HOW GOOD IS THAT HYDRAULIC FILTER?

BY

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Introduction

No matter what is being bought, the purchaser should want to know whether the item is suitable for the particular application in mind and whether he is getting value for money. A cost-effective appraisal would indicate whether a better (and probably more expensive) item would be justified or whether a cheaper item would perform just as well. Such an appraisal requires a yardstick by which usefulness or performance can be measured and compared. If the item is a hydraulic fluid filter, there is unfortunately no recognized yardstick which enables its performance to be compared with the ideal requirements or with other filters.

This article illustrates some of the problems of measuring filter performance, and indicates some of the shortcomings in existing filter performance ratings used by manufacturers. Annex A to this article proposes a filter rating system which would allow the performance of different filters to be compared. The article should provide guidance to those concerned with the selection of filters for hydraulic systems; the principles can also be applied to liquid filtration generally.

The Need for Filtration and a Filter Rating System

It has been established that particles of dirt in a hydraulic system will, when present in sufficient quantities, significantly reduce performance and reliability. The quantity which will cause a system to be declared unserviceable will vary considerably, depending on the design of the system and the performance required from it[1].

In a system with recirculating fluid, the contamination level will usually settle down at an equilibrium level where the particulate contamination generated by the system will be balanced by that removed by the contamination control devices. The equilibrium level at any point in the system should be below that level which would lead to an unacceptable degree of degradation of performance or to failure of any system component.

Since the purpose of the filter is to control the contamination level in a hydraulic system so as to achieve the right contamination balance, the selection of the filter is a matter of importance involving both the cost of the installation and its subsequent reliability. It is surprising, therefore, to find that no national or international standard method exists for rating hydraulic filters to enable their performance to be assessed. The matter is further confused by the lack of agreed definitions for many of the terms used in hydraulic fluid filtration[2]. This leads to the present situation whereby a filter manufacturer can claim a filtration performance for his product using his own definition for performance measurement; this could (and often does) grossly exaggerate the performance of the filter without any infringement of the Trade Descriptions Act.

Unfortunately the performance of filters (1) cannot be predicted by measuring what would appear at first sight to be critical dimensions, for example: pore diameter (13), and filter medium (4) surface area. Although the flow of fluid through a surface type filter (i.e. one in which the particles are trapped at the inlet surface as in a sieve) can be analysed, the analysis of the probability of particle retention is complicated by the size distribution of the pores and the size and shape distribution of the particulate contaminant. Depth type filters, which trap the contaminant as the fluid flows through the pores of the medium, introduce an additional feature known as the *tortuosity of the flow path;* this affects both resistance to flow and the probability of particle capture. There is also a variation, often considerable, in the diameter of the pore throughout the flow path of the filter medium. The analysis of both fluid flow and particle retention for depth type filters is more complex than for surface type filters. In practice, filter performance is normally determined by trial and error rather than by analysis at the drawing-board stage of design. The only sure way of knowing how a filter will perform under specified conditions is to test it under those conditions.

To enable useful comparison to be made between filters, it follows that the complete filter should be tested under specified test conditions, each condition being toleranced sufficiently to allow repeatability of results at different times and on different rigs.

Besides the resistance to flow and particle removal characteristics already mentioned, the contaminant capacity (7) is important because this gives some

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[1]Further information on the need for cleanliness, the nature of contamination, and the meaning of an optimum contaminiation level for hydraulic systems can be obtained from the article 'Particulate Contamination in Hydraulic Systems' which appeared in Vol. 20, No. 2 of the *Journal of Naval Engineering*.

[2]A glossary of some filtration terms used in hydraulics is included as Annex B to this article. Where a number in brackets follows a term used in this article, it refers to the entry in the Annex.

idea of the amount of contaminant a filter can retain before it becomes clogged; this in turn indicates how frequently the element needs to be changed in service. Contaminant capacity, however, also depends upon the nature of the flow path, the pore diameter, the effective surface area of the medium, and the particle size and shape distribution of the contaminant; this characteristic too is normally determined by test rather than by attempting direct measurement and applying empirical formulae.

The test procedures should therefore be laid down and the data obtained must be presented in a suitable standard format to aid the hydraulic system designer in the selection of a suitable filter. The designer should also, however, bear in mind that the difference between the standard test conditions and the system operating conditions will lead to differences in performance characteristics.

