NATIONAL BUREAU OF STANDARDS REPORT

4687

PERFORMANCE OF TWO AIR-MAZE OIL BATH AIR CLEANERS

by

Carl W. Coblentz
William F. Goddard, Jr.

Report to
Office of the Chief of Engineers
Department of the Army
Washington 25, D. C.

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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Heating and Air Conditioning Section
Building Technology Division

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Abstract

The operating characteristics of two oil bath air cleaners of the same type but of different size were determined for an air flow rate of 50 CFM. Using A. C. test dust "fine" the filtering efficiency of the larger model, designed for an air flow rate of 143 CFM, was 83% and the efficiency of the smaller unit designed for 83 CFM was 92%. Both specimens employed a rubber like diaphragm as a relief valve which opened to let air flowing from the pipe line by-pass the oil bath and closed during the intake part of the cycle. The free floating diaphragm on the larger model performed well at -30 F ambient temperature, whereas the diaphragm of the smaller model, which was riveted to the valve seat, did not close at temperatures below -13 F, permitting dusty air to by-pass the filter element during intake cycle.

1. INTRODUCTION

Upon requests by the Office of the Chief of Engineers, Department of the Army, dated April 5 and May 1, 1956, two specimen air cleaners were tested to determine their performance characteristics as filters of the ventilating air for elevator oil tanks.

It is essential that a filter for this purpose shall have a high efficiency when air is being drawn into the tank. Filters tested were equipped with rubber flap valves designed to by-pass the oil bath when air was being expelled from the tank.

2. FINDINGS

The first specimen tested was designed for an air flow rate of 143 CFM. The efficiency of the device at the operating air flow rate of 50 CFM was only 83% and an examination of the effluent air indicated that dust particles of 80 micron size had passed the filter; this was the maximum size of dust particles in the test dust used for testing this specimen. The pressure loss increased from 1.9 in. W. G. with clean oil to 2.5 in. W. G. after the introduction of 260g of dust. These 260g of dust are equivalent to the total dust which would have been introduced into the air cleaner during 1040 operating cycles at a dust concentration of 10 mg/cu ft. The pressure loss during the discharge portion of the cycle, when pushing air from the oil tank through the device, was 0.5 in. W. G. No change in the flexibility of the diaphragm, that served as a relief valve, was noticed when it was cooled to -33F; at -36F some stiffening was perceptible and at -51F the rigidity of the material was such that it could no longer be expected to operate properly. When operating the device with the recommended oil, MIL-0-6083, the loss due to splashing during 100 operating cycles was 22.2g. A flame test revealed that at an oil temperature of 147.2F no back flash occurred when the filter screen of the device in operation was touched with a burning torch.

Further tests made with this specimen showed that using a heavier oil, SAE-20W-30, instead of MIL-0-6083, did not change the filtering efficiency. The loose fit of the brass grommet in the relief valve, which enabled the same to float on the center stem, did not produce an air leakage that affected the efficiency to a noticeable degree. No change in the performance of the relief diaphragm could be noticed when the ambient temperature was reduced from 70F to -30F.

The other test specimen was designed for an air flow rate of 83 CFM and showed a fitering efficiency of 92% at a 50 CFM air flow rate and using A. C. test dust "fine". When using A. C. test dust "coarse" which contained dust particles up to 200 micron size the largest particles observed in the effluent air stream were 80 micron size.

The pressure loss with clean oil, MIL-O-6-83, was 2.8 in. W. G. and increased to 3.2 in. W. G. after 50g of dust had been introduced into the device. The oil lost during 100 operating cycles was 29.2g.

The relief valve of this model was riveted to the valve spider and the diaphragm was curled up. At room temperature, the suction caused by the air flow would securely close the valve; however, when the device was operated in a -30F ambient air the diaphragm remained in its curled shape permitting in-flowing dusty air to by-pass the oil bath. After increasing the ambient temperature slowly to -13F the diaphragm commenced to operate properly.

3. SPECIMEN AND TEST APPARATUS

The test specimens were manufactured by the Air-Maze Corporation of Cleveland, Ohio, as their models FV143S and FV83S. They were supplied to the Office of the Chief of Engineers by the Wayne Pump Company of Salisbury, Maryland, as prototypes for filtering the ventilating air of elevator oil tanks. The latter specimen was furnished after the performance of the first one had been tested by this laboratory and found to be not satisfactory.

