Fuel Filter

Test Method - SAE J905

Handbook Supplement
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SAE Recommended Practice

Report of Engine Committee approved November 1964.

1. SCOPE

This test method describes laboratory testing of final stage fuel filters used to protect engines from abrasive contaminant. It has been developed to provide a standardized method of rating fuel filter performance in terms of flow, pore size, contaminant holding capacity, efficiency, and media migration. Although development of this test method was based on diesel fuel filters, it is applicable to all types of liquid fuel filters used on automotive type internal combustion engines. Typical filter systems, service and space problems, environmental and other special factors which influenced the development of this test method are covered in more detail in "Fuel Filter Test Methods" (SAE Technical Progress Series, Vol. 1).

Since the contaminant used in this test is a hard, dry, and abrasive material, the ratings for efficiency and contaminant holding capacity are not necessarily applicable under conditions where a soft, gummy, sludge type contaminant is present. Efforts are being directed toward the development of methods for evaluating the effects of a filter under such conditions, which are sometimes encountered in actual engine operation.

2. TEST MATERIALS

2.1 TEST FLUID - Calibrating fluid (high flash) MIL-F-27351, available from Phillips Petroleum Co., Bartlesville, Okla.

2.2 TEST CONTAMINANT - AC Fine Dust, Part No. 1543094, available from AC Spark Plug Div., General Motors Corp., Flint, Mich.

3. TEST APPARATUS

3.1 FLOW AND CAPACITY APPARATUS - The stand presented in Figs. 1 and 2 represents a minimum. (It is essentially a 25-150 gph test device.) This test stand and procedure were developed on the basis of tests conducted on 3 in. dia × 8 in. length. When larger or smaller elements are tested, increased or decreased flow and/or contaminant addition rate may be required in order to keep the test time within a reasonable limit such as 8 hr. If filters are to be tested outside the range of the stand described herein, a smaller or larger stand could be built to proportional scale. The stand has been developed to be used exclusively in fuel filter testing. Refinements are, of course, possible in order to make the stand more automatic, but such refinements should leave the significant features intact.

3.1.1 Materials and Equipment (Figs. 1 and 2) -

A. Conical bottom reservoir 15 gage stainless steel 15 in. OD, 8 in. (minimum) vertical wall, and 90 deg bottom.

1. Special bypass discharge nozzle. Five inches of copper tubing 1/2 in. OD, 1/16 in. wall. (see Fig. 3).
2. A 1/2 in. × 90 deg smooth flow copper elbow.
3. Coupling 5/8 - 1/2 in. transition.
4. A 1/2 in. smooth joint union.
5. A 5/8 × 1/2 in. ID coupling brazed to bottom of cone (smooth flow copper).
6. Mechanical mixer (optional, see paragraph 3.1.2.1, item 1).

B. Pump: Moyno size 1L3 driven to deliver 300 gph. (Source: Robbins and Myers Inc., Pump Div., Springfield, Ohio.)

NOTE: The pump should be located directly under the reservoir as shown in Fig. 1. Fittings chosen to connect the reservoir to the pump should provide smooth flow with no ledges, crevices, or throttling. The transition from the pump to the 5/8 in. OD system flow lines should meet these same requirements. (The plugged opening in the bottom of the pump should be equipped with a drain cock for convenience in draining the stand.)