Fluid Filtration—Points to be considered when selecting a filter

Before proceeding further, it is desirable that the reader has some idea of the mechanics of fluid filtration and of the more important points which should be taken into account when considering how a filter will perform under system operating conditions.

A popular misunderstanding is that a filter will have absolute control over the maximum size of particle in a system. Microscopic examination of fluid samples taken from a system employing fine filtration clearly reveals the presence of a considerable number of particles many times larger than the 'pore size' of the filter medium. In an operational hydraulic system, filters do not exhibit an absolute cut off. Even with a wire-mesh filter, the absolute filtration concept is meaningless when one considers the significance of particle shape and pore size distributions. In practice, transient flows, shock waves, and vibration lead to a degradation of filter performance on particles of all sizes depending upon the filter medium used and its construction.

The hydraulic engineer is more interested in the amount of contamination passing through the filter than that which is removed, although the latter is of interest when considering the contaminant capacity rating (7). It is more realistic, therefore, to think of filtration performances in terms of a particle size distribution pattern of contaminant which passes through the filter rather than some arbitrary cut off or absolute filtration rating.

The particle size distribution pattern of particles transmitted through a filter as well as the pressure drop/flow relationship and the amount of contaminant which the filter will hold before an unacceptably high pressure

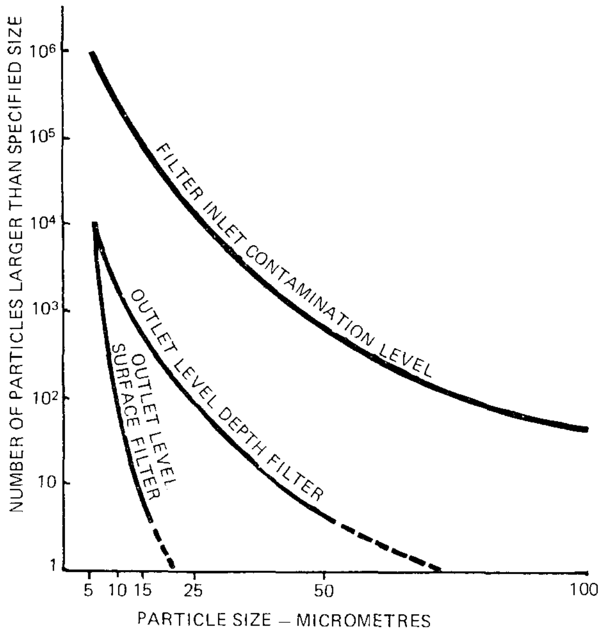

FIG. 1—COMPARISON BETWEEN DEPTH AND SURFACE FILTER MEDIA ON TEST RIG
(EACH FILTER HAS A SIMILAR PERFORMANCE RATING ON PARTICLES LARGER THAN 5 MICROMETRES IN SIZE)

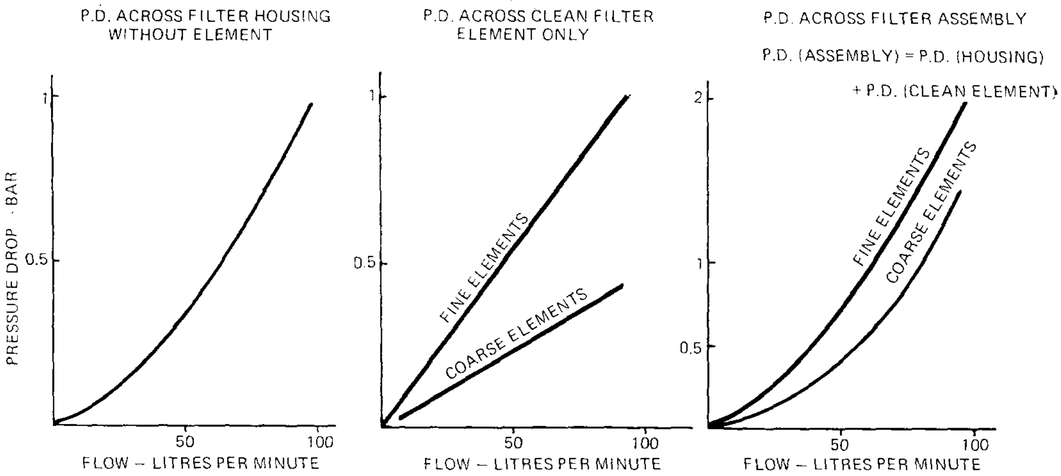

FIG. 2—PRESSURE DROP/FLOW CHARACTERISTIC (USING FLUID AT 30 CENTISTOKES KINEMATIC VISCOSITY AND 0·9 SPECIFIC GRAVITY)