Both specimens were oil bath air cleaners provided with a relief valve to by-pass the air around the oil supply in the filter during the discharge portion of the cycle. The first model was designed for a 143 CFM air flow rate and weighted 2.880kg (6 lbs 6 oz). The other model was designed for 83 CFM and weighted 1.256kg (2 lbs 12 oz). The design of both devices was very similar, the difference being only their size and the construction of the air relief valve. These relief valves had a diaphragm of about 1/16 inch thick, flexible, rubber-like material. In the larger model the diaphragm was provided with a brass grommet which centered the same to the spider seat and allowed the diaphragm to float free when air was blown into the air cleaner from the oil tank. Fig. 1 is a photograph of the components of this filter. It shows the tank into which the oil is filled to a stamped-in mark: the filter element consisting of several layers of corrugated wire mesh screen surrounded by a steel jacket and with the spider seat of the relief valve in its upper part, the cover with the stem, and the base, which had a

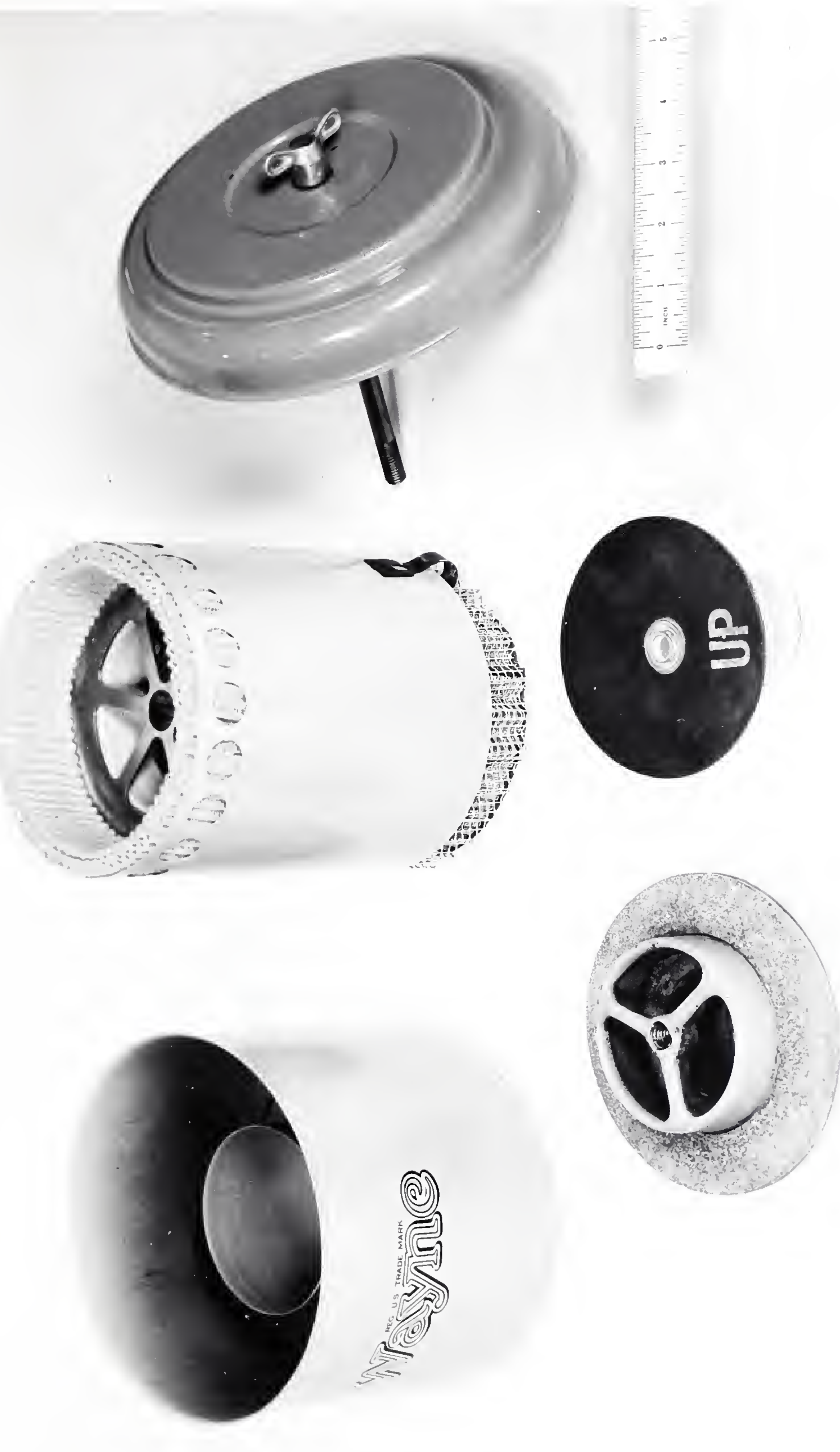

fig. 1

2in SPT, to connect the air cleaner to the pipe line and a cork washer as an air seal to the tank. The diaphragm was placed on a glass beaker for photographic reasons; this beaker ~~adversely~~ shows below the diaphragm.

The oil supply of the large device was 491g and that of the smaller model was 144g.

Fig. 2 shows the FV83S model assembled and fig. 3 is a view into the filter element to show how the diaphragm was curled up due to the distortion of the material by the center rivet that holds it to the spider seat.