C. A 5/8 in. OD × 1/2 in. ID hard copper tubing (approximately 15 ft required).

D. 5/8 × 5/8 × 5/8 × 3/16 side outlet tee, smooth flow (1 required).

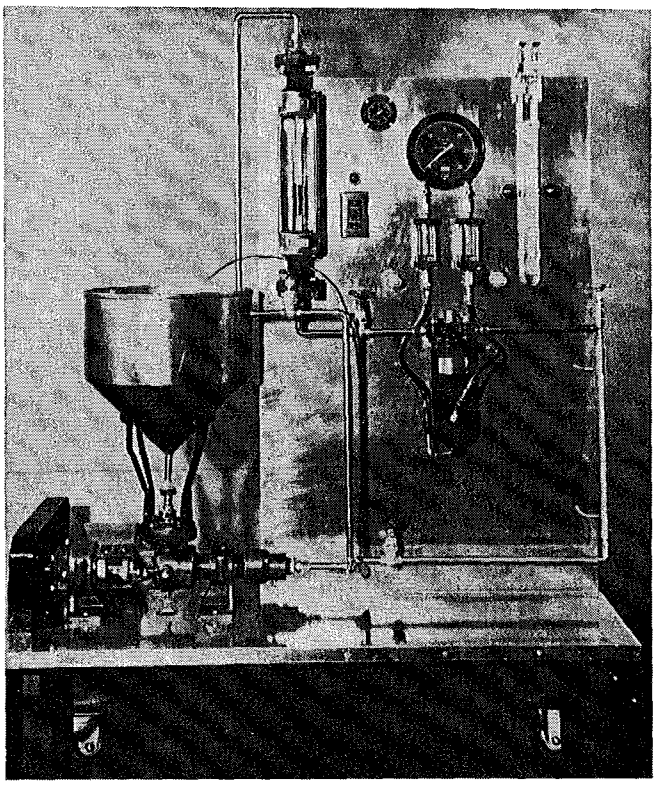


Fig. 1 - Fuel filter test stand

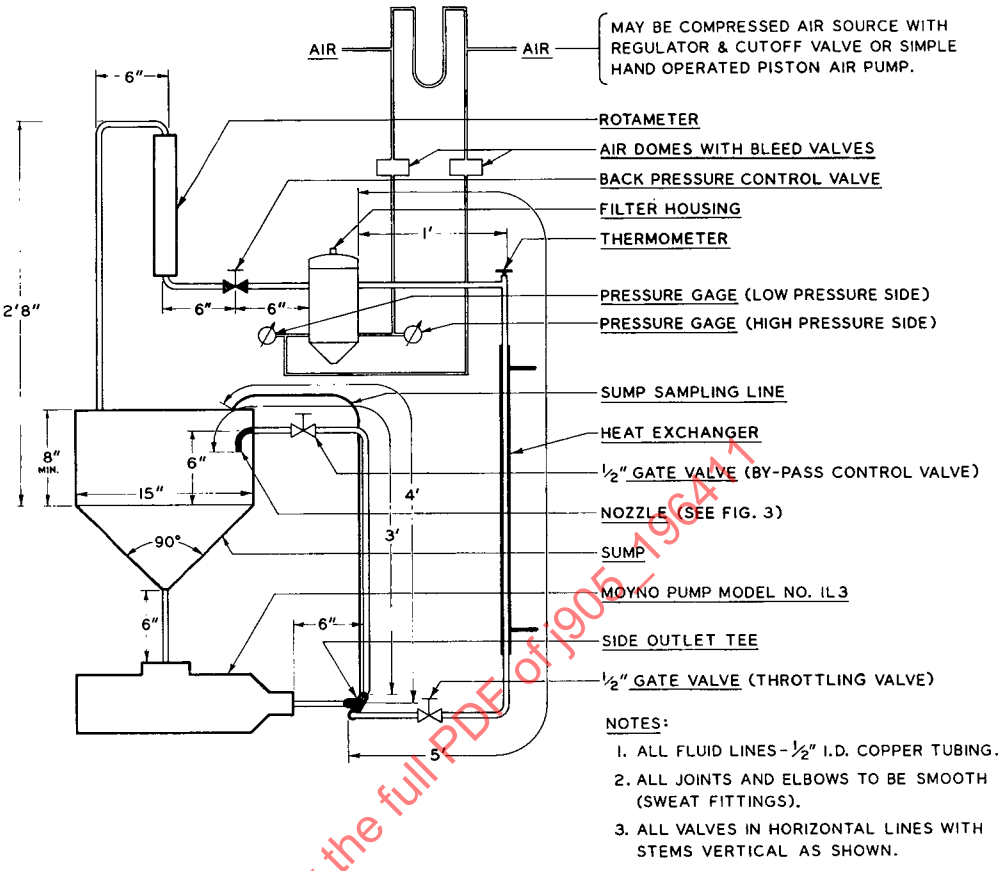


Fig. 2 - Diagram of fuel filter test stand

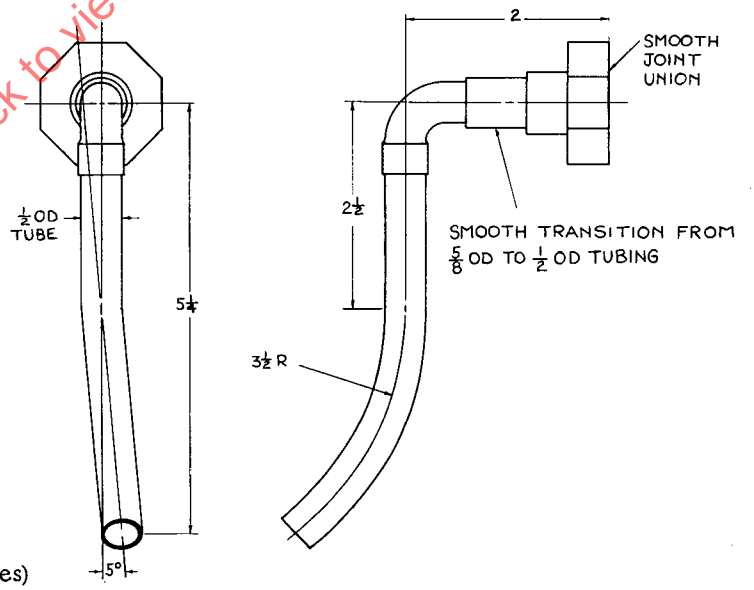


Fig. 3 - Special bypass discharge nozzle (in inches)

E. Sampling line: 3/16 in. OD x 0.30 wall soft copper tubing (6 ft required).

F. A 1/2 in. bore to fit 5/8 in. OD tubing smooth flow gate valve (3 required).

G. Elbows: 5/8 in. 90 deg elbow (7 required).

H. Heat exchanger (Fig. 4).