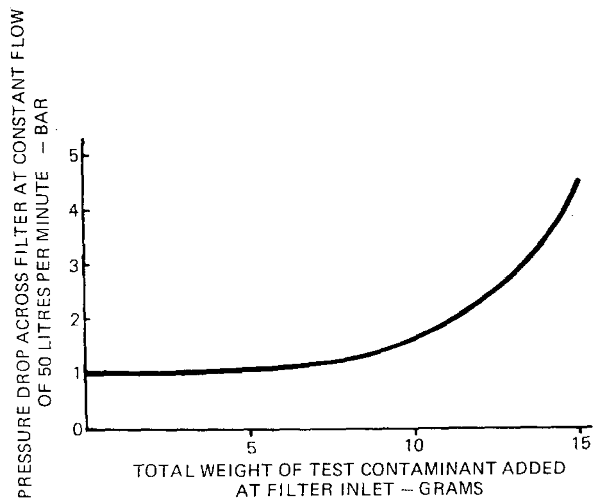

FIG. 3—CONTAMINANT CAPACITY/PRESSURE DROP CHARACTERISTIC (FILTER BY-PASS VALVE HELD SHUT, AND USING FLUID AT 30 CENTISTOKES KINEMATIC VISCOSITY)

drop is reached, all depend largely upon the type of medium and the way the medium is formed into an element for a given size of filter.

Consider a depth type filter (e.g. a felt or paper medium) and a surface type filter (e.g. a fine woven wire mesh screen); the relative performance of these two filters can be seen from FIGS. 1, 2, and 3. Frequently a filter element is made up of a combination of depth and surface type media.

FIG. 1 clearly shows a performance curve which is typical of a filter medium of this type. In fact, variations in the material used and the method of construction will also lead to significant variations in slope between one filter element and another. Thus selection of one point on each curve to indicate its filtration performance would be misleading. If, for example, the 5 micrometre particle size filtration ratio (5) point were selected to rate filter performance, this would give an indication of the filter's ability to control the small particles but would provide no information on the control of the larger particle sizes. Filtration performance should, therefore, be indicated by providing information at two points on the particle size distribution curve; the slope of this curve is also significant.

It has already been stated that the actual particle removal performance achieved by a filter under system operating conditions is normally measurably

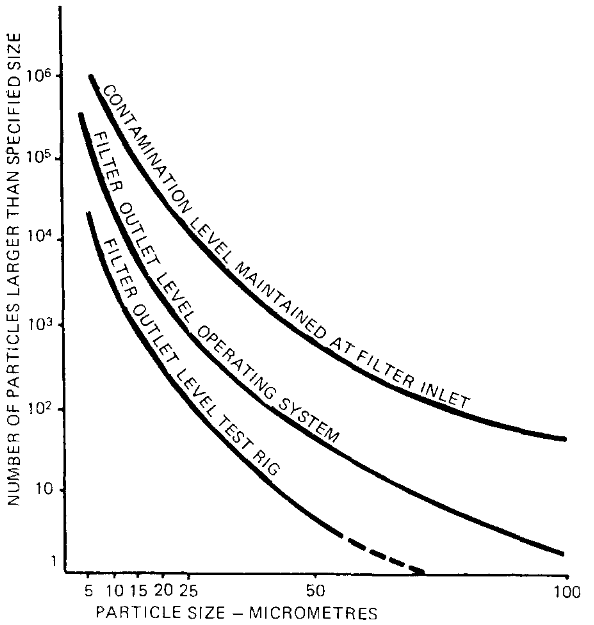

FIG. 4—COMPARISON OF PERFORMANCE BY DEPTH FILTER IN TEST RIG AND IN OPERATING SYSTEM

worse than that achieved under the steady state conditions applied during the test from which the filtration performance was obtained. This can be illustrated by the following example and by reference to FIG. 4.

