POLYURETHANE FOAM

Aircraft Air Filter Information Manual

Brackett Air Filters

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INFORMATION MANUAL

BRACKETT AIR FILTERS

INTRODUCTION

Brackett Aero Filters, Inc., intent of this manual is to provide engineers, mechanics, pilots, and aircraft homebuilders with information concerning polyurethane foam as a filter media for aircraft engines. The initial development and application of the foam filter for aircraft was developed by General Motors Corp., AC Spark Plug division circa 1966. When AC Spark Plug decided to divest themselves of general aviation products, they asked if we would like to purchase their filter line. Prior to this, we had designed and manufactured three of their filter assemblies. Brackett Aircraft subsequently purchased their line of nine filter models, and has since added an additional seventy-nine models.

We have divided this manual into the following parts:

Part I. The AC Polyurethane Foam Filter Story

Part II. Selecting the Proper Filter Size

Part III. Care and Maintenance of Your Air Filter

PART I

THE AC POLYURETHANE (FOAM FILTER) STORY

Excerpts from Data Supplied by AC

The polyurethane developed for air filter media is a foam type, plastic material which is formed into cells by the generation of carbon dioxide gas. This cell structure is chemically treated to form the open cell structure. Thus, the filter material consists of a flexible polyurethane that has a three dimensional (dodecahedron) structure of skeletal strands.

Pore Size

Pore size is defined as the average number of linear pores per inch and will be referred to as the number of PPI. In establishing a control on PPI and on the 45 PPI urethane used, the pore count is maintained within 45 $\pm$ 5 PPI. AC's control on the pore count has been established with a comparator board and with an actual count using a grid and microscope.

Restriction

The restriction drop across both the element and the entire air cleaner is of primary importance when performance of the power plant is considered; and therefore, it must be treated as a limiting parameter. With the size of the air cleaner sheet metal fixed, it is possible to establish a set of equivalents based on a comparison to a known element. Assuming equal element inside diameters, the following table gives an approximate set of values when comparing the oiled urethane to an AC paper element.

Table of Equivalent Element Restrictions, Sheet Metal Considered

AC Paper	30 PPI 1” Thick	45 PPI ¾” Thick	60 PPI ½” Thick	80 PPI ¼” Thick

With different air flow and diameter requirements, a very slight thickness adjustment allows actual restriction matching, if this is desired. Due to the pleats in a paper element, and due to the extra space usually occupied by a paper element, a paper element will run at a higher restriction on the sheet metal than a urethane element if the elements are initially set up with equal restrictions.

Efficiency

One of the laboratory considerations of prime importance is the efficiency at which the filter media collects dust. This is, of course, important because lower efficiencies generally produce greater engine wear. However, if this interpretation is to be placed on efficiency, field tests must substantiate this in all cases, and this has turned out not to be always correct. Therefore, this corollary must be tempered with judgement and substantiated with controlled field tests.

For example, if steady air flow is considered, an oil bath air cleaner may look much worse in the laboratory than on the field tests. Even with variable air flow, this may be the case. Why is this so? AC feels that the corollary is upset because the laboratory tests do not and cannot consider all of the actual variables encountered.

Some of the variables which affect laboratory efficiencies are:

(1) Rate of air flow

(2) Variable air flow

(3) Vibration

(4) Rate of dust feed

(5) Particle size of dust feed

(6) Physical dimensions of element

(7) Velocity of air per square inch of filter surface

(8) Type of filter media

Because of the number of variables encountered, and because different filter media are affected to different degrees by these variables, it is quite understandable that laboratory efficiencies in themselves are not the final answer to engine wear predictions. However, it is not intended that laboratory efficiencies be ignored; they are certainly a good guide to filter performance. The following graphs show a comparison between paper, aluminum mesh, and urethane elements when build up of fine dust and particle size are compared against efficiency under certain test conditions. In all cases, the urethane is considered to be treated with a wettant since its efficiency is greatly increased when it is used as an oil wetted type of element. Some oil "run off" is experienced. However, our field tests indicate that an adequate amount of oil remains on the elements for good performance.

