2. Edge-type filters

Edge-type filters involve the use of cartridge-type elements with flow directed from the outside inwards, but the element is composed of a stack of discs or washers of paper, felt, plastic or metal clamped together in compression. Flow takes place from the edge inwards between the discs which may be in intimate contact in the case of non-rigid disc materials, or through the controlled clearance space between individual discs provided by spacing washers.

Such a construction has the advantage that the collected contaminant can be scraped from the upstream surface more easily and completely than it can be from a screen and this cleaning can be performed during operation of the unit. In addition, this type can be manufactured with inherent self-cleaning properties, so that cake build-up on the upstream surface can be virtually eliminated.

An edge-type filter element employing stacked paper discs is shown in Figure 3. The pack is held under compression by springs at the top of the assembly, so that the liquid undergoing filtration can only pass through the minute interstices between the discs in layers of near molecular thickness. Virtually all solid impurities are, in fact, left on the edge of the discs since such an element can be capable of yielding an absolute cut-off of 1 μm or less.

A further property of such an edge filter employing unimpregnated paper discs is that it can trap and retain finely dispersed water in fuels, oils or similar fluids. It is even possible to remove dissolved water by the provision of moderate heat and vacuum. The presence of water will, however, substantially increase the back-

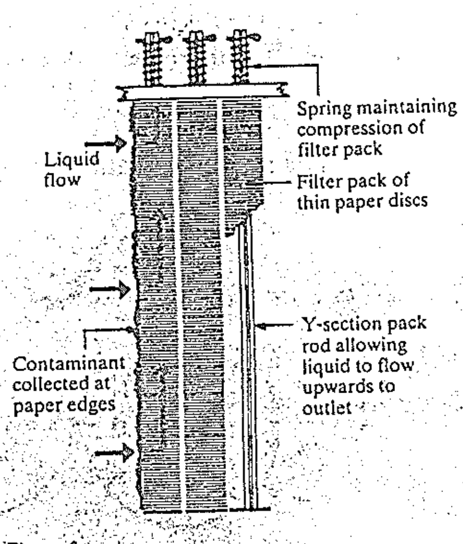


Figure 3

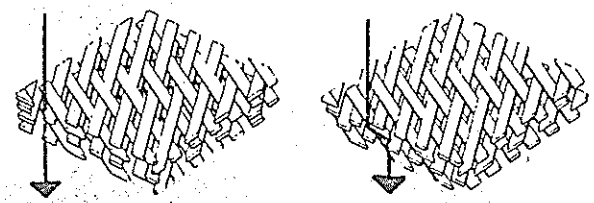
pressure of the filter due to the swelling of the discs, further restricting the clearance space available for flow. This can, if necessary, be used to operate a warning device that water is present in the fluid being filtered.

It will also be appreciated that whilst the performance of such a paper element is often better than that of a pleated paper element, its normal resistance, and thus back-pressure, is very much higher, or, size for size, its capacity is appreciably less. However, it is one of the best types of filters for removing very fine solids from liquids, even colloidal graphite from oils, it is virtually immune to the effects of shock pressure and its element life is long with a minimum of maintenance requirements. Cleaning can usually be accomplished quickly and efficiently by a reverse flow of compressed air. The ultra-fine filtering properties may inhibit its use for particular applications due to the build-up of ultra-fine solids, restricting flow where very fine and frequent cleaning is impractical. A particular example is its unsuitability for use as a bypass filter for engine lubricating oil systems employing detergent oils.

3. Stacked disc filters

A stacked disc filter employs individual discs which are stacked over a perforated inner tube, with intermediate spacing washers. Flow is between, and subsequently through, the filter discs and into the inner tube. The discs are typically of composite construction, eg. the face of the disc is formed by a fine metal wire screen with a further back-up screen to provide effective use of the full filtration area; in the centre of the pack is a fitted separator to provide radial passageways for flow into the central perforated tube. The complete disc assembly is then held together by inner and outer binding rings.

Performance is nominally that of the mesh elements or filter screen apertures, typical standard openings being from 0.25 to 0.025 mm (0.01–0.001 in), equivalent