For test purposes an enclosure was designed and built that completely covered the device so that the amount of test dust introduced into the air cleaner could be determined. Fig. 4 is a photograph of the arrangement used for determining the filtering efficiency. On the left side is the dust feed apparatus which consists of a variable speed drive onto which a turntable with two concentric grooves is mounted. A weighed amount of test dust is placed into the hopper from which it fills one of the grooves to a constant level. The dust is then picked up by a high pressure aspirator which breaks up any agglomerations and introduces the dust in a steady stream of air into the inlet pipe of the air cleaner enclosure. By varying the speed of the turntable any desired dust feed rate can be obtained. By dividing the dust feed rate, in grams per minute, through the flow rate of the air drawn through the device, in CFM, the concentration of the dust, in g per cu ft is obtained. This concentration was maintained at about 0.01 g/cu ft during the efficiency tests.

The air was drawn through the filter with an exhaust blower and the air flow rate was measured with orifice flow meters designed in conformance with the ASME Research Publication , "Fluid Meters, Their Theory and Application".

4. TEST PROCEDURE AND OBSERVATIONS

The efficiency of the air cleaner was determined by drawing a small amount of air from the center of the duct downstream the filter. The sampling air was blown through a glass fiber paper whose smallest fibers were about 0.3


AIR-MAZE
OIL BATH AIR FILTER
INSPECT ONCE A WEEK, DAILY IN VERY DUSTY OPERATION. DUMP OIL AND DIRT FROM BOWL. REFILL WITH MOTOR OIL TO BEAD. USE SAME OIL AS IN CRANKCASE.
CAUTION: FELTED END OF SCREEN ELEMENT MUST BE IN OIL.
AIR-MAZE CORP. CLEVELAND, OHIO U. S. A.