Bear in mind that the efficiencies of urethane increase with increased air velocity while paper units decrease with increased air velocity. In addition, the efficiency of the urethane, aluminum mesh, and oil bath elements increase at all air velocities when coarse dust is used.

Dust Capacity

The dust capacity of an element is defined as being the quantity of dust the element can collect to the point that the restriction build-up affects the power plant performance to some selected degree. This will vary with the type of carburetion selected, the power plant, and the designer's preferences.

In order to have a common laboratory base, AC usually considers the 5" water buildup point at 200 CFM air velocity as the service or replace point. The following comparisons are based on the above standard.

A urethane element has about twice the dust capacity at high variable air velocity (150 CFM average air velocity) as it does at low variable air velocity (48 CFM average air velocity). However, the capacity of the urethane element is approximately equal to the paper element at low velocity, while it has twice the capacity of the paper element at high velocity. But here again, we must qualify our statements because the paper element capacity increases and decreases as the amount of filter paper increases and decreases. Essentially, both the urethane and paper elements collect dust on the upstream surface. As the air flow increases, however, the effective surface of the urethane picks up depth, and its capacity for collecting dust is soon doubled.

Urethane elements designed such that the air flow is from the outside to the inside of the element have increased capacity, because with proper design the pores on the outside diameter are opened up and the pore size on the inner diameter is reduced. Thus, a degree of variable element density is created.

The urethane elements of 45 PPI or finer construction also have another interesting feature. That is, as the buildup process continues the element begins to shut off at a very rapid rate. This minimized any tendency for the dust to pound through the element and forces the owner to service his air cleaner.

The graphs shown below are typical dust capacity comparisons between paper and urethane elements. These comparisons will, of course, vary as the size of the air cleaner elements and power plants are varied.

If AC coarse dust is used, the capacity of the urethane element is increased, and may even be doubled at both high and low air velocities.

Field Tests and Engine Wear

Here is where one can find out if an element material will or won't do the job. Since the evaluation of any air cleaner must be made on the vehicle for which it is intended, field tests at both accelerated and at normal rates should be run. Certainly all of the laboratory tests, theories, and calculations are worth very little if the final product does not do the job for which it is intended.

Field tests were run with 30 and 45 PPI polyurethane, AC paper, hog hair backed with "NY-SUL-LOFT", and aluminum mesh elements. Older oil bath field tests were also studied. These tests consisted of controlled accelerated dust tests that were run by our customers at GM's Arizona Desert

Proving Grounds. From these tests, cylinder bore wear, ring wear, and valve stem and valve bore wear were measured under like and controlled conditions. These tests indicate that the 45 PPI urethane is certainly equal to the paper for all wear measurement points. Thus, it is our conclusion that the laboratory tests do not support the field tests 100% in this case. Why is urethane equal to the paper in field tests and not as good as paper in several laboratory tests? Perhaps the graduated particle graph indicates the answer. Note that the paper efficiency is considerably lower than urethane in 10 to 40 micron particle size range.

Advantages of Foam

Foam wettant as a filter media may not be the final answer, but in our opinion, it is superior to paper in aircraft application in that it is more efficient in the smaller particle range sizes which are more frequently encountered at above ground level. In the final analysis, foam element media has some additional advantages over the other filter media.

(1) The aircraft induction system can be designed with and integrated cavity that will accept only the foam element. This saves weight by eliminating the filter frame.

(2) The element is self sealing where it is pressed against the frame and does not require a gasket.

(3) Air flow resistance can be varied by density and thickness

(4) Foam can be cut to most any shape

(5) Foam can be bent around corners.

(6) Foam is resistant to abrasion.

(7) Foam is resistant to most chemicals.

