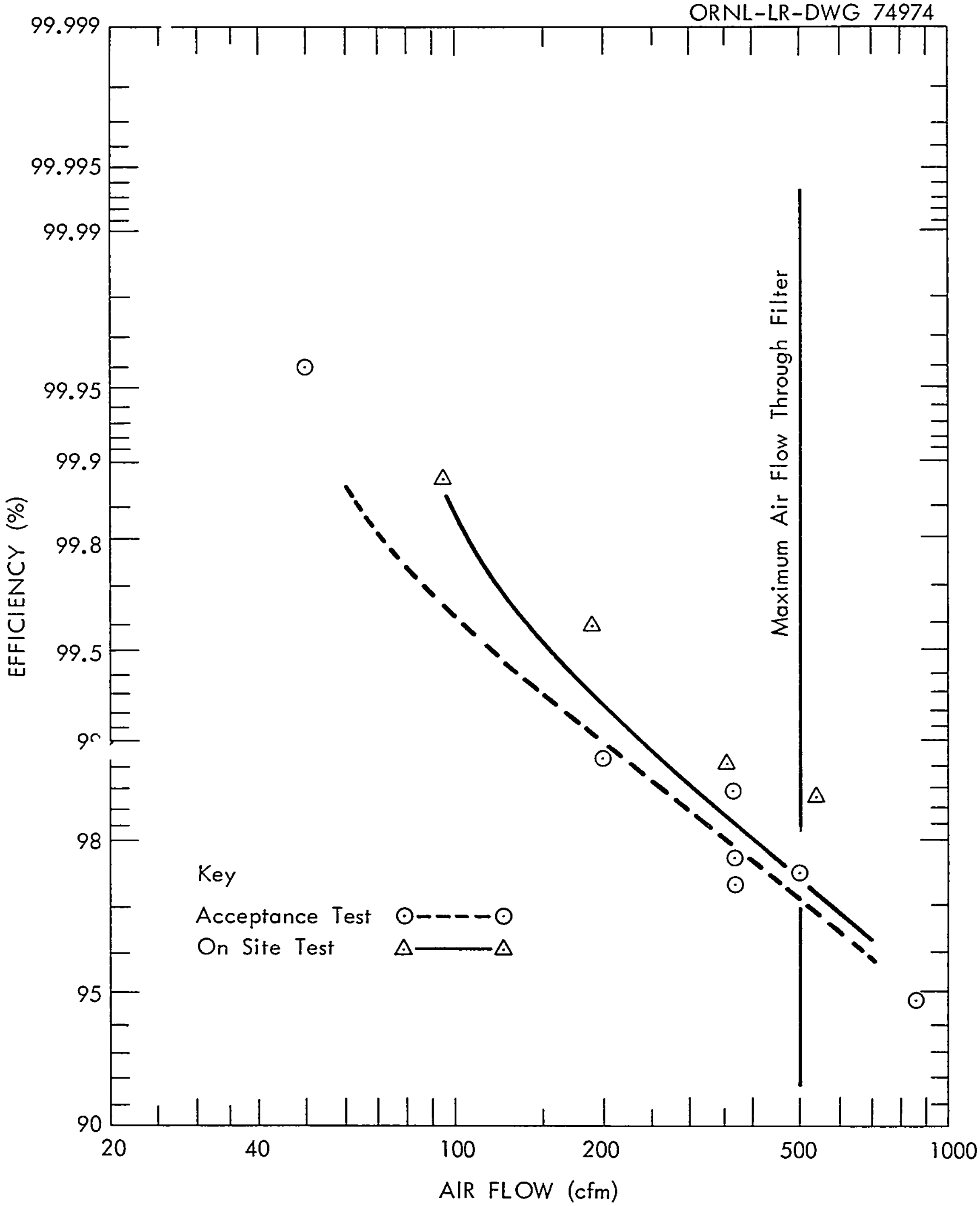

Fig. 12. Off-gas filter - effect of air flow on filter efficiency.