Consider two identical filters, one fitted in a test rig operating under standard test conditions and the other in a hydraulic system where it experiences actual operating conditions, but in each case (for the purposes of this example) the same contamination level (representing the system equilibrium level) is maintained at the filter inlet. In practice, of course, the filtration characteristic of the filter would largely dictate this inlet level as the particles which pass through the filter are recirculated back to the filter inlet. Because of vibration, flow surges, and pressure transients experienced by the filter fitted in the hydraulic system, more contaminant is passed through this filter than through the identical filter in the test rig. The more the system conditions depart from the standard test conditions, the more the filter performance is degraded and the curve moves towards the inlet level curve. Under a very severe transient condition, that contaminant which has previously been trapped may be released and for a very short period this curve may coincide with or even move beyond the inlet curve. Under these conditions, some of the poorer filters exhibit a characteristic known as *medium migration* whereby the filter medium breaks away and passes into the effluent stream.

No mention has been made so far of the variations in filtration performance throughout its service life. FIG. 3 indicates how the pressure drop rises as the pores become progressively more clogged; in addition, the filtration performance tends to improve as the contaminant is retained and the effective pore size diameter is reduced. Some filters, however, indicate a marked fall off in efficiency after a short period in use before the expected improvement takes place. Periodic release of previously retained contaminant and medium migration both lead to a fall off in filtration efficiency and this can be observed in some filters.

Another point which should not be overlooked when measuring filtration efficiency or contaminant capacity is that of obtaining a representative sample of fluid and subsequently obtaining a count of the number of particles in the sample. In addition to the statistical errors involved, it has been established that different sampling, counting, and sizing methods yield different results and that the repeatability achieved by each method can vary. The subject of sampling and particle size analysis is, however, outside the scope of this article; reference is made to it because of its relevance to the interpretation of test results.

Shortcomings of Existing Methods of Rating Filters by Manufacturers

Hydraulic filter catalogues do not provide sufficient information to allow any useful comparison between different manufacturers products.

(particularly the element) would stand up to transient conditions, cyclic conditions, flow surges, or flow reversal, any of which could lead to a failure.

From the foregoing, the most significant shortcoming when considering information provided by filter manufacturers is the inadequate data on filtration performance. Undoubtedly this is largely because of the difficulty of obtaining and providing the information in an understandable form, aggravated by the lack of any standard to guide manufacturers. When a standard test procedure[3] is adopted, it is the hydraulic system manufacturers and system users who stand to gain more than the filter manufacturers. Filter performance requirements must, therefore, be established by the users, that is by the filter manufacturers' customers. The filter manufacturer would then be asked to provide the data required to enable a comparative assessment of potentially suitable filters; the products of manufacturers unwilling to provide this information should be suspected.

What Information does the Hydraulic System Designer require from the Filter Manufacturer

At this point, it is logical to consider in more detail the information that the hydraulic systems designer requires from the filter manufacturer.

To facilitate the selection of the most suitable filter for controlling the particulate contamination level in a hydraulic system, the information should be presented in such a manner that those filters which are unsuitable for any particular application may be quickly eliminated, the potentially suitable filters remaining then being considered in more detail.

A proposal for a standard method of presenting this information is given in Annex A. This proposal has been accepted by a BSI committee as a basic working document.

The information required to select a filter is outlined below. The data should be obtained from tests carried out under standard conditions if it is to provide a useful basis for comparison:

(*a*) Filter Rated Operating Pressure. This is the steady state pressure at which the filter is designed to operate without structural damage to the filter element or housing, taking into account a margin to allow for over pressures due to component failure or transient conditions.

(*b*) Filter Rated Pressure Drop. This is the maximum acceptable pressure drop across the filter arising from the normal direction of flow which can be applied without failure of the filter element medium or significant contaminant migration. This information is particularly important under cold start and transient flow conditions which could produce large pressure drops liable to damage the element. The filter rated pressure drop must not be exceeded as particulate builds up at the filter medium.