(8) Foam element inserts are inexpensive compared to complete assemblies.

(9) Foam elements are designed as a throw-a-way, making servicing easy, economical, and assures constant efficiency.

PART II

SELECTING THE PROPER SIZE FILTER AREA

Homebuilders Guide

The way we arrive at selecting a filter or in building one of your design is to determine the required filter area that is needed. What you desire is a free flowing filtering device with a restriction of 1.5" to 2.0" of H_2O at full rated horsepower. (Note: 13.6" of H_2O is equal to 1 Hg manifold pressure). To find the desired area in square inches you will need to determine the cubic foot per minute (CFM) of air that your engine requires. The engine manufacturer usually expresses air consumption in pounds per hour (PPH). To find CFM divide your pounds per hour (PPH) by 60 for minutes, then divide by the density of air .07651 lb./ft^3 (@ STP 59°F) which will give the CFM

For example:

TSIO-520 (325 hp) uses 2166 (PPH)

$$\frac{2166 \text{ lb./hr}}{60 \text{ min/hr}} \div .07651 \text{ lb./ft}^3 = 472 \text{ CFM}$$

This is based on standard day and 100% Volumetric Efficiency (VE). Another way to find CFM (for non turbo supercharged application) is:

$$\frac{\text{CID} \quad \text{X} \quad \text{RPM}}{2 \text{ rev } (1728 \ \underline{\text{In}}^3)} = \text{CFM}$$

After you have found your required CFM, we will need to convert this volume of air to a velocity of air passing through the filter. This is expressed in Feet Per Minute (FPM). Normally the flow is to be between 600 and 1200 FPM for either the 1" thick 45 PPI or 1 7/8" thick dual stage 45/20 PPI foam. The equation is as follows:

$$(.88 \text{ VE}) \frac{\text{CFM x } 144 \text{ In}^2/\text{Ft}^2}{\text{FPM}} = \text{area of filter}$$

The reason we like to keep the air velocity in this range is that as your air velocity increases past 1200 FPM, your air flow restriction increases to where it can start to rob engine power. The volumetric efficiency (VE) generally ranges from the 90's to the high 60's, using a larger value will yield a larger size of filter. To keep things simple we have developed a quick reference chart for selecting filter areas. See Chart "A", Page 10.

Our suggested <u>filter minimum area</u> is based on 75% Volumetric Efficiency (VE). However, remember the larger the filter you have, the slower that the air velocity flows through the filter and the more efficient the filter will be in restriction. So <u>larger</u> is always better than smaller. After determining the approximate size filter you need, you can now proceed with such considerations as:

1. Location of filter in engine compartment and the physical space available.
2. Should you select an off the shelf filter and, if so, the shape and thickness?
3. Should you build your own filter frame or integrate the foam filter element into a designed cowling cavity?
4. Allow for reserve filter area (50%) for service levels beyond bare minimum.
5. Provide the required plenum chamber behind your filter.
6. Keep ducting smooth and to the minimum number of bends.
7. a) Provide alternate air (heat) in the form of a pull cable. Do not use a spring loaded door. Heat is your only weapon to eliminate any encounter with icing.
   b) Keep in mind dust tends to collect in the alternate air source, design to minimize this.
8. Provide a sealed airbox except:
   1. Provide a water drain with the aircraft in its ground stance, if rain water can enter the filter area.
   2. Provide a fuel drain hole at the low point, to eliminate any build up after over priming.
9. Locate filter for high pressure recovery.

Consideration should be given to integrating your foam element directly into the cowling cavity or along the cowling side with a NACA opening. This is done by several of the manufacturers. It is simple, saves weight and costs less.

For selecting stock filter (off the shelf), see Brackett Aero Filters, Inc. filter catalog. This catalog gives the size and shapes of our stock filters.

If you have any questions or specific requests, we at Brackett Aero Filters will be glad to help you however we can.