1. 7/8 in. OD x 3/4 in. ID copper tubing (18 in. required).

2. 5/8 in. ID x 7/8 in. ID reducer coupling smooth flow copper (2 required).

3. 1/4 in. OD copper tubing (length optional, 2 pieces).

I. 5/8 in. OD tubing tee smooth flow copper (1 required).

J. Dial type thermometer. (Fitting or method of attaching thermometer shown in detail in Fig. 4.)

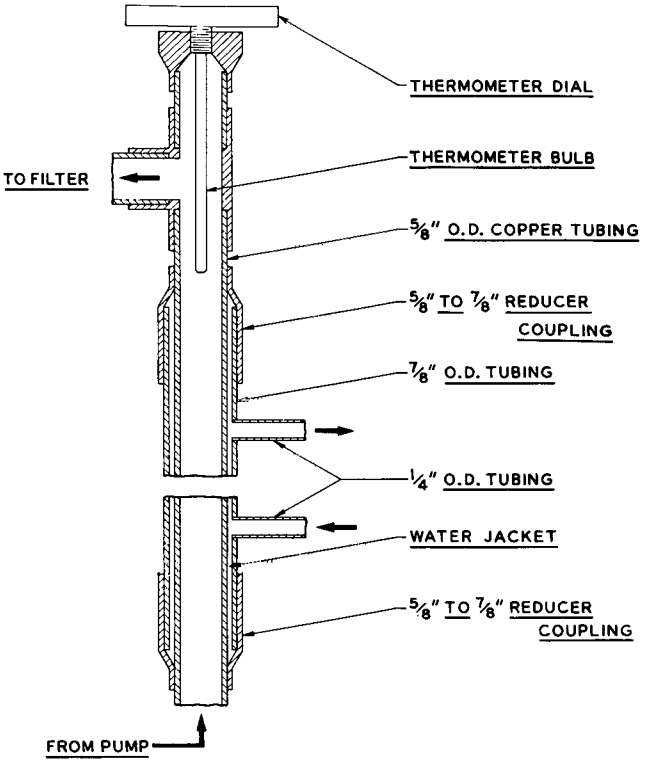
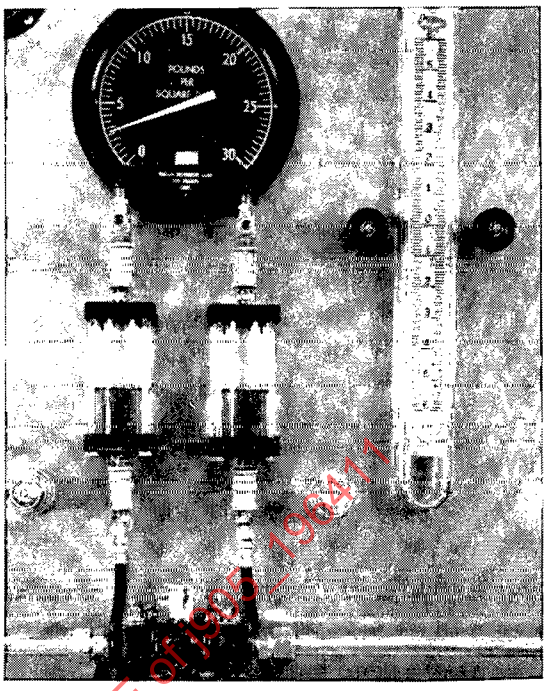


Fig. 4 - Cutaway of heat exchanger showing dial-type thermometer



Note: Air bleeds are on top of domes, small manual air pumps below and to each side. Knobs flanking manometer are optional valves for locking out manometer and differential gage.