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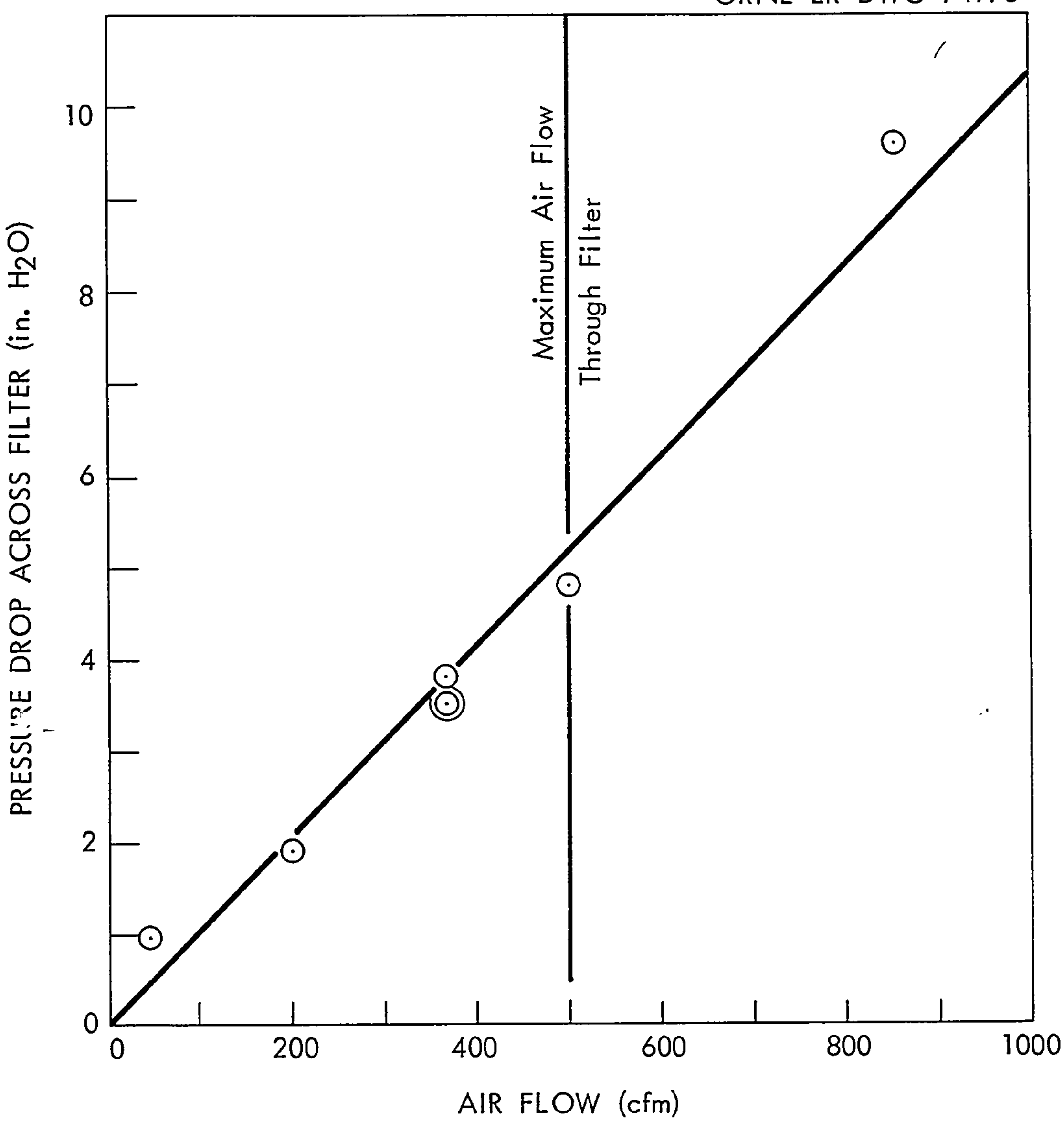

Fig. 13. Off-gas filter acceptance test - effect of air flow on pressure drop across filter.