Quick Reverence Chart "A"

Engine Horsepower	Minimum. Square Inches Required for 75% VE
75	12.6"
100	16.8
125	21.0
150	25.2
175	29.4
200	33.6
225	37.8
250	42.0
275	46.2
300	50.4
325	54.6
350	58.8
400	67.2
425	71.4
450	75.6
475	79.8
500	84.0

*The square inch area opposite the horsepower will give approximately a 2.5 inch H_2O restriction. These are tested values with the foam element mounted in a metal frame and a screen backing plate with a 72% open area.

**Material tested was 1" thick with 45 PPI.

NOTE: Mil Specification MIL-F-7194A allows a maximum pressure drop of 8" H_2O prior to servicing. However, Brackett recommends servicing prior to 5" H_2O.

INTEGRATED INTO COWL

PART III

CARE AND MAINTENANCE OF YOUR AIR FILTER

Some owners and mechanics do not realize the importance of an air filter. In the past it was not uncommon to see aircraft over 20 years old with the original filter. You can see through the filter without ever taking it off. The same owner replaces his car filter every 20,000 or 30,000 miles which is equivalent to approximately 200 hours at 150 mph

Continental Engine Operator's Manual says (quote):

> "Extreme importance is attached to proper servicing of air and oil filters. Too much attention cannot be given these two very important units.
>
> The air filter should be checked daily for:
>
> 1. Cleanliness.
> 2. Condition of seals and gaskets.
> 3. Condition of air box and ducting.
> 4. Be absolutely sure that no air leaks exist in the induction system at any point that would allow unfiltered air into the engine.
>
> <u>The filter should be cleaned as often as it becomes dirty, every day under severe condition.</u>
>
> REMEMBER, NO AREA IS DUST FREE, and in some areas dust in substantial quantities will be encountered as high as 17,000 feet. If any of the foregoing items are overlooked, severe damage to the engine can occur in as little as 25 hours (end of quote)".

Lycoming Flyer states (quote):

> "As little as one tablespoon of abrasive material entering the induction system can cause enough damage to necessitate a complete overhaul (end of quote)".

Enough said as to the importance of clean air! The philosophy of Brackett Air Filters is to manufacture a filter that is efficient in capturing harmful material, efficient in airflow, rugged to the normal environment, backfiring forces, water, and chemicals. We also wanted an inexpensive, replaceable element that has a scheduled replacement change time. We felt a maximum replacement time was important since human nature likes to say, "It doesn't look that bad. Guess we will let it go another year." Yet that same person will religiously change the oil filter. I feel this is mainly because of oil filter company's education and the ready availability of oil filters. We would like to get the same message across concerning air filters. Your filters, air and oil, must be maintained at full efficiency year in and year out to get full T.B.O. The religious use of oil analysis is one of the best aids available to ascertain a change in the system performance.

BRACKETT FILTER INSPECTION AND MAINTENANCE GUIDE

Preflight: Pilot

(1) Check filter face for excess dirt on the face of the foam. Most dirt on the face can be easily brushed off.

(2) Look at the face for possible erosion of foam caused by a flooded engine start and subsequent backfire.

NOTE: If the filter has been on fire, the indication is that the surface looks like it has been eroded away. The foam when on fire (it requires gasoline to keep burning) will vaporize and the vapors are harmless to the engine. If a filter shows these signs, stop and have the complete intake system inspected for damage prior to flight.

(3) Under normal conditions (operating from hard surface runways or good grass runways) you can expect your filter element to give you its full scheduled interval of service as indicated on the service decal. If you are operating under extremely dusty conditions, element replacement may be required daily.

(4) All Brackett Air Filter elements are required to be replaced each 12 calendar months regardless of actual flight time. The reason is to ensure acceptable levels of the wettant remain to provide optimum filtration characteristics. In most cases the cost of the replaceable element is about the same as the labor of a mechanic to properly clean the reusable type filter.