Fig. 5 - Air domes with manometer and differential pressure gage

K. Test filter housing.

NOTE: Connections into and out of the housing should provide smooth flow without ledges, crevices, or throttling.

L. Pressure gage (2 required).

M. Transparent air domes or balancing tubes.

N. Small manual air pumps (2 required) or compressed air source.

NOTE: Air domes between pressure source and manometer maintain cleanliness of the manometer fluid and eliminate the necessity of fuel leg correction as illustrated in Fig. 5. These air domes should be equipped with small air pumps and air bleeds to aid in maintaining fuel at the same level in both domes.

O. U tube manometer.

P. Differential pressure gage optional.

NOTE: The filter assembly should be modified to permit measurement of pressure differential across the element only. Pressure pickups should be located in the same horizontal plane. These pickups should be so located as to be as insensitive to flow as possible. A representative means of modifying a filter housing to accommodate these pressure pickups is shown in Fig. 6. System pressure gages should be connected to the high and low pressure sides of the differential pressure measuring device.

Q. Air cocks (4 required).

R. Flowmeter (tapered tube and float type) - 200 gph capacity for testing fliters up to 100 gph rating, 300 gph capacity for those up to 150 gph rating (graduated in millimeters or percent of full scale).

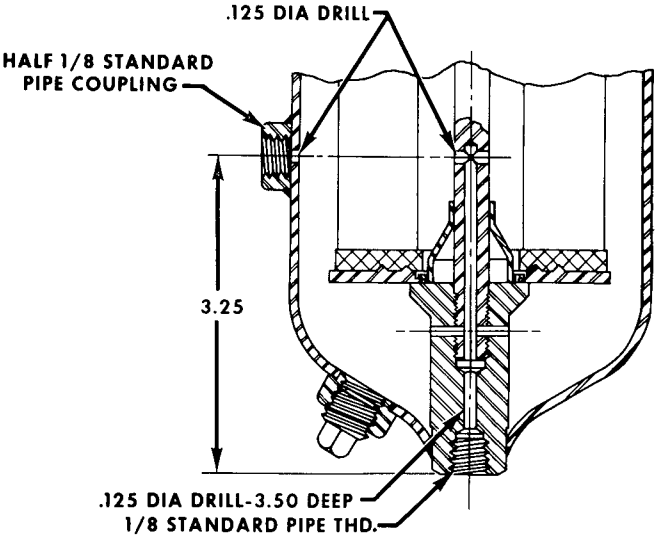


Fig. 6 - Detail of filter modification for pressure taps

NOTE: Connection into and out of flowmeter should provide smooth flow without ledges, crevices, or throttling.

S. All components of the test circuit shall be electrically

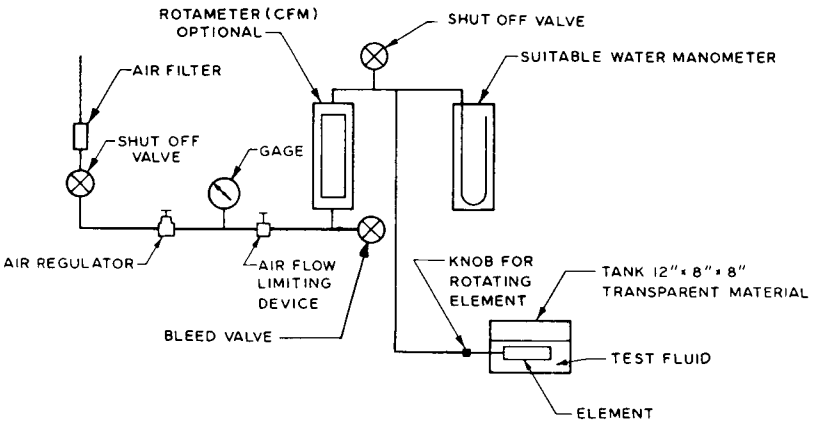


Fig. 7 - Diagram of air bubble test

grounded to a common ground with good electrical conductors.