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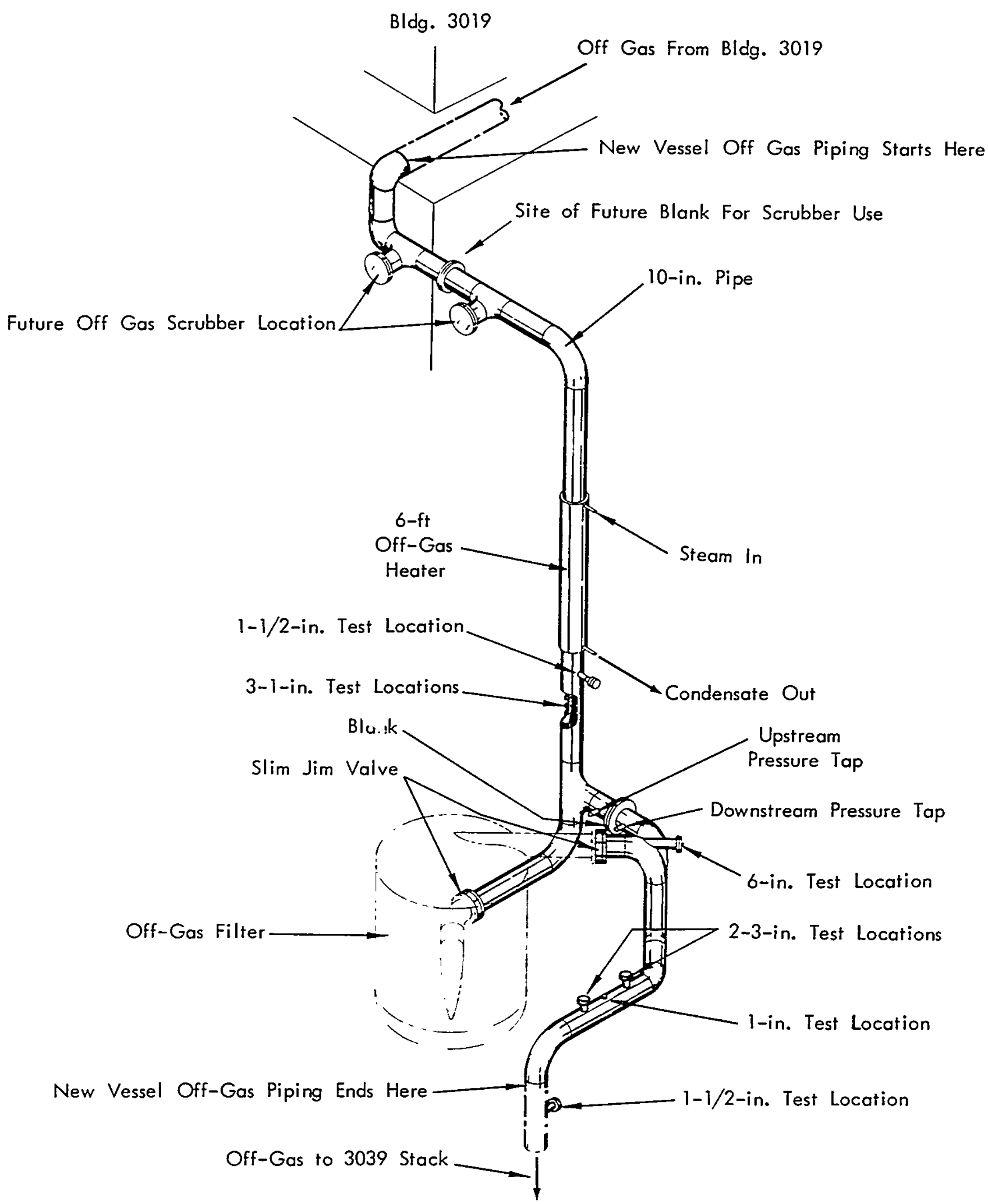

Fig. 14. Vessel off-gas filter piping.

in Fig. 15. The old 10-in. vessel off-gas line was cut out, and the new piping for the filter was installed. The new piping elbows down at the edge of the building and then east to get down below an existing steam line. Two 10-in. tees, with flanges for installation of a blank, are provided so that a gas scrubber can be installed in this line when required. Leaving the scrubber site, the pipe elbows down to a 6-ft length of steam jacketed pipe (12-in. jacket). The steam jacket will heat the gas so that the dew point will not be reached and liquids (water) will not condense out in the filter or in the lines leading to the filter due to the colder outside temperatures. The off-gas line is insulated from 6-in. above the top of the heater to the blank in the by-pass line and to the filter inlet.