(*c*) Filter Specific Flow Rating. This is the flow through a filter using a fluid at a specified kinematic viscosity and density which will produce a specified pressure drop across the filter when fitted with a clean element. Calculations based on this specific flow rating will only be approximate because the flow will normally be turbulent through the

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[3]Work is being undertaken nationally by the British Standards Institution and internationally by the International Standards Organization with co-operation from hydraulic system manufacturers, operators, maintainers, and filter manufacturers to draw up standard test procedures and agree terminology. The Ministry of Defence is participating in this work.

filter except for the filter medium where it will be laminar. It will, however, give an indication of the expected initial pressure drop under various flow conditions.

(*d*) Filter Rated Flow. This is the maximum flow through the filter recommended by the manufacturer when using a fluid at a specified viscosity.

(*e*) Filter Particle Penetration Rating (6). This is a method of indicating the filtration performance to enable a quick but useful comparison between filters. This is described more fully in Annex A.

(*f*) Filter Contaminant Capacity. This is the weight of a specified contaminant which has to be added upstream of the filter to produce a given increase in pressure drop across the filter under standard test conditions. This will indicate the comparative life of a filter element in service. Since this rating (for practical reasons) depends upon the weight of contaminant presented to the filter (not the weight retained by the filter), the rating can only be used to compare filters with a similar particle penetration rating. Clearly the coarser the filter medium, the greater the amount passing through and the greater the amount that must be added to the influent to produce a specified pressure drop.

Before finally selecting the filter for a particular application, the following information should also be considered, the designer bearing in mind the expected operating conditions and performance requirement of the system:

(*a*) Flow/Pressure Drop Characteristic Curves using a clean element (FIG. 2). A standard fluid viscosity and density should be used to obtain this information; a kinematic viscosity of 30 centistokes and SG of 0·9 are recommended as being typical for hydraulic systems. Separate curves for housing and element alone are also useful.

(*b*) Collapse Pressure (or Burst Pressure depending upon normal direction of flow). This will indicate the maximum acceptable pressure drop across the filter arising from the normal direction of flow which can be applied without failure of the structure or medium of the filter element. The most common direction of fluid flow through the element is from outside to inside; excessive flow in this direction will give rise to an unacceptable high pressure drop which in turn leads to a 'collapse' failure; flow in the opposite direction will lead to a 'burst' failure. For special applications, filter manufacturers can provide filters which will accept a pressure drop across the filter equal to the system operating pressure.

(*c*) Pressure Drop/Contaminant Retention Characteristic Curves throughout the filter life (FIG. 3). These indicate the increase of resistance to flow as the filter pores become progressively more clogged.

(*d*) Pressure Drop/Viscosity Characteristic Curves on a clean element (FIG. 6). These will indicate how the expected pressure drop across the filter will vary when using fluids at viscosities other than 30 centistokes.

(*e*) Particle Transmission (or Filter Penetration) Characteristic Curves throughout the filter life (FIG. 5). These curves illustrate typical performance of a filter on irregular-shaped particles of test contaminant with a broad band size distribution pattern, and will indicate the variation in filtration performance as the filter pores become clogged.