3.1.2 Apparatus Checkout and Calibration -

3.1.2.1 Sump Analysis - The purpose of this analysis is to determine that the test stand has been constructed and adjusted to provide a uniform concentration of contamination. The method to be followed is outlined below:

A. Place approximately 7 gal. of test fluid in the test sump.

B. Circulate fluid through a cleanup filter element installed in the test filter housing until the contaminant concentration has been reduced to 2 mg/l or less.

C. Open all valves. Drain system through the pump drain.

D. Close throttling valve. Accurately measure the equivalent of 5 gal. (100 F) of prefiltered fluid into the test sump. Prefiltered fluid shall have a contaminant concentration of 2 mg/l or less.

E. Start pump and allow fluid to circulate through the bypass line. Temperature of fluid during the test shall be maintained at 100 ± 5 F.

F. After at least 5 minutes of circulation, take a 500 ml sample from the sampling line for analysis. This sample shall have a maximum contaminant concentration of 2 mg/l.

G. Add 500 ml of prefiltered fluid to the system.

H. Oven dry and weigh 4000 ± 1 mg of test dust. Prepare a slurry using this dust and approximately 100 ml of fluid taken from the test system. Prepare this slurry in a 150 ml beaker using a hand stirring rod.

I. Dump the slurry into the sump and rinse the beaker and stirring rod under the sampling tube outlet. The time the slurry is dumped will be considered time zero.

J. After 5, 10, and 15 minute intervals, draw a 500 ml sample at the sample tube outlet. Do not add any makeup fluid to the system at these times.

K. Analyze each sample for contaminant concentration using the analysis technique. (See paragraph 5.3.3.)

L. Actual concentration levels shall not deviate more than 5% from theoretical calculated concentration of 211.4 mg/l. If deviation is greater than 5%, check bypass discharge nozzle for proper orientation and configuration and repeat this test until the actual concentration is within 5% of the theoretical calculated concentration. Experience has shown mechanical agitation may be necessary to achieve theoretical concentration of the sump sample. A mechanical mixer is permissible in the sump.

3.1.2.2 Flowmeter Calibration - Using test fluid at test temperature 100 ± 5 F and with the test stand operating, the throttling and back pressure control valves shall be adjusted to permit flow through the flowmeter. Flow through the flowmeter shall be stabilized over the full range in increments of 10% of full range. Volumetric samples shall be drawn at each increment and carefully timed with a stop watch. Each volumetric measure expressed in gallons per hour shall be plotted against its corresponding reading on the flowmeter. Five successive runs shall be made with all points plotted. A faired curve drawn through the points shall be prepared and shall be used as the flowmeter calibration curve.

NOTE: It is very important that this calibration procedure be exercised at intervals frequent enough to assure that the calibration curve is representative of the flowmeter's response. The amount of use the stand receives will, of course, guide the user as to the desired frequency of calibration.

3.2 PORE SIZE TEST APPARATUS (BUBBLE METHOD) - The material required is shown in Fig. 7.

A. Air supply.

B. Valve to isolate stand from air supply.

C. Pressure gage to measure supply air pressure (1 required).

D. Air line filter dehydrator (1 required).

E. Airflow limiting device (1 required).

F. Adjustable regulator to limit air pressure (1 required).

G. Water manometer, 36 in. suggested (1 required).

H. Flexible air hose terminating at a rotary joint and fixture suitable for holding the filter element during test (1 required).

I. Transparent tank of suitable dimensions to comfortably accommodate element (1 required).

J. Flowmeter, optional (for air).

See Figs. 8-10.