fig. 2

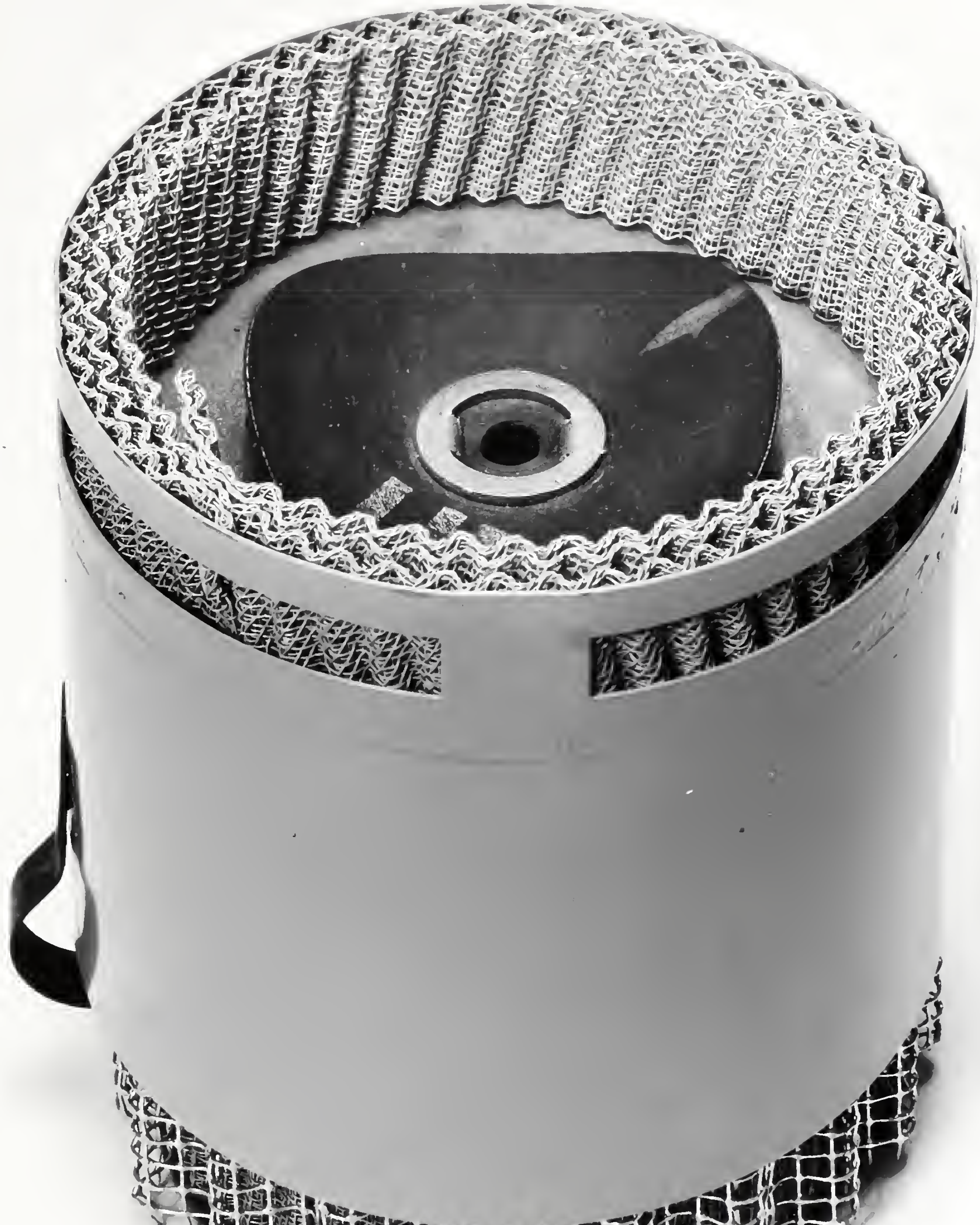

fig. [illegible]