Below the heater four test locations are installed. These are one 1-1/2-in. flanged opening and three 1-in. half couplings. These test locations will be used to remove and re-introduce DOP laden gas, to check air velocity (velocity probes), to determine gas temperature, introduction of small particulate test solids, and such other uses as are deemed to be necessary.

Below the test locations the line splits, one 10-in. line goes directly to the filter off-gas inlet at the bottom of the filter and the other 10-in. line is a by-pass line around the filter. The by-pass line has a blank normally installed in it between two flanges. Pressure taps are located on each side of the blank in the by-pass to determine the upstream and downstream pressures and the pressure drop across the filter. The off-gas inlet line has a "slim jim" butterfly shut-off valve to close off the air flow to the filter.

On the outlet side of the filter in the filter body is located a 1-in. test location which terminates inside of the filter with its discharge four inches above the top grating and perpendicular to the outlet gas flow direction. This nozzle may be used for introduction of small particulate test solids for checking of instrumentation at a downstream location.

As the 10-in. pipe leaves the filter a 6-in. test location is installed for radiation probe use. A "slim jim" butterfly shut-off valve is located in the off-gas outlet line to close off the air flow to the filter. Two 3-in. flanged test locations, a 1-in. half coupling and a 1-1/2-in. half coupling are located in the off-gas line as the pipe leaves the filter. These will be used for radiation monitors as well as DOP aerosol concentration.

7.0 OFF-GAS FILTER INSTRUMENTATION

Absolute downstream (from the filter) and upstream (from building to filter) air pressure and pressure drop across the filter are indicated on three magnahelic gauges installed in a weatherproof case at the filter site (see Fig. 15). The