3.3 MEDIA MIGRATION TEST APPARATUS - The ma-

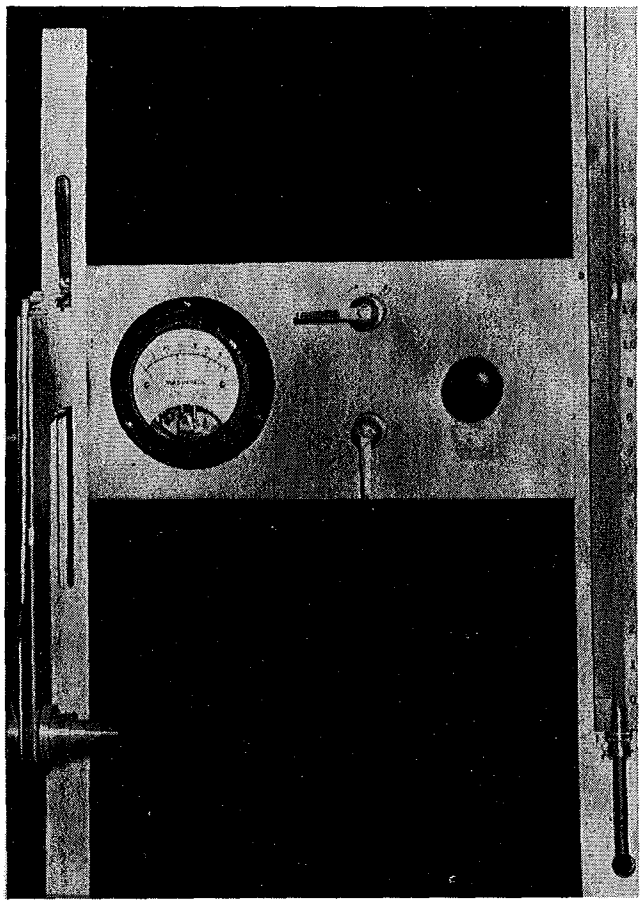


Fig. 8 - Bubble test stand, front view

Fig. 9 - Bubble test stand, side view, L

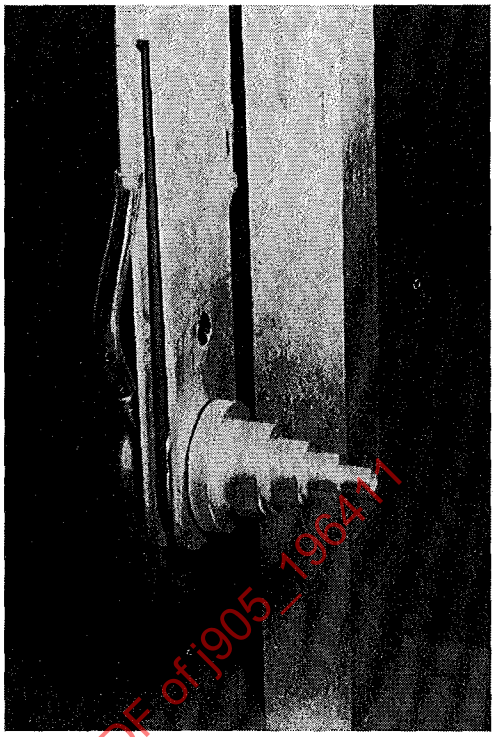


Fig. 10 - Bubble test stand, side view, R

terial required is shown in Fig. 11:

A. Reservoir.

B. Pump.

C. Fuel filter body.

D. Metal edge strainer, spacing 0.0015 in.

E. Flowmeter (optional).

F. Smooth joint tubing of sufficient length to connect above in closed circuit series.

NOTE: The components should be connected in series as shown in Fig. 11 and should be connected so as to eliminate sharp corners, ledges, crevices, or other spots where contaminants are likely to build up. Smooth bore tubing may be used for piping. If sweated joints are employed, they should be carefully joined in order to prevent buildup of flux or solder inside the flow circuit.

G. Cover for reservoir.

4. ANALYTICAL APPARATUS, MATERIALS, AND METHODS

4.1 ANALYTICAL APPARATUS -

A. Millipore Pyrex Filter Holder Catalog No. XX1004700 or equivalent which includes: fritted glass base and rubber stopper, holding clamps, and 250 ml Pyrex glass funnel.