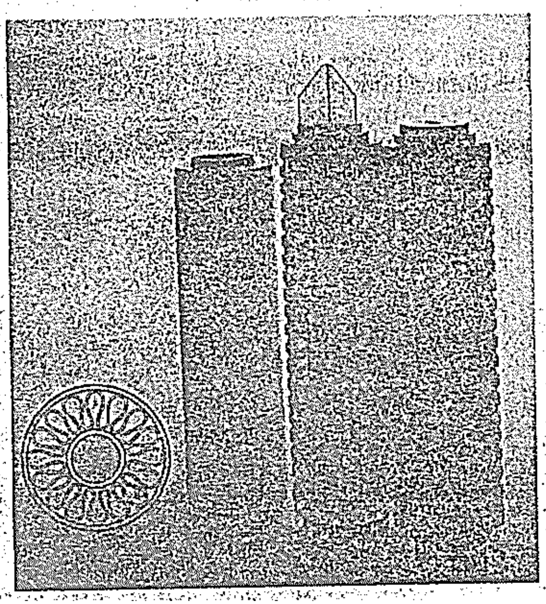


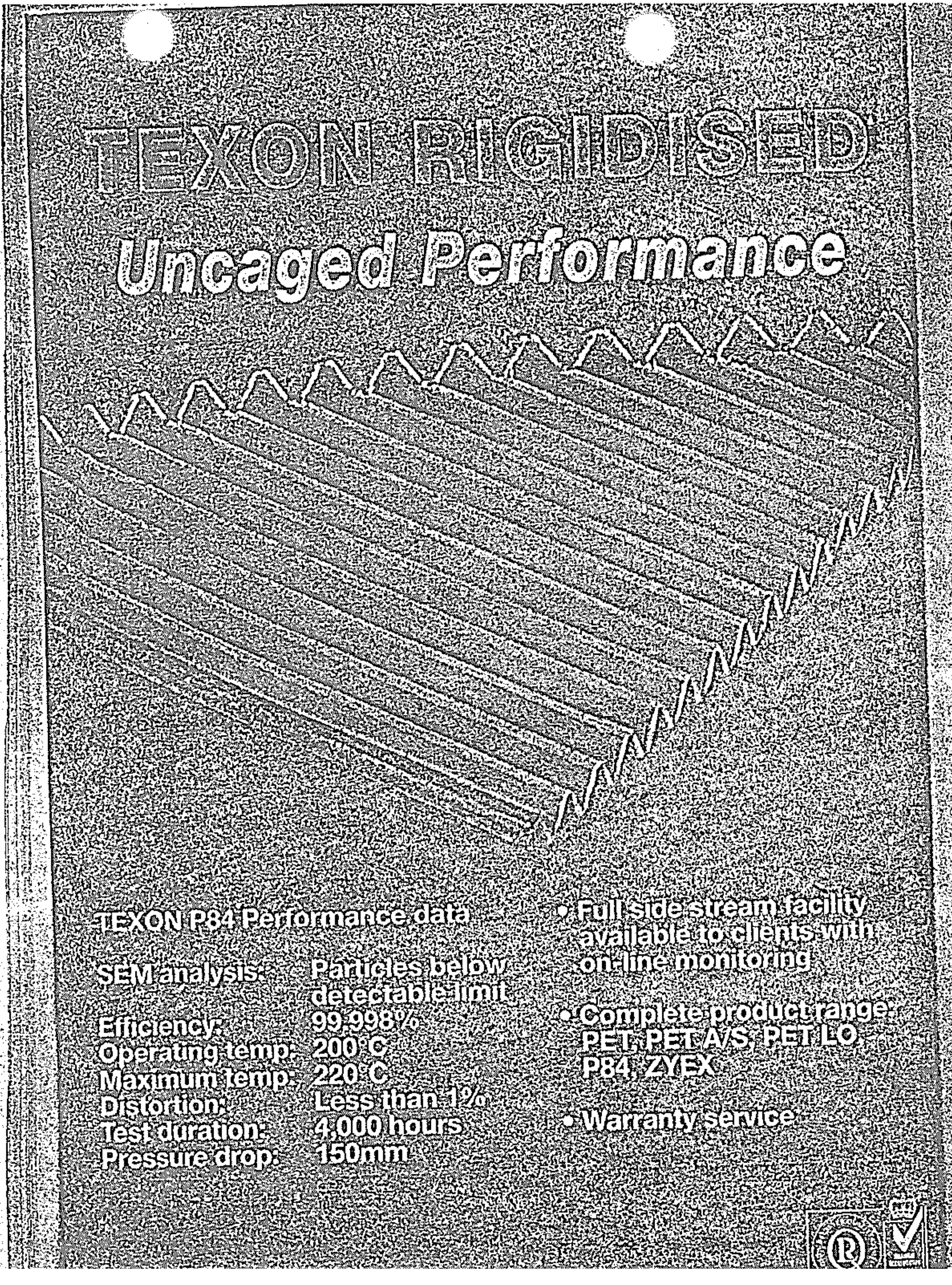
Examples of different flow paths provided by flat wire mesh filter elements to ratings of approximately 250 and 25 μm, respectively. With this form of construction, however, performance materially improves as dirt collects in the screen, providing increasingly finer filtration.

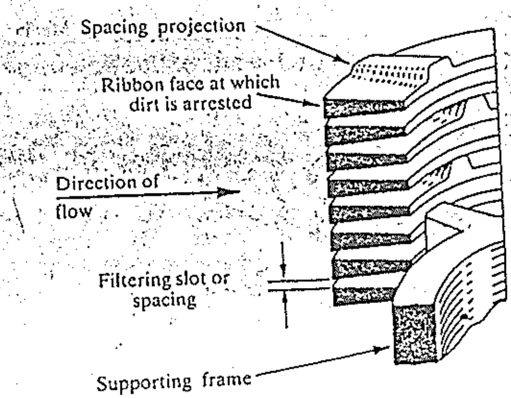
This particular form of filter is an aperture, rather than an edge type, with the depth of filtering restricted to the depth of the face screen and back-up screen. It provides a large surface area in a compact volume and low pressure drop.

Depth filtration

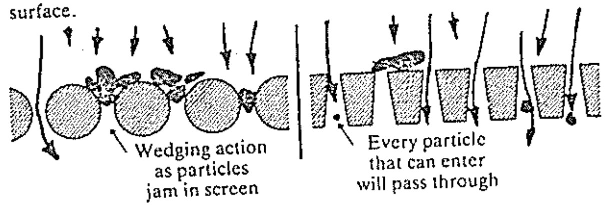
The other basic type of mechanical filter employs a medium with a significant amount of thickness providing filtering in depth. The mechanism of filtering then becomes much more complex. The path through the filter is much longer and random, providing greater possibility for both direct interception and dirt retention. Retention efficiency is achieved by means of a series of low efficiency particle captures. In general, larger particles will tend to be trapped in the surface layers, with the finer particles trapped by succeeding layers. If necessary, the structure of the filter can be density graded. This has a particular advantage where the particle sizes of the contaminant are widely distributed; less so if they are of more or less uniform size where a surface filter may be equally effective. Also, filtering in depth will give a higher pressure drop than a surface filter.