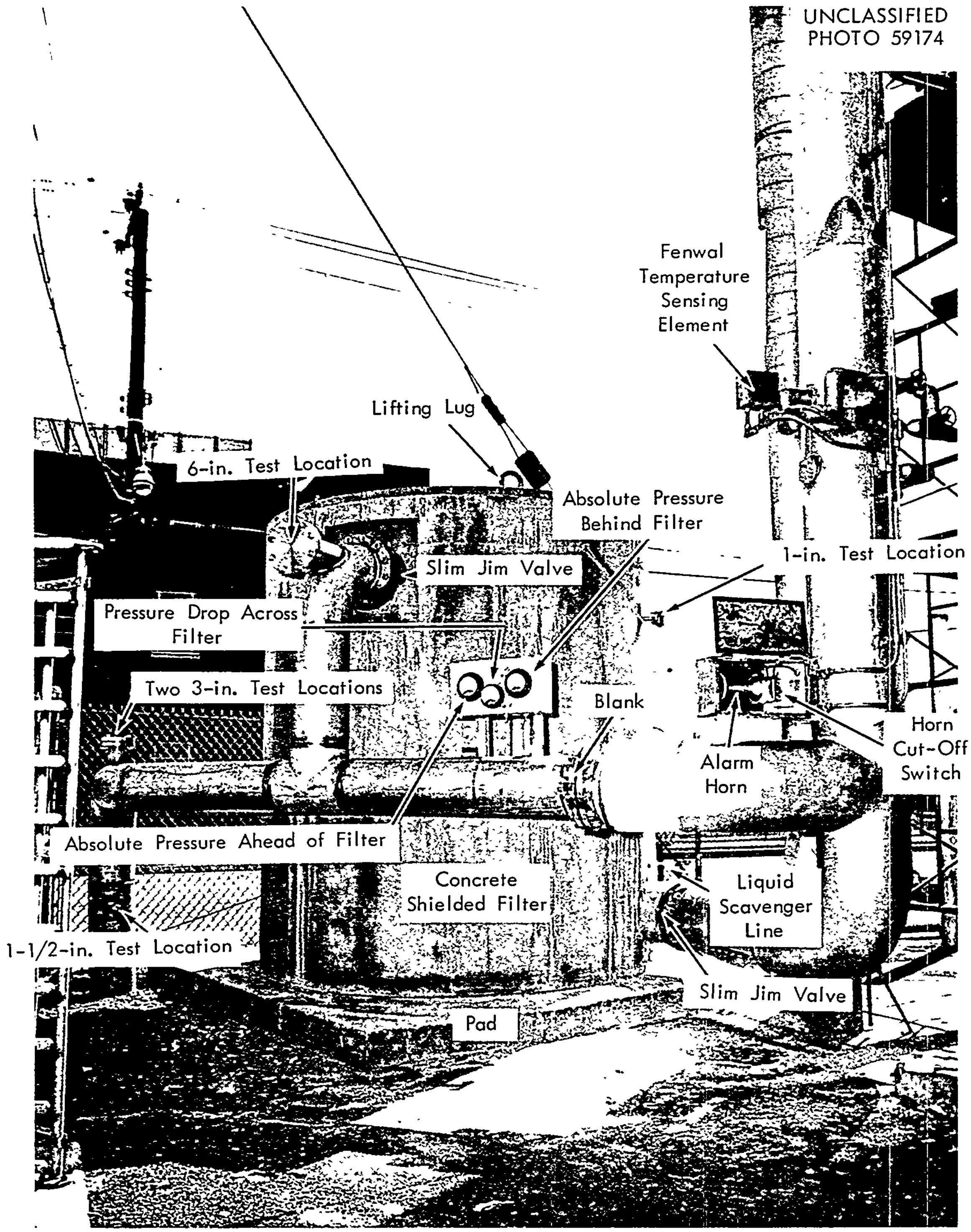

Fig. 15. Vessel off-gas filter installation.

absolute pressure gauges have a range from 0 in. to 48 in. water, and the differential pressure gauge has a range from 0 in. to 20 in. water. Two valves are provided on a tee at each pressure tap on the 10-in. line so that manometers can be installed periodically to check the gauges. In the near future two recording instruments will be installed on the Containment Panelboard in Bldg. 3019. These will record the absolute and differential pressures. An alarm at a differential pressure of 15-in. of water will be installed. A high pressure drop across the filter could be due to: 1. Excessive dust load on the filter, 2. Excessive gas flow through the filter, or 3. Filter loaded with liquids.

Steam supplied to the off-gas heater (jacketed section of pipe) is monitored by a Fenwal thermostat. The thermostat actuates an alarm (horn) locally (mounted in a weather-proof box) and causes a light to come on in the sample gallery of Bldg. 3019 when the steam supply fails or is cut off. The horn may be deactivated, after the trouble is recognized, by a locally mounted switch. In the near future an alarm and light will be installed on the Containment Panelboard. Steam supply to the heater could fail due to: 1. Someone accidentally cutting off steam, 2. Trap failure, or 3. Supply regulator failure.

In the near future a 0-500 cfm recorder will be installed on the Containment Panelboard to indicate and record the off-gas usage for the building. It will have an alarm set for low flow (25 cfm) and high flow (300 cfm).

The temperature of the off-gas filter, thermocouple located-gas inlet stream at bottom of the filter, will be recorded on the Containment Panelboard.

A continuous filter will be installed on a by-pass stream from the filter effluent. The material retained on the filter paper will be periodically tested for alpha-, beta-, and gamma-activity.

8.0 OFF-GAS FILTER ON STREAM TEST

On completion of the installation of the filter, a second series of tests were run using DOP aerosol. The aerosol was introduced into the filter through an open flange (scrubber site) and the vacuum from the blower at the 3039 stack pulled the air through the filter. The data collected are presented in Table 2.