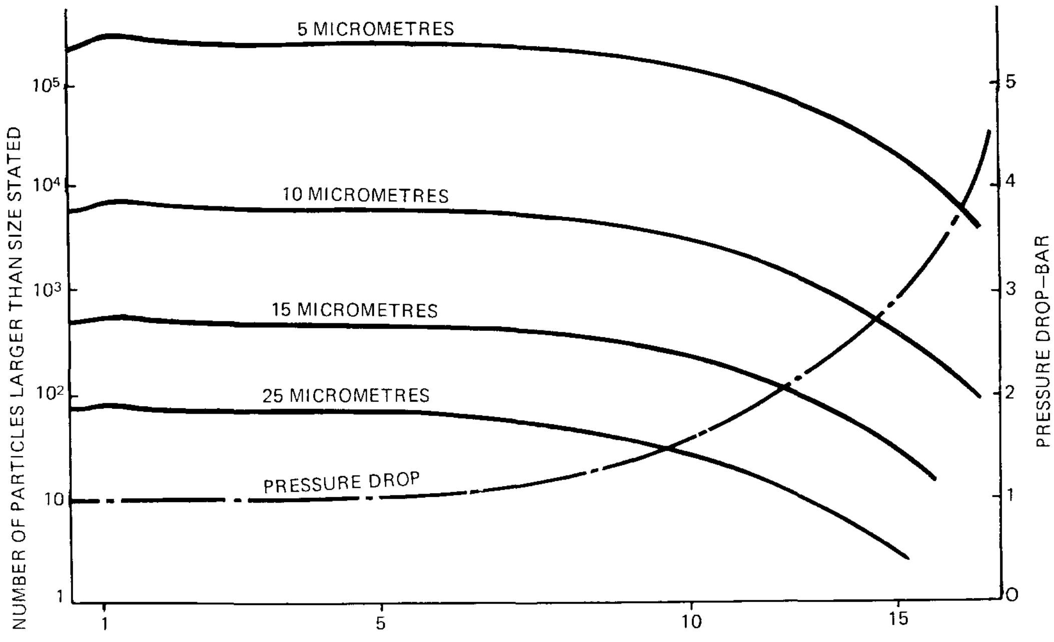

FIG. 5—PARTICLE TRANSMISSION CHARACTERISTICS OF FILTER UNDER TEST CONDITIONS

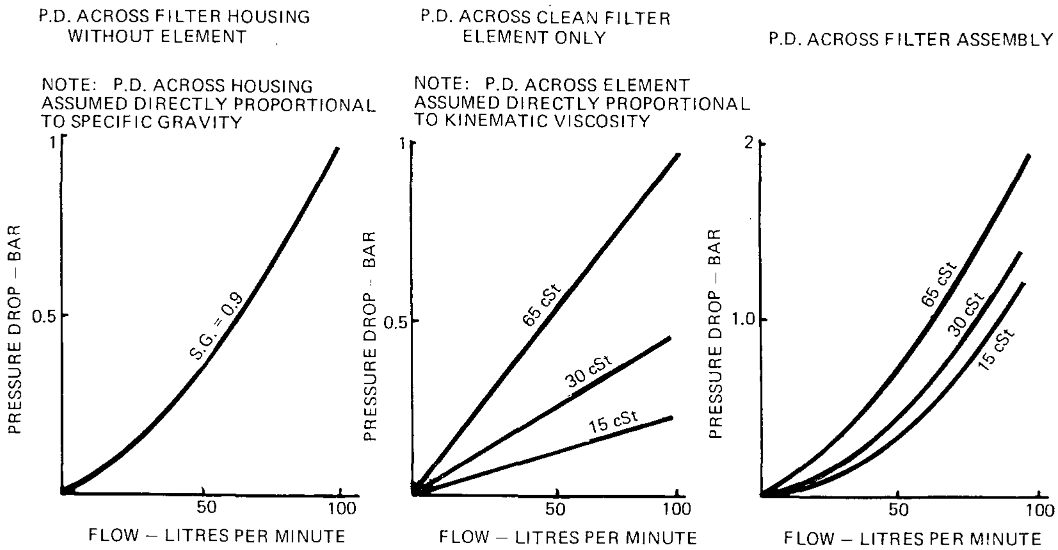

FIG. 6—PRESSURE DROP/VISCOSITY RELATIONSHIP

(*f*) Flow Fatigue Performance. This will indicate the ability of a filter to resist structural failure of the filter medium due to flexing caused by cyclic flow conditions.

(*g*) Cost of complete filter. The cost of a special filter can be 10 or 15 times higher than the cost of a standard commercial filter[4].

(*h*) Cost of replacement elements. The price of these varies considerably, ranging from less than £1 to over £100 each.

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[4]The Ministry of Defence is currently undertaking an evaluation of commercial filters to determine their applicability to R.N. hydraulic systems with a view to standardizing on a suitable range of commercial filters.

(*i*) Ease of replacing the filter element. Ideally this should be carried out quickly and without loss of system fluid.

(*j*) Whether a filter element by-pass valve is fitted and if so whether an indicator is supplied to show when it has opened or is about to open.

(*k*) Whether an indicator is fitted to show when a filter element needs to be replaced. This could be combined with the by-pass valve indicator referred to in (*j*) above.

(*l*) Whether the element is cleanable or disposable and, if cleanable, the recommended cleaning procedure and cost of cleaning. Some elements can be cleaned locally, whereas others have to be returned to the manufacturer.