Tapered flow paths in a metal-edge element prevents clogging. Particles that fail to pass through may fall off or can be scraped off the surface.



Metal edge-type filter.

The overall performance of a depth-type filter, however, can be better than that given by its purely mechanical action of direct interception. The inertia of particles impinging directly on to the filter medium may generate absorptive surface forces, and Brownian movement effects may be present with fine particles again developing absorptive retention. As a result, the depth filter may trap and retain particles finer than that provided by pure mechanical filtration alone.

Brownian movement applies only to particles of about 1 μm in size or less, causing such particles to diffuse through the filter medium regardless of fluid flow, where they are likely to be retained by adsorptive forces. This phenomenon is most marked where the fluid carrier is a dry gas (the dryer the gas the more powerful the electrostatic adsorptive forces) and least marked with higher viscosity liquids.

Depth-type media

The ideal depth-type filter medium has increasingly dense layers from the outside (upstream) to the inside (downstream) side (Figure 4). Such a graded structure provides an increasing chance of finer particles being trapped on their passage

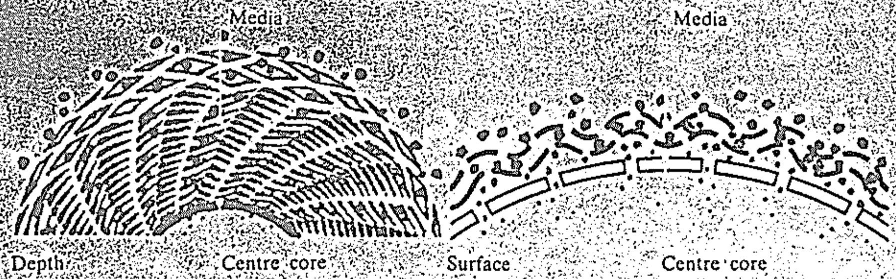


Figure 4
Graded depth-type filter compared with surface filter.

through the filter. Practical depth-type filters are made from media which may be generally categorised as:

(i) Fibrous.
(ii) Porous.
(iii) Cake-like.

Fibrous media comprise a layer, or mat, of numerous very fine fibres, of diameters ranging from 0.5 to 30 μm, depending on the material. These fibres are randomly oriented to each other, intermixed and intertwined so that they create numerous tortuous flow-passages or pores in which the particles are trapped and held by the mechanisms described previously.

The fibrous materials most commonly used are: polymeric materials; cellulose; cotton; microglass fibre; synthetics (eg. rayon, polypropylene).

Table 1 gives a typical indication of the factors which influence the retention rates of depth filters.

Relative efficiencies of these media types are a function of fibre diameter, where the narrower the fibres, the closer they can be compacted. The result is that smaller diameter fibres have smaller flow paths. Microglass fibre is smaller in diameter than cellulose and has, therefore, a better filtration efficiency.

Typically, the layer is 0.25–2 mm (0.010–0.080 in) thick and is impregnated with resin (phenolic, epoxy or acrylate) to bind it together. The maintenance of a stable structure, including pore size, and therefore of stable filtration characteristics throughout the medium's service life, referred to as filter integrity, is a function of the fibre-binding system.

Fibrous filter media are used for the collection of sub-micrometre particles in clear air environments. Filter media made from electret fibres have an open

TABLE 1

Factors affecting the retention rates of depth filters			
Mechanical factors		**Adsorptive factors**	
Product	**Depth filter**	**Product**	**Depth filter**
• Nature of the impurities/particles • Number and size of the impurities/ particles • Viscosity • Chemical com- position	• Void volume of the filter medium • Structure of the three-dimensional screen • Size of the internal surface area (dirt holding capacity) • Thickness of the filter medium • Nature, upgrading and composition of the individual mate- rial components	• Chemical com- position • Charge of the impurities/particles • Concentration of the impurities/ particles • pH-value • Flow velocity • Polarity of the impurities/particles • Temperature	• Structure of the three-dimensional screen • Number of the charge carriers • Nature of the charge carriers • Magnitude of the charge • Polarity of the charge carriers

Electrets are permanently charged dielectrics made in most cases from polymeric materials that generally permit substantial sub-micrometre size particle penetration.

Contaminants such as viruses or bacteria must be removed from air supplied to operating theatres in hospitals and the need for near dust-free air is important for the manufacture of microelectronic equipment. Electret filters can provide a solution to the efficient cleaning of air and gases in these environments.

Binder-free media

The introduction of a three-dimensional layered binder-free borosilicate microfibre webbing has assumed considerable importance in depth filtration, particularly in relation to the filtration of compressed air and gases.

The characteristic feature of this material is that the fibres are 'welded' together by temperature and pressure.

Advantages claimed for this type of fibrous media are:

1. If the fibre diameter is the same throughout, the void volume increases. This automatically reduces pressure loss, increases retention and can prolong filter

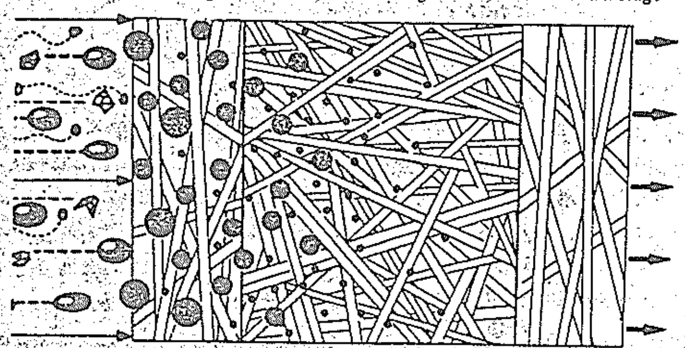
2. The fibres are incorporated into the filter material in their natural state, and their retention properties are unaffected by the insulating acrylate layer.
3. The fibre diameter starts off the same, and an insert of acrylate increases it. However, the diameter reduces exponentially when the degree of retention is measured (sic).
4. The pure fibre is inert, chemically, biochemically and biologically inactive and neutral. Glass can only be attacked by hydrofluoric acid and the strongest of alkalis. The resistance of fibres with binders is determined by the chemical resistance of the binder.
5. A fibre consisting solely of glass is resistant to temperatures up to 500°C. Binders soften at temperatures between 80°C and 150°C and lose their resistance, with the basic characteristics of the filter material also lost.