TABLE II

Off-Gas Filter on Stream Test

(Ambient Air Temperature 22°C)

Test No.	Off-Gas Temperature Rise Through Heater, °C	Pressure Drop Across Filter, in. H_2O	Gas* Flow Rate, cfm	Corrected** Gas Flow Rate, cfm	Time Allowed for Aerosol to Reach Equilibrium in Filter, min	Aerosol (DOP) Removal Eff., %
1	10.0	5.63	710	540	4	98.50
2	11.5	3.66	422	355	8	98.80
3	12.0	2.05	218	190	15	99.58
4	14.0	1.00	50	95	30	99.88

* Gas flow rate based on pitot tube flow meter (not recommended for air velocities of less than 400 ft/min)

** Based on previous data - see Fig. 13

Based on data obtained with a pitot tube flow meter, the gas flow was calculated and the upstream butterfly valve was throttled to restrict the flow. Upon examination of the gas flow rate data, it became suspect. Not only were the last two tests made at air velocities below the recommended ranges at which the instrument is suitable but also air control personnel at the 3039 stack stated that the maximum flow permitted during the test was 500 cfm. These data were therefore discarded and air flows were calculated based on pressure drop across the filter and Fig. 13.

Plot of the efficiency vs gas flow (tri-angular points, Fig. 12) indicates that these data, while they are slightly more efficient than the previous data, are in the same family. The solid line is the least squares line (16) for the eleven pieces of data.

The off-gas pre-heater for the filter was operated during this test and the temperature rise of 10 to 14° centigrade should keep the gas above the dew point and keep the filter dry.

9.0 OFF-GAS CHARACTERISTICS

The particulates, aerosols and smokes, which will be generated in Bldg. 3019 by the many processes to be installed in the building over the period of years, contemplated to be the life of the filter, have been characterized and studied, and a

(16) $y = 100.431 - 0.005976\ X.$

report (17) has been prepared.

The normal operations which will generate aerosols in the vessel off-gas are mixing of solutions, bubblers for level determination, sparging, venting, etc. Studies have established that these have a mass mean particle size of 2.1 μ.

Figure 16 shows the theoretical particle distribution of a stable aerosol which has encountered several changes in direction in a pipeline.

Smokes vary over a range of particulate sizes of from 0.01 to 0.1 μ. Neither the deep bed glass fiber filter nor the "absolute" filter will quantitatively remove smokes.

An aerosol of di-octyl-phthalate is used to test filters at ORNL. This aerosol as generated has 0.3 and 0.7 μ particles. This range of particulate sizes is noted in Fig. 16. Therefore, the efficiency of the filter to an aerosol as generated in the building should be higher than the efficiency noted for the test aerosol.

10.0 OFF-GAS FILTER TEST PROGRAM RECOMMENDATIONS

In order to establish the feasibility and applicability of this filter, it is recommended that:

1. It be tested using standard 0.3-0.7 μ DOP smoke at six-month intervals for the life of the filter (estimated 6-8 yrs) to determine the effects of time and dust loading on the pressure drop and efficiency,

2. The amount of radioactivity be tested at weekly intervals. This data may be used to estimate the loading and to determine when the filter needs additional shielding,

3. An analyzer be procured and used in conjunction with future tests of this filter to determine not only the average over-all filter efficiency but to determine the efficiency for narrower particulate size ranges of particles,

4. A smoke or powder be procured for use in future tests that will more closely simulate actual generated aerosols (Fig. 16),

5. The quantity of the vessel off-gas usage be minimized and controlled where possible so that the filter may operate as efficiently as possible.

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(17) E. D. Arnold, A. T. Gresky, and J. P. Nichols, "The Evaluation of Radioactive Releases from Chemical Plants," ORNL-TM-19, Oct. 3, 1961.