Filter Inspections: Mechanic

(1) At the 25 hour or 50 hour engine inspection, check the condition of the foam element. The backside can easily be checked by pushing the foam down with your finger and peeking at the backside (downstream). This side should look in almost new condition and show no signs of dirt. Be sure and push the element back in place after inspecting. Inspect filter frame attachment and gasket. Inspect complete induction system for looseness, cracks, paying special attention to the alternate air (carb heat) doors. Normal vibration causes wear but the occasional backfiring may send tons of air pressure into the induction system and cause substantial damage in just one start. Enough emphasis cannot be placed on the above inspections since the induction system, from the filter to the cylinders is vulnerable to possible failure if neglected.

(2) Prior to installing a new element or filter assembly, wipe the entire area clean. (Tip on clean up: WD-40 performs nicely) The wettant does make a mess and has a habit of holding dirt, so a few wipes may be necessary.

(3) Be sure to make a log book entry.

REMEMBER: Clean Oil and clean Air will reduce wear.

BRACKETT AIR FILTER DOCUMENT I-194

PLACE IN AIRCRAFT RECORDS

CONTINUED AIRWORTHINESS INSPECTION
REQUIREMENTS AS PER FAR 23.1529
AND GENERAL PROCEDURES OF PART 43

INSPECTION INTERVALS: Pre-flight inspections, engine backfire inspection, 100 hour inspections, annual inspections, filter element replacements.

INSPECTION PROCEDURES

A. Pre-flight inspection: Per Pilots Operating Handbook, check filter assembly for security, damage or 50% contamination of element face. If found report to maintenance personnel prior to flight.

B. Engine start-up backfire inspection: Prior to flight, check the entire intake system for security or damage. If a fire was present, the downstream face of the foam element will show erosion. If any irregularities are found see Chart I and also refer to the Aircraft Maintenance Manual for the intake system.

C. At element replacement intervals: With the element removed, inspect the filter grill, filter frame, filter mountings and entire intake system for security, wear and any deformation. Note: On filter assemblies with gaskets, visually inspect inside and outside of frame for any signs of gasket looseness, movement or deterioration. If found refer to Chart I or the proper maintenance manual for your aircraft or component.

PART	REPLACE	REWORK	INSTRUCTIONS
FRAME	X		COMPLETE NEW ASSEMBLY
GASKET	X		ON FILTER FRAME, REMOVE OLD NEOPRENE GASKET AND ALL TRACES OF ADHESIVE DOWN TO A CLEAN ANODIZED FRAME SURFACE. USE ADHESIVE 3M#847 OR DOW CORNING RTV-732. COAT ENTIRE MATING SURFACE (GASKET TO FRAME). APPLY ADHESIVE FOLLOWING MANUFACTURER'S LABEL DIRECTIONS. WHEN FRAME AND GASKET ARE PLACED TOGETHER, CLAMP OR WEIGHT DOWN AT .75 LB./SQ. IN. OF CONTACT AREA. ALLOW TO CURE 24 HOURS PRIOR TO INSTALLATION. PRIOR TO REINSTALLATION OF FILTER, CHECK AIRBOX MATING SURFACE FOR IRREGULARITIES. IF FOUND, CORRECT PER MANUFACTURER'S REQUIREMENTS. UPON REINSTALLATION CHECK THAT THE GASKET MAKES 100% CONTACT. THE GASKET SHOULD BE COMPRESSED 50% FOR OPTIMUM SEAL.
GRILL	X		REPLACE WITH NEW GRILL
HARDWARE	X		REPLACE UNSERVICEABLE WITH NEW
SCREEN	X		COMPLETE NEW ASSEMBLY
SCREEN/GASKET	X		COMPLETE NEW ASSEMBLY (ASSEMBLIES USING SCREEN GASKETS PRE 1981; BA–4106, BA–5110 AND BA–8110.)
ELEMENT	X		REPLACE ELEMENT

DATE: 3-16-94

CHART 1