Porous media are similar in that they have flow pores presenting a capillary-type passage. This differs from a fibrous medium in that its parent material is solid or in the form of randomly shaped particles of roughly spherical proportions.

There are three major forms of porous media:

(i) Particles of the parent materials are cast into shape, then baked or sintered to bond them together into a self-supporting structure. Typical materials are metals, ceramics and stone.
(ii) A sheet of parent plastic materials is cast, then pores are formed by solvent evaporation, leaching, stretching, piercing or nuclear bombardment.
(iii) Porous media are formed by the foaming of plastic materials, typically polyurethanes.

Cake-type media are more limited in application and generally employed in bed-type filtration for removal of solids in significant bulk (Figure 5).



By utilizing direct interception, inertial imapction and diffusion, liquid and solid particles down to 0.01 µm are retained by the filter.

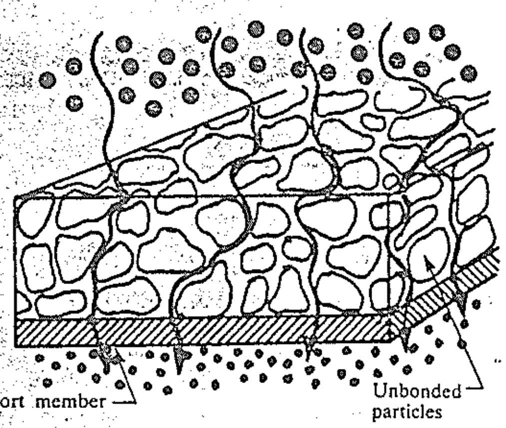


Figure 5
Cake-type filter medium.

They comprise a layer or bed of separate, loose, discrete particles formed into a 'cake' on a supporting screen or mesh, usually by the action of fluid flow. The voids between the particles form the pores and flow passages required for filtration. Binding materials are not used to bond the particles to each other.

Typical materials used to form the cake are: diatomaceous earth; sand; clays; wood fibres; cotton fibres.

This loose bed construction makes them generally unsuitable for fluid power applications, where stability, compactness and resistance to vibration are of prime importance. The characteristic of recirculating some of the discrete particles through the system, until the cake is formed, is a definite deterrent to its use in fluid power systems.

See *Handbook of Filter Media*, published by Elsevier Science Ltd. ISBN 1 85617 278 3.

Filter Ratings

FILTERS ARE rated on their ability to remove particles of a specific size from a fluid, but the problem is that a variety of very different methods are applied to specifying performance in this way. Quantitative figures are only valid for specific operating or test conditions.

Absolute rating

The absolute rating, or cut-off point, of a filter refers to the diameter of the largest particle, normally expressed in micrometres (μm), which will pass through the filter. It therefore represents the pore opening size of the filter medium. Filter media with an exact and consistent pore size or opening thus, theoretically at least, have an exact absolute rating.

This does not usually apply in practice, as pore size is not necessarily consistent with the actual open areas, and is further modified by the form of the filter element. Also, tests to establish ratings employ spherical glass beads as the artificial contaminant in the fluid (or a mixture of glass beads and carbonyl iron E for 5 μm absolute measurement). In a practical filter system the actual form of the contaminants are not necessarily spherical, in which case the nominal diameter is generally taken as the largest of the linear dimensions. The actual shape of the particle, however, may be such that its two other linear dimensions are very much smaller than the nominal diameter, permitting it to pass through a very much smaller hole. As a typical example, consider the edge-type filter where the open space is a slot with the rating fixed by the dimension of the slot (Figure 1). A disc-shaped particle with a thickness less than the slot opening will readily pass through the slot, although the nominal particle size, established by the disc diameter, is very much larger than the filter rating. Having passed the filter, this particle could well cause scoring by jamming at a different attitude in a clearance space less than the particle diameter—a very strong possibility since the particle is more likely to

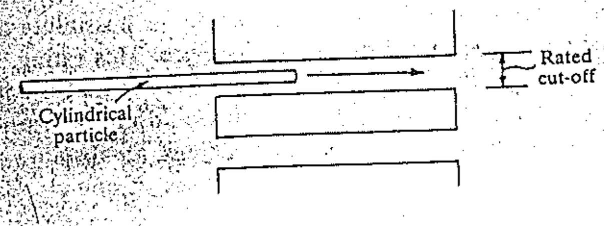


Figure 1

The passage of 'oversize' particles in this manner depends very largely on the size and shape of the opening, and also the depth over which filtering is provided. With elements filtering in depth, the chance of such asymmetric particle shapes being trapped increases. This also depends on the physical arrangements of the element. Thus, a random arrangement of pores in successive but interconnecting layers would eliminate the possibility of a direct through passage via individual pores in line.