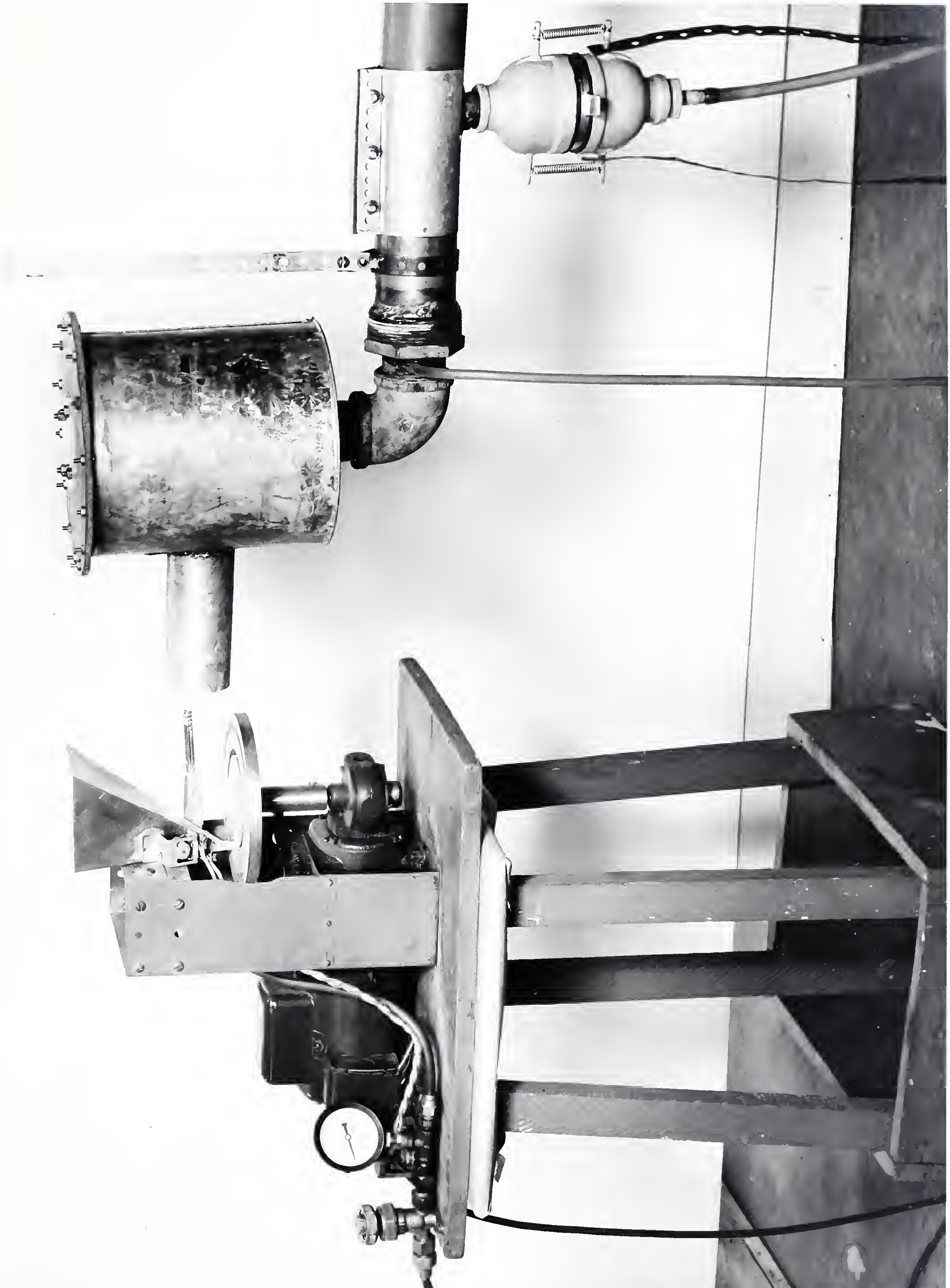

Fig. 4

micron thick. Tests of the dust retention ability of a similar material by the Atomic Energy Commission indicated that this paper would retain more than 99.99% of all particles 0.3 micron and larger and could, therefore, be considered an absolute filter. The filtering efficiency was determined from the formula:

$$E = \left(1 - \frac{RxS}{W_1 - W_2}\right) x\ 100$$

where E = efficiency, %
R = ratio of filter flow rate to sampler flow rate.
S = weight gain of sampler, g.
W_1 = weight of dust introduced into filter enclosure, g.
W_2 = weight of dust fallen out in enclosure and collected after test.

The test dust used for determining the filtering efficiency was Arizona road dust classified by the A. C. Spark Plug Division of General Motors Corporation and nationally accepted as a standard air cleaner test dust. It had the following particle size distribution by weight.

0 to 5 microns	39% ± 2%
5 to 10 microns	18% ± 3%
10 to 20 microns	16% ± 3%
20 to 40 microns	18% ± 3%
40 to 80 microns	9% ± 3%

The filtering efficiency of the specimen was determined as the average value of four test runs in each of which 20g of dust were introduced into the filter. The efficiency of the larger model FV143S was 93% and that of the smaller one FV83S was 92% at 50 CFM air flow rate. These efficiency values were determined on both models with light oil, MIL-O-6083, and heavier motor oil, SAE-20W-30, and no difference could be noticed at room temperature.