B. Type HA (0.45 ± 0.02 microns required) White plain 47 mm Millipore Filter or other equivalent membrane filters.

C. Vacuum flask, 1000 ml or larger.

D. Aspirator or vacuum pump capable of pulling a minimum of 26 in. Hg.

E. Forceps, flat bladed.

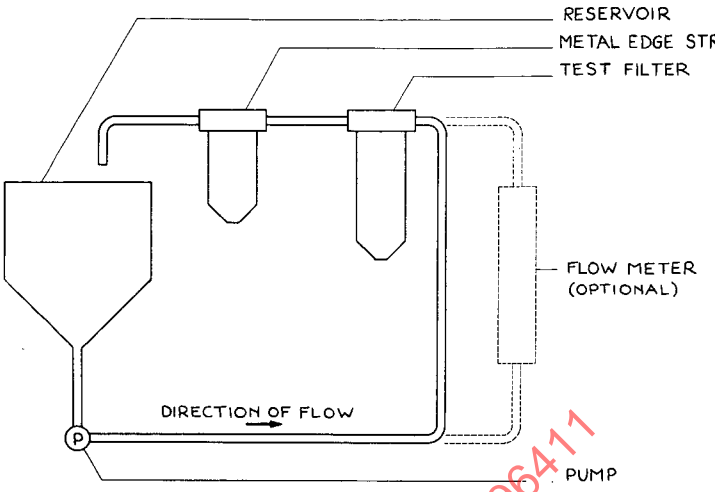


Fig. 11 - Diagram of media migration test stand

F. Analytical balance (with established accuracy) sensitive to 0.1 mg.

G. Class S standard balance weight, 100 mg.

H. Balance, sensitive to 0.1 gm, with a capacity 1000 gm or greater.

I. Calibrated 500 ml narrow-mouth Erlenmeyer collection flasks.

J. Volumetric 500 ml flask, Class A accuracy.

K. Gravity convection type drying oven 160 F.

L. Desiccator.

M. Wash bottle, polyethylene, fine stream.

4.2 REAGENTS - The rinse reagent may be either of the following which have been filtered: petroleum ether (ASTM Precipitation Naphtha); or n-pentane, commercial grade.

NOTE: Reagents shall be filtered once through 1/2 micron filter.

4.3 GENERAL METHOD - Sampling of test fluid for n-pentane or petroleum ether insolubles shall be at the times specified. Samples for sump analyses shall be obtained directly from the sampling tube, and dust capacity test samples directly from the effluent return line. The system shall be replenished with an equal volume of fresh membrane filtered fluid immediately after each sample is withdrawn. Samples shall be collected in a calibrated flask of 500 ml capacity. All sample collection flasks shall be cleaned with a self-rinsing pipe detergent and tap water, rinsed, and dried.

4.4 SAMPLE COLLECTION FLASK CALIBRATION - It is desirable to have a sufficient stock of calibrated collection flasks to collect and store all of the samples from an element dust capacity test. The required degree of accuracy for the 500 ml calibrated collection flask shall be ± 2.5 ml at 100 F. Collection flasks may be calibrated against Class A accuracy volumetric 500 ml flasks, which are commercially available and accurate to ± 0.15 ml at 20 C, by using the following procedure:

A. Determine the weight of 500 ml of test fluid at 20 C in the volumetric flask described in paragraph 4.1 item J. The weight determination shall be made on a balance having a minimum sensitivity of 0.1 gm per scale division.

B. Add fluid equal in weight to that found in step A to the collection flask.

C. Place the filled collection flask on a level surface and heat to 100 F, then scribe the flask at the level of the fluid surface.

4.5. TECHNIQUE SELFCHECKING PROCEDURE - It is recommended that the analyst conduct parallel determinations on samples of known weight of AC Fine Dust suspended in test fluid. Accurate results depend upon procedure combined with suitable equipment and proper skill. The results of the recommended parallel determinations will enable the analyst to recognize and to eliminate the determinate errors. Deviations in precision will, therefore, be due to the indeterminate type of error which is usually small. The analysis of the known sample shall comply with the procedure used for test sample analysis with the exception of preparation of the sample which shall be as follows:

A. AC Fine Dust dried to constant weight at 160 F in an oven shall constitute a supply for known sample preparations.

B. Check samples of 100 mg dried dust shall be prepared by weighing them against a 100 mg Class S balance weight and shall be suspended in 500 ml of membrane prefiltered fluid by swirling them in a calibrated collection container. This shall constitute a sample for technical evaluation. The membrane prefiltered fluid shall have been filtered in a single pass through a 1/2 micron membrane filter within 1 hr of the time of known sample makeup and analysis. The remainder of the analysis shall comply with procedure outlined in paragraph 5.3.3. The allowable deviation of parallel analysis shall be within 1 mg of the theoretically correct value of 100 mg. For greater accuracy, a "control filter" may be carried along through the steps of the selfchecking procedure with the exception that no dust shall be included. Results of samples analyzed with dust may be corrected with filter weight change of the "control filter."

5. TEST PROCEDURES

(Rated flow as used herein will be specified by the user.)