There is also the fact that the majority of filters do, to a large extent, generate a filter bed. That is to say, contaminants collecting on the surface impart a blocking action decreasing the permeability of the element and improving filter efficiency. Efficiency can go on improving, up to the point where the blocking is so severe that the pressure drop is excessive, seriously decreasing the flow rate through the filter. This explains why the performance of a filter can often exceed its given rating (based on the performance of a clean element), and also why test figures for identical elements can differ widely with different test conditions. The former description explains why particles larger than the cut-off figure may also be found downstream of the filter.

Certain types of filter media, such as papers, felts and cloths, have a variable pore size and thus no absolute rating at all. The effective cut-off is largely determined by the random arrangement involved and the depth of the filter. Performance may then be described in terms of nominal cut-off or nominal rating.

Although widely used for types of filters which cannot be rated on an absolute basis, a nominal cut-off rating is meaningless, and often misleading, since cut-off is seldom, if ever, complete at this rating. Thus, a block felt element with, say, a typical nominal rating of 30 μm may well pass 20–40% of particles of this size. At the same time, it may well stop a high proportion of much smaller particles. A proportion of particles smaller than the cut-off rating will always be stopped, the actual amount depending on the design, type and the specific flow velocity through the element.

It may be argued that the term 'absolute rating' is not in most cases a realistic description. Strictly speaking, an absolute rating is absolute and no particle larger than that rating can pass through the filter. This limits the type of media which can have an absolute rating to those of consistent pore size where they show 100%

retention of particles, although this does not preclude the possibility of individual larger particles actually penetrating the filter in service. This rating, also, would tend to be so much higher than a mean or nominal rating that it could give the impression that the filter was very 'coarse', which would not necessarily be true.

However, even with consistent pore sizes or openings, an absolute rating is not realistic if based on the smallest dimension in the case of non-circular openings (such as squares, triangles and rectangles).

Considerable difference between actual performance and quoted ratings may also occur due to the differences between actual service and test conditions. Practical tests to establish ratings are normally conducted with high concentrations of contaminant which will tend to yield a higher filter efficiency because of the 'bed' effect. Many tests, in fact, may be conducted under near clogged conditions of the filter. In service, the filter may be operating with relatively clean fluids over a long period when the efficiency of the filter will be that much lower. The only performance figure which holds good under such extremes is a true absolute rating.

Nominal rating

A nominal filter rating is an arbitrary value determined by the filter manufacturer and expressed in terms of percentage retention by weight of a specified contaminant (usually glass beads, again) of given size. It also represents a nominal efficiency figure, or more correctly, a degree of filtration. Figures normally used are 90%, 95% or 98% retention of a specified contaminant size. The only standards relating are MIL-E5504A and MIL-F5504B, where version A defines a 10 μm filter as being capable of removing 98% by weight of test dust larger than 10 μm at a certain high concentration, and version B defines a 10 μm filter as being able to remove 95% of 10–20 μm glass beads at a high concentration.

Many filter manufacturers use similar tests but, due to lack of uniformity and reproducibility of the basic method, the use of nominal filter ratings has fallen into disfavour.

Mean filter rating

A mean filter rating is a measurement of the mean pore size of a filter element. It is far more meaningful than a nominal rating and, in the case of filter elements with varying pore size, more realistic than an absolute rating. It establishes the particle size above which the filter starts to be effective. This is relatively easy to establish by the bubble point test (see chapter on *Filter Tests*).

Beta (β) ratio

The *Beta* (β) *ratio* is a rating system introduced with the object of giving both filter manufacturer and user an accurate and representative comparison amongst filter media. It is determined by a *Multi-Pass test* which establishes the ratio of the number of upstream particles larger than a specific size to the number of downstream particles larger than a specified size, ie.

$$\beta_x = \frac{N_u}{N_d}$$

where β_x is the β rating (or β ratio) for contaminants larger than x μm, N_u is the number of particles larger than x μm per unit of volume upstream and N_d is the number of particles larger than the x μm per unit of volume downstream.

It follows that the higher the β ratio the more particles are retained by the filter and hence the greater the efficiency of the filter. Efficiency for a given particle size (E_x) can be derived directly from the β ratio by the following equation:

$$E_x = \frac{\beta_x - 1}{x} \times 100$$

Alternatively, as a guide to efficiency see Table 1.

Filter efficiency

As noted previously the nominal rating is expressed in terms of an efficiency figure. Efficiency usually expressed as a percentage, can also be derived directly from the

TABLE 1—FILTER RATING

β Value at x μm β_x	Cumulative efficiency % particles x μm	Stabilised downstream count x μm where filter is challenged upstream with 1,000,000 particles x μm
1.0	0	1,000,000
1.5	33	670,000
2.0	50	500,000
10	90	100,000
20	95	50,000
50	98.0	20,000
75	98.7	13,000
100	99.0	10,000
200	99.5	5000
1000	99.90	1000
10,000	99.99	100

This quantity is derived as twice the swept volume of one cylinder multiplied by engine speed multiplied by number of intake strokes occurring together, where D is the bore in inches, L is the stroke in inches, N = revolutions per minute and n is the number of inlet strokes occurring together.

For practical calculation, this formula can be simplified to:

$$\text{Filter capacity (ft}^3\text{/min)} = \frac{2D^2LN}{K}$$

where bore and stroke dimensions are in inches.

$$\text{Filter capacity (m}^3\text{/min)} = \frac{2d^2lN}{1000k}$$

where bore (d) and stroke (l) dimensions are in centimetres.

Appropriate values of the respective constants K and k are given in Table 5.