(*m*) The physical configuration of the filter to indicate the flow path through the filter. Ideally the fluid flow should neither impinge directly on the by-pass valve (if fitted) nor on the filter element, and any contaminant which collects in the bottom of the filter housing should be on the inlet side of the filter element.

(*n*) The compatibility of the filter and the operating fluid (11) under the expected operating conditions, with particular reference to the medium and seal materials. Work is at present in hand to produce a standard procedure for high and low temperature compatibility tests for the filter medium.

(*o*) The ability of the element to withstand a pressure drop due to flow in the opposite direction to normal may be a requirement for some applications. Normally the filter element is constructed to withstand pressure drop due to flow in one direction only and accordingly a relatively low flow rate in the reverse direction could lead to failure. It is possible for a transient flow reversal to be present in an apparently uni-directional flow line under some conditions.

(*p*) Size of filter. For most applications, the designer is interested in keeping the filter size as small as possible for any given flow rate. This entails designing a filter with a maximum surface area within the smallest possible volume and using a medium with low specific resistance to flow. The former is the reason for the pleated filter medium found in many elements.

From the system designer's point of view, the information under sub-paragraphs (*a*) to (*p*) should answer the questions: Will the filter physically withstand the system operating conditions? Will the filter be compatible with the fluid? What is the cost in terms of price and of system energy loss?

The designer may also require assurance that the manufacturer's quality control procedures will ensure repeatability of the filter's performance over long manufacturing runs, freedom from unnecessary contamination when purchased, and that the item is suitably packaged for transit and storage. A bubble point check[5] is a non-destructive test that can be used to check the control of pore size and physical integrity of the filter by measuring the gas pressure required to allow bubbles to pass through the element when it is

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[5]This is based on the capillary equation:

$$\text{Bubble Point (Gas Pressure)} = \frac{\alpha \,.\, 4 \cos \theta}{D}$$

Where: α is the surface tension of the fluid
θ is the angle of contact between the fluid and capillary
D is the internal diameter of the capillary.

immersed in a suitable fluid. To assist the purchaser to check the cleanliness aspect of the filter, a test known as a 'Built-in Dirt and Medium Migration Test' is under consideration.

However, none of the above information provides the answer to the question: What is the filtration performance of the filter under system operating conditions as opposed to standard test conditions? This problem has already been referred to in this article. Unfortunately, not only does filtration performance measurement lead to practical problems under transient conditions but the actual conditions will also vary considerably from system to system, so that the agreement of standard conditions to suit all systems would lead to a conflict of requirements.

If agreement can first be reached on providing data obtained under steady state conditions, at least a useful basis of filter comparison will be available; the other requirement could be considered later.

What should the System Designer know about his own System when Selecting a Filter?

When considering the information which the system designer requires from the filter manufacturer, it becomes clear that the system designer in his turn must know what filtration performance he requires and what system conditions he requires the filter to withstand.

The primary function of a filter is to control the contamination in a system to an acceptable level. The designer must have a good idea of the particulate contamination balance in the system (FIG. 4), and the maximum acceptable contamination level for units in the system; he, therefore, needs to know:

(*a*) The maximum acceptable contamination level for the system. This level is achieved by selecting a filter with the appropriate contamination control characteristic.

(*b*) How much contaminant the filter will be required to remove. This is related to the contaminant capacity of the filter (7) and the frequency of changing (or cleaning) the filter element.

(*c*) The maximum energy loss which can be accepted due to pressure drop across the filter. This is related to the filter flow/pressure drop characteristic.

System design can significantly influence the requirements under (*a*) and (*b*) above. For example, the amount of contaminant required to be removed in service can be reduced by better environmental control combined with more effective cleaning and flushing procedures, improving the sealing devices, avoiding open-ended pipes for breathers, using material with lower contamination generation characteristics, and by filtering the fluid as it is added to the system.

The use of units which are more *contamination tolerant* will enable the system to operate under a dirtier level allowing in turn relatively coarser filtration to be specified.

Another point that must not be overlooked, particularly where fine filtration is employed, is the filterability factor of the working fluid (19). Although this is essentially a fluid characteristic, experience indicates that some filters are more liable than others to clog up rapidly due to some of the additives or impurities in the fluid.