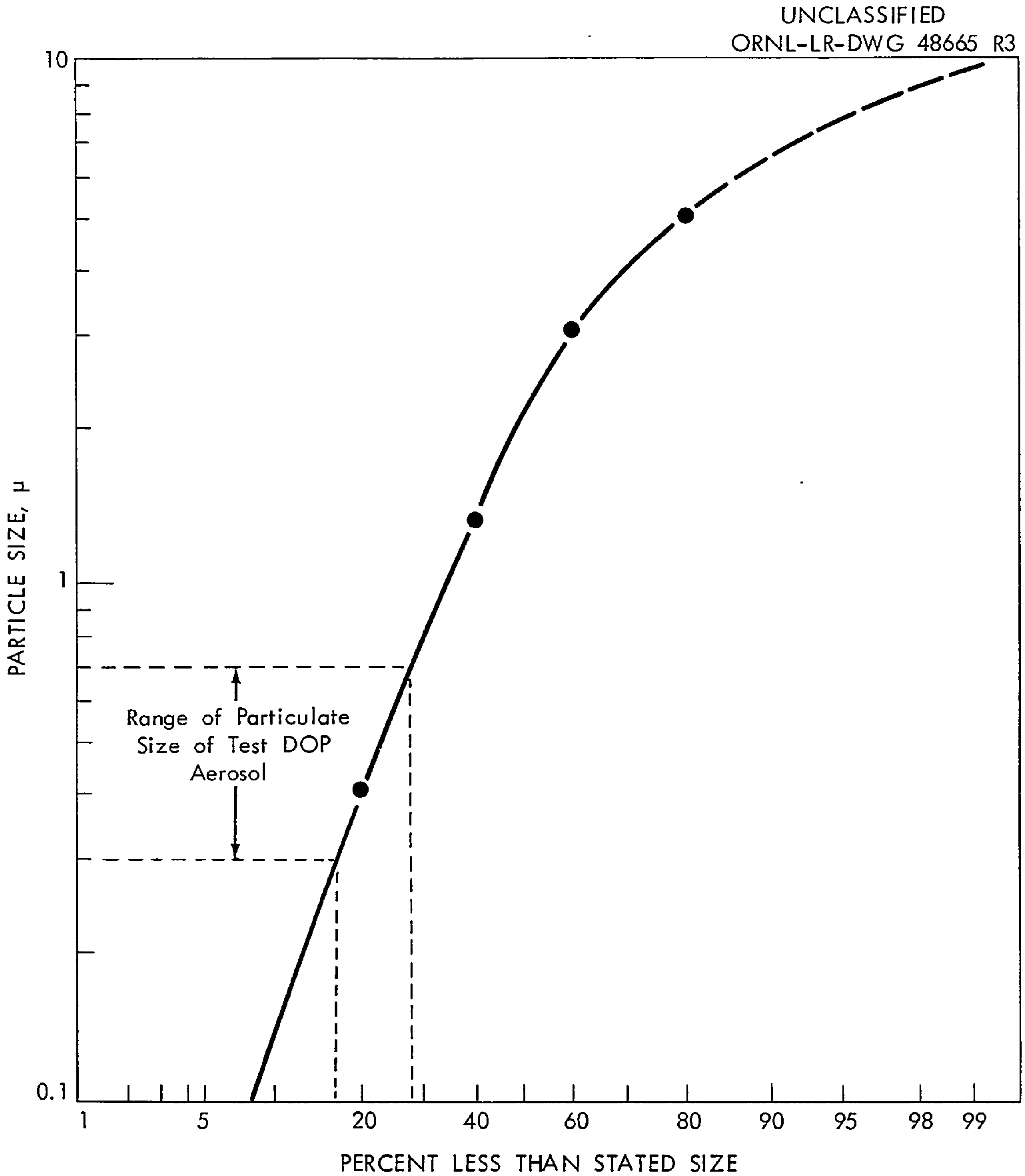

Fig. 16. The particle size distribution of a stable aerosol which has encountered several changes in direction in a pipeline.

APPENDIX A

List of Applicable Drawings

No.		Approved Date	Latest Revision No.	Latest Revision Date
C-SK-164	Filter Test Assembly	5/29/62	-	-
D-35703	New Radioactive Off-Gas Lines Leaving Bldg. 3019, Plan and Sections	5/15/62	3	4/7/62
D-46050	Vessel Off-Gas Filter Piping Plan and Location	2/15/62	4	10/3/62
D-46051	Vessel Off-Gas Filter Assembly and Shielding Details	2/27/62	3	7/18/62
C-46060	Vessel Off-Gas Piping Instrumentation	2/23/62	1	2/23/62
C-46070	Vessel Off-Gas Filter Support Pad	2/16/62	1	10/9/62
D-46071	Assembly, Filling, Testing and Installation Procedure	2/27/62	1	4/16/62
D-46078	Relocation of BT Storage Tank Off-Gas Line	2/27/62	-	-
EV-21202	Recovered Acid Storage Tank Assembly and Details	7/12/56	1	5/4/62