TABLE 5—CONSTANTS FOR AIR FILTER SIZING

Type of engine or compressor	K	k†
1 Cylinder four-stroke or two-stroke	1100	18,000
2 Cylinder four-stroke or two-stroke	1100	18,000
3 Cylinder four-stroke or two-stroke	1100	18,000
4 Cylinder four-stroke or two-stroke	1100	18,000
3 Cylinder two-stroke	733	12,000
5 Cylinder four-stroke	733	12,000
6 Cylinder four-stroke	733	12,000
4 Cylinder two-stroke	550	9000
7 Cylinder four-stroke	550	9000
8 Cylinder four-stroke	550	9000
12 Cylinder four-stroke	366	6000
16 Cylinder four-stroke	275	4500
1 Cylinder single-acting single-stage compressor	1100	18,000
2 Cylinder single-acting single-stage compressor	1100	18,000
3 Cylinder single-acting single-stage compressor	733	12,000
4 Cylinder single-acting single-stage compressor	550	9000
6 Cylinder single-acting single-stage compressor	366	6000
1 Cylinder double-acting single-stage compressor	1100	18,000
2 Cylinder double-acting single-stage compressor	550	9000
3 Cylinder double-acting single-stage compressor	366	6000
2 Cylinder single-acting two-stage compressor	1100	18,000
4 Cylinder single-acting two-stage compressor	1100	18,000
6 Cylinder single-acting two-stage compressor	733	12,000
2 Cylinder double-acting two-stage compressor	1100	18,000
4 Cylinder double-acting two-stage compressor	550	9000
6 Cylinder double-acting two-stage compressor	366	6000

Alternatively, the following formula can be used:

$$\text{ft}^3\text{/min displacement formula} = \frac{D^2 \times L \times r/\text{min} \times N}{K_1 \times K_2}$$

where D is the bore in inches, L is the stroke in inches, r/min is the revolutions per minute, N is the number of cylinders (A) in the engine and (B) the number of low pressure cylinders in the compressor and

K_1 = 2200 for (A) two cycle engines with scavenging blower
= (B) four cycle engines naturally aspirated of four or more cylinders
= 1760 for (A) pump scavenged engines
= 1760 for (B) air compressors, single cylinder, single acting
= 1760 for (C) air compressors, single cylinder, single acting
= 1760 for (D) air compressors, two or more low pressure cylinders, double acting
= 1760 for (E) four cycle engines, one, two or three cylinders

K_2 = 1 for two cycle engines
= 2 for four cycle engines
= 1 for single-acting compressor
= 1/2 for double-acting compressor

Ventilation filters

Vehicle ventilation filters are designed to supply fresh filtered air into the passenger compartment through the automotive heating and air conditioning, or interior air recirculation systems (see Figure 12).

These filters can be more than 90% efficient and, where electrically charged, fibres made from 100% polypropylene are used as the filter media, so dust, pollen, bacteria, etc, are trapped mechanically like conventional filters and electrostatically to capture both charged and uncharged air-borne particles.

Oil filters

The function of the oil filter is to deal with contaminants which may be contained in the lubricating oil and prevent them from reaching sensitive engine parts without restricting normal oil flow, to the various points requiring lubricating. The oil pump is mounted within the engine sump with the filter connected to give either full flow, or bypass circuits. The former passes all the oil output from the pump through the filter. This is normal in modern practice, although the bypass system is still used on some designs.

Internal sources of contamination include wear products from the rubbing surfaces of the engine, blow-by gases leaking past the rings of the pistons, and [illegible] Modern crankcase lubricants are capable of

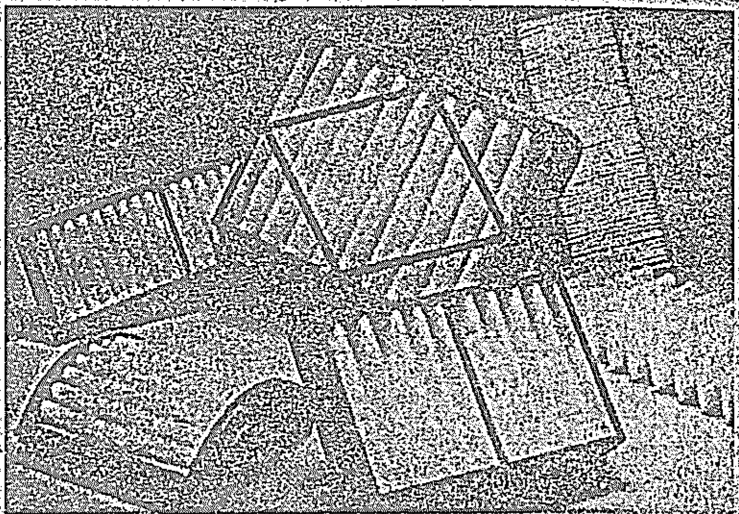


Figure 12
Vehicle ventilation filters for heating and air-conditioning systems.

deposits to occur, as well as containing additives that greatly extend oil life (that is prevent oxidation, chemical breakdown, or other forms of degradation). Synthetic lubricants are also meeting the demands of high performance engines and the 'API SG' standards in resisting the build-up and formation of 'Black Sludge' that can cause engine failure by the blockage of oil flow.

Conventional oils are based on blends of mineral oils produced from natural crude oil by well-established refining processes. Multigrade oils that are light and have a low viscosity provide good flow properties but can be unstable at high temperatures. Heavy, high viscosity multigrade oils generally do not have the flow properties necessary to maximise protection over a wide range of temperatures.

In many cases, oil manufacturers add carefully selected chemical additives to the base blend so as to control flow characteristics or boost protective properties and other aspects of the oils behaviour. In addition, at the initial refining stage, a further process is sometimes introduced to remove sulphur and aromatic compounds from the crude oil, thereby modifying the molecular structure of the oils from which the lubricant is selected. This oil can generally provide better resistance to the oxidising effects of air and reactive combustion gases in an engine even under sustained revs and high stress, as well as improved thermal stability and better resistance to wear.