The pressure loss of the test specimens was determined as the pressure drop between the base flange and the inside of the enclosure for the air flow during the air intake portion of the cycle, i.e., during the efficiency

test runs. This pressure loss increased on the larger model from 1.9 in. W. G. with clean oil to 2.5 in. W. G. after introduction of 260g of dust. This dust load did not exhaust the dust holding capacity of the device, however, as the 260g of dust corresponded to the total amount of dust that could reasonably be expected to be introduced into the air cleaner during 1040 operating cycles, it was felt that an earlier servicing of the device would be advisable and the full dust holding capacity would not be needed. The pressure loss during the discharge portion of the cycle, when flowing air from the oil tank, was 0.5 in. W. G. This pressure loss was independent of the dust load in the air cleaner, which indicated that the main flow of air was through the by-pass valve.

The pressure loss of the FV83S model at 50 CFM flow was 2.8 in. W. G. and increased to 3.2 in. W. G. after 50g of dust was introduced into the device and when oil MIL-O-6083 was used. Using heavier oil, SAE-20W-30, the pressure loss with clean oil was 3.3 in. W. G. at room temperature.

It was investigated whether a back-flash could occur when the air cleaner was heated due to solar radiation and then touched by a flash. For this purpose the specimen FV143S was installed in the enclosure shown in fig. 4. A plexiglass window was then built into the center of the lid of the enclosure, the cover of the air cleaner was removed and the rubber diaphragm replaced with a plexiglass plate, so that the inside of the filter screen could be observed while the device was in operation. Three thermocouples were installed at the air inlet, the air outlet and one in the oil to measure the temperatures at these points. Air was then drawn in from an electric heater at a rate of 50 CFM. After reaching an air outlet temperature of 130F the filter screen was touched with the tip of a welding torch introduced through the inlet pipe of the enclosure. As no flash could be noticed the temperature was further increased until the inlet temperature was 150.0F, the oil temperature was 147.2F and the outlet air temperature 145.0F. No back flash was observed under this condition.

The flexibility of the diaphragm of the 143 CFM unit at low temperatures was observed by mounting it on a stand and placing it in a low temperature chest. The flexibility of the disk at room temperature was then compared with that after exposure to the low temperature, for several minutes. It was noticed that the flexibility had not changed at -33F. At -36F some stiffening was perceptible and at -51F the rigidity had become such that a proper operation could not be expected. When operating this specimen in a -30F ambient temperature the operation of the by-pass valve appeared to be the same as at room temperature.

The operation of the smaller model FV83S in a -30F ambient showed that the curled up diaphragm did not close when air at a flow rate of 50 CFM was drawn into the filter. (In actual operation the dusty air would have by-passed the oil-filter and blown into the oil tank). The air temperature was then slowly increased while the direction of the air flow was continuously altered. The diaphragm commenced to close when the ambient temperature had increased to -13F.

An examination of maximum size of dust particles in the effluent air was made by inserting a microscopic slide into the air duct. This slide was prepared with an adhesive made up from Canadian balsam and castor oil.

The larger model was tested with A. C. dust "fine" that contains dust particles of up to 80 micron size, whereas the smaller unit was tested with A. C. dust "coarse" having particles up to 200 micron size. A microscopic examination of the slides showed particles of up to 80 micron size from both models. This revealed that the smaller model did retain all particles larger than 80 microns.

4. DISCUSSION AND CONCLUSIONS

The performance tests revealed the apparent usefulness of this type of air cleaner for the intended purpose. The comparatively low efficiency of 83 percent on the larger model, rated at 143 CFM, is attributed to the fact that it was being used at less than 30% of its design air flow. The filtering efficiency of this unit was too low. Experience with other oil bath air cleaners has shown

that the efficiency decreased with the air flow rate. It was therefore, to be expected that the efficiency would be higher on the smaller unit designed for 83 CFM and being utilized at 60% of this air flow rate. The efficiency of 92% of this model compared favorably with the other acceptable oil bath filters.

If this smaller model FV83S can be procured with a floating diaphragm similar to that being employed on the larger model, it is recommended that it be used. Unless this modification can be obtained, the installation of paper air filters should be considered.

THE NATIONAL BUREAU OF STANDARDS

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