5.1 FLOW TESTING -

A. With 5 gal. of fluid in the reservoir, a cleanup element is installed in the filter housing. Fluid is circulated through the cleanup filter until the contamination level of the fluid falls below 2 mg/l.

NOTE: Precleaning of the fluid through an analytical grade filter prior to introduction into the stand can often shorten the time required for step A.

B. With 5 gal. of fluid cleaned to less than 2 mg/l contamination level, a new test element is installed in the filter housing.

C. Fluid is flowed through the test element at 0-200% of rated flow in increments of 20% of rated flow. Differential pressure readings are taken at each separate flow increment for three separate runs of 0-200% of rated flow. A curve is plotted through the average pressure value at each flow rate. This curve is the flow restriction characteristic for the element with the test fluid used at the temperature at which this test is conducted. Temperature should remain stabilized at 100 ± 5 F throughout the test.

5.2 PORE SIZE TESTING (BUBBLE METHOD) - For rating purposes, this test is to be run on an element which has not previously been tested.

A. Mount the element to be tested in the fixture (as shown in Fig. 7). IMPORTANT: THE TEST STAND MUST BE MOUNTED ON A STEADY, VIBRATIONFREE BASE.

B. Slowly rotate the element under the surface of the test fluid in order to insure that the element is thoroughly saturated by the fluid and all air pockets on the wet side of the element have been eliminated. A 10 minute soak period is generally satisfactory. Test fluid may be any fluid capable of completely saturating the element, provided that both the surface tension and specific gravity of the fluid at test temperature are known. Several fluids which have been used successfully are: isopropyl alcohol; Solox-190, ethyl-alcohol, No. 2 diesel fuel; and calibrating fluid (high flash) MIL-F-27351.

C. Slowly increase air pressure in increments of 1 in. of water manometer reading. At each increment, slowly rotate the element through 360 deg and note bubbling. Also note any steady bubbling between increments. A steady stream of bubbles at extremely low pressure (2 in. water) may indicate a defect. This can best be judged by the operator.

D. The first bubble point, in inches of water, is to be noted only when air bubbles escape through element in a steady series of bubbles. If any bubbles escape sporadically or intermittently, discontinue test and start over from step A or inspect element for defects.

E. Continue increasing air pressure until the foam-all-over point is attained. This is the point at which bubbles boil all over the surface of the filter media. Foam-all-over is difficult to define and may vary from operator to operator. Therefore, it is desirable to use a flowmeter such as the one shown in Fig. 7 to define the foam-all-over point. One may be able to determine the point when the pressure tends to level off while the airflow rate continues to increase and the element exhibits foaming all over.

F. In the event that the bubble point results on a test element are to be duplicated, start over from step A.

G. With the foam-all-over point obtained, the following equation is used to obtain the pore size of the element in ten thousandths of an inch. (This pore size is defined as the maximum realistic particle size rating of the element and will appear as the second number in the four number code.)

$$D = \frac{6.33\ (S)}{P - (h)\ (sp\ gr)}$$

where:

D = Element pore size, ten thousandths of an inch
S = Surface tension, dynes/cm
P = Air pressure, in water
h = Vertical distance from surface of fluid to top of element, in.
sp gr = Specific gravity of wetting fluid

1. Do not disturb element media during test; delicate balance between air and test fluid in the pores may be broken, thereby indicating a false bubble point reading.

2. Caution must be taken so that the manometer will not be sealed by a pocket of test fluid. This will dampen manometer readings, thereby introducing a false bubble point reading. This problem can be eliminated for the most part by introducing the manometer pressure line into the air inlet line above the test fluid level.

5.3 CAPACITY AND CLEANLINESS LEVEL -

5.3.1 Standardized Contaminant, Handling and Addition-

5.3.1.1 Description - AC Fine Dust is a true dust or particulate matter consisting primarily of silica with some quartz and other crystalline matter. The chemical analysis shown in Table 1 is typical.

The dust is collected from selected areas of Arizona deserts and then classified by Roller analysis for particle size distribution. The specified distribution of AC Fine Dust is listed in Table 2. The dust is supplied in glass jars suitable for laboratory shelf storage.

Table 1 - Chemical Analysis of AC Fine Dust

Ingredients	Weight, %	Ingredients	Weight, %
SiO_2	67-69	MgO	0.5-1.5
Fe_2O_3	3-5	Total Alkalis	3-5
Al_2O_3	15-17	Ignition loss	2-3
CaO	2-4		