Synthetic oils and semi-synthetic oils have been developed from blends of chemicals which are more man-made than natural. They are considered high

controllable, stable flow characteristics. Thet attempt to achieve a careful balance between the desired flow properties and a high level of protection without compromising performance at different temperatures.

Wear products are normally highly abrasive, and produced mainly during the first 10–20 h of the engines life. Satisfactory protection is provided by both an oil change after a nominal running-in period, as specified by the manufacturer, and the system filter. In some cases, running-in may be completed on a dynamometer rig.

Blow-by gases are comprised of exhaust gases and unburnt fuel mixtures leaking into the crankcase with each complete cycle of the piston. They are, in the main, removed through the crankcase breather, but can react with an oil which is not in good condition, or on other contaminants. Piston rings can never provide a complete gas seal, so blow-by gases are always present in the crankcase. It is also significant that the presence of foreign matter in the piston ring areas can seriously decrease their efficiency, resulting not only in loss of engine performance, but giving a higher proportion of blow-by gases below the pistons

Full flow filtering

A typical full flow system is shown in Figure 13, where the filter is in-line between the pump and bearings, or points at which the oil is distributed. The main limitation is that the oil pressure in the bearings depends partially on the restriction due to the filter, plus the fact that the filter must be large enough to handle the volume of oil flow involved. This may be as high as 23 litres/min (5 gal/min) on larger automobile engines.

Pressure drop through the filter will be affected by the condition of the filter, and also the viscosity of the oil. Thus, with cold oil, pressure drop may be excessive and to safeguard against this, such filters usually incorporate a valve which opens to bypass the filter element. This is normally set to open when the pressure drop across the element reaches a figure of about 1 bar (15 lb/in^2). The bypass valve closes immediately the oil has warmed up and its viscosity falls to reduce the pressure drop through the filter below 1 bar (15 lb/in^2). If the excessive pressure drop is due to another cause, such as a clogged element, the bypass valve will remain open as long as that cause remains. In such circumstances, the filter remains out of circuit.

A further refinement which may be incorporated in full flow filters is an anti-drainback valve. Its sole purpose is to prevent oil draining back through the filter into the oil pump, and therefore the sump when the engine is stopped, thus retaining the filter full of oil. On restarting, oil is immediately circulated from the filter to the bearings. If the filter could drain when the engine is stopped, no oil would flow to the bearings until the engine had run for a sufficient time on

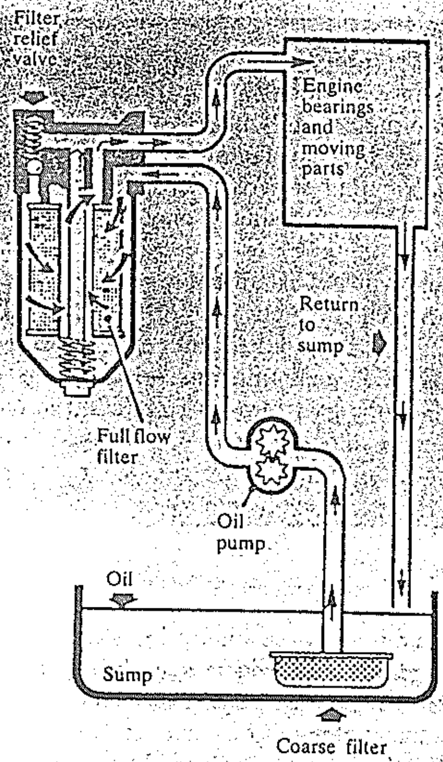


Figure 13
Full flow system.

An alternative solution is to mount the filter at such a position that with the engine stopped, it cannot drain back and empty itself through the pump. Since the filter is normally mounted externally and higher than the sump, for ease of replacement of the element or cartridge, the attitude of the filter alone may not be sufficient to guard against 'siphon' draining, when an anti-drainback valve can be used to advantage.

Bypass filtering

Four cycle diesel engines generally need full flow and bypass filters. Bypass filtration helps to reduce rod and main bearing wear by piston ring wear.

A bypass system is shown in Figure 14. Here, the oil pump feeds the main gallery directly, but this line is tapped and taken to the filter with a return line from the filter to the sump. Oil is fed at the same pressure to the bearings and filter,

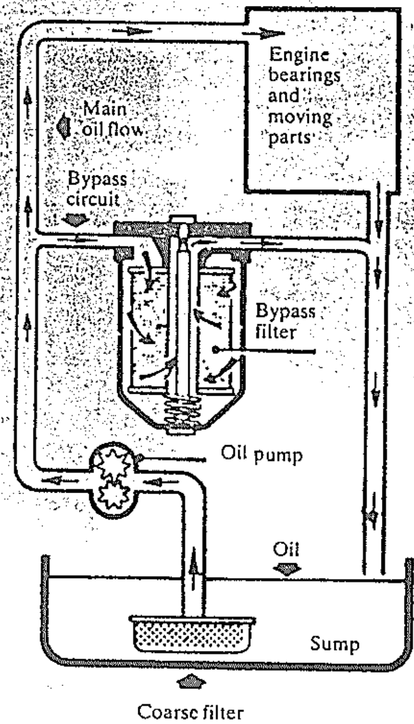


Figure 14
Bypass filter system.

incorporated in the filter itself. This ensures that the bearings receive the main oil supply, with only a proportion of the oil delivered by the pump passing through the filter. This part-flow filter requires no relief valve as it automatically isolates itself in the event of becoming clogged. Nor does it need an anti-drainback valve, as initial flow from the pump to the bearings is not dependent on the filter being filled with oil. In some cases, though, an anti-drainback valve may be incorporated in the filter, to ensure faster initial circulation to the bearings.

In the case of bypass filter systems it is generally recommended that the rate of flow through the filter should be at least one-tenth of the flow rate of the engine, and that the quantity of oil treated by the bypass filter should be at least five times that of the total oil volume in the circulating system.

The bypass system has the advantage that the same size of filter will have a higher efficiency than a full flow filter, since the flow rate is lower. However, the protection offered is incomplete and the oil has to circulate a number of times

Bypass filters.

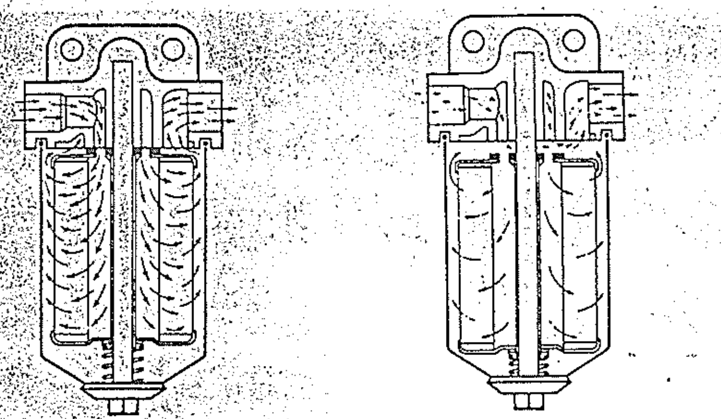
This is still a probability rather than a certainty, and particles can readily bypass the filter line and be fed directly to the bearings. It offers a solution where volume flow is high and would need a large size of full flow filter, or high flow rates with lowered efficiency through a small full flow filter. Practical evidence favours the full flow filter as the logical choice for modern automobile engines, of all types and sizes.

Figure 15 shows the action of a bypass device.

Centrifugal-type oil filters are also employed as bypass filters, particularly on larger engines and stationary engines. Their performance is generally superior to paper or felt element filters, particularly in regard to their filtering capacity at high levels of contamination, see Figure 16. They are appreciably more expensive than simple filters, and are not normally employed for general vehicle application. Also, they are not regarded as suitable for full flow filters.

Additional protection for the oil circuit is also provided at the oil pump intake, usually in the form of a simple strainer. This will prevent larger particles from entering the pump and the recirculatory system. Properly located and with a suitable design of sump, this will also prevent the pump from picking up water which may have contaminated the oil. This water will normally, but not necessarily, separate out at the bottom of the sump. In the presence of contaminants, it may form an emulsion with the oil.

Some protection may also be provided at the oil filter, although this is not common. Again, a simple strainer is usually sufficient. Since oils are now



Closed – normal full-flow filtration

Open – small percentage of oil bypasses element

Figure 15
Action of a bypass device.

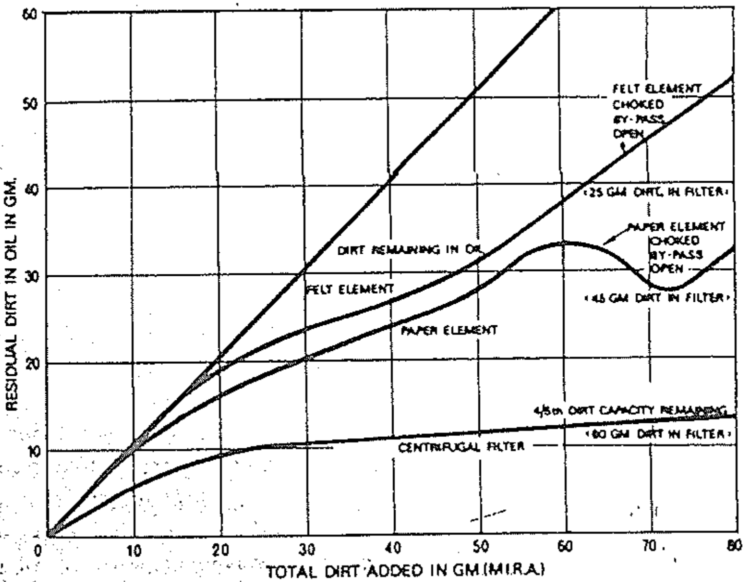


Figure 16
Comparison between the performance of paper element, felt element and centrifugal

TABLE 6—NORMAL OIL FILTER ELEMENT LIFE

Application	Normal use	Arduous conditions	Poor operating conditions and unfavourable ambient surroundings
Automobile engines	500 – 1000 h or 10,000 miles	Up to 500 h or 5000 miles	100 – 250 h
Marine engines	1000 h	500 h	500 h
Large stationary engines	1000 h	500 h	—
Turbines, etc	2000 h upwards	Up to 2000 h	—
Portable power units	1000 h	500 h	200 – 500 h

much closer intervals. Equally, if a filter change is specified in terms of engine hours or mileage only, the oil filter should be changed at least once a year regardless of whether the recommended hours or miles have been realised. This is particularly necessary in the case of marine engines derived from automobile engines where less than 500 hours engine running time is commonplace during a single year.

Oil–Water Separators

NUMEROUS PROCESSES and service operations generate oil waste water, the disposal of which may be subject to legislatory and environmental requirements. Tankering is a direct answer whereby a contractor is paid to collect waste water and dispose of it, but can prove to be the least cost-effective. Also, it only transfers the basic problem from one site to another. On-site treatments are therefore generally to be preferred, but need to be matched to the kind and proportion of oil contaminant, its condition (ie. whether free or emulsified), and the presence of other contaminants.