Since the filter finally selected must be capable of withstanding system operating conditions, the following information about the point at which the filter is to be fitted must be known:

(*a*) Maximum pressures including transients.

(*b*) The range of fluid flow conditions.

(*c*) Temperature and fluid viscosity ranges.

(*d*) System fluid characteristics to ensure material compatibility throughout the operating temperature range.

Because these conditions are related to the actual position of the filter in the system, the designer must also give consideration to the optimum position for the filters, deciding whether full-flow filtration in the pressure line, return line, or suction line is required or whether some form of by-pass filtration would be more suitable. The need for optional design features such as an integral element by-pass valve and an indicator to show when the by-pass has operated (or is about to operate) must be taken into account. In addition, weight, size, and access limitations may dictate the physical configuration, type of filter, and materials used in its construction, the latter also being influenced by environmental compatibility.

With so many factors to take into account and the lack of data on filter performance under varying system operating conditions, it is recommended that the performance of the selected filter is checked in the hydraulic system before final acceptance. Opportunity could be taken to examine the performance of the filter under system operating conditions at the prototype stage of development during shop trials; any desirable changes in the filter would then be made before introduction of the hydraulic system into service.

ANNEX A

PROPOSAL FOR A STANDARD SYSTEM FOR RATING AND CLASSIFYING FILTERS FOR HYDRAULIC SYSTEMS

Introduction—Selection of the optimum filter for a hydraulic system

The purpose of the rating code is to enable the performance of different filters to be compared by giving an indication of the following characteristics:

Filter Rated Pressure

Filter Rated Pressure Drop

Filter Specific Flow Rating

Filter Rated Flow

Filter Particle Penetration Rating

Filter Contaminant Capacity.

The information succinctly provided by the rating code should narrow the field of potentially suitable filters for any hydraulic system to a relatively small number each of which may then be considered in detail in the light of the following information (which should also be provided by the filter manufacturer) and bearing in mind the expected system operating conditions and requirements:

Flow/Pressure Drop Characteristic Curves on a clean element.

Particle Transmission Characteristic Curves throughout the filter life.

Pressure Drop Characteristic Curves throughout the filter life.

Pressure Drop/Viscosity Characteristics on a clean element.

Collapse/Burst Pressure and Collapse/Burst Pressure Rating.

Flow Fatigue Performance.

Compatibility of filter components (particularly seals and media) with the operating fluid at predicted extremes of fluid operating temperature.

Filter Proof Pressure.

Whether a bypass valve is fitted and, if so, whether an indicator is available.

Whether the element is cleanable or disposable and, if cleanable, the recommended cleaning procedure and cost of cleaning.

Ease of replacing the filter element.

Cost of filter complete and of replacement elements.

Scope and Applicability

This Annex proposes a standard method for rating filter performance for hydraulic system applications, and in addition recommends a broad band system for classifying filters for system pressure, flow, and contamination control.

The test procedures for grading and rating filters are not included in the scope of this document.

Filter Performance Rating Code

The proposed filter rating code will provide the information as given in sub-paragraphs A to F below. The information is to be obtained from the standard test procedures; if the actual tests depart from the standard test conditions, the characteristic concerned should be annotated (x) and details of the departure stated.

(*A*) *Filter Rated Pressure*

The actual rated pressure is to be stated in bars, e.g. 200. The factor of safety or relationship between the rated pressure and the filter test pressure and the actual (or calculated) burst pressure also needs to be standardized.

(*B*) *Filter Rated Pressure Drop*

The maximum acceptable pressure drop across the filter is to be stated in bars, e.g. 20.

(*C*) *Filter Specific Flow Rating*

The specific flow rating will enable a quick assessment of the resistance to flow under system flow conditions by assuming that pressure drop across the filter is directly proportional to flow.

The flow through the filter (in litres per minute) required to produce a specified filter pressure drop (TABLE I) is to be stated. The test is to be carried out with a clean element fitted in the filter using a fluid at 30 centistokes kinematic viscosity and 0·9 specific gravity.

TABLE I—*Standard pressure drops for specific flow rating*

Pressure Drop	*Remarks*
1·0 bar (14·5 lbf/in.^{2})	Preferred Category.
0·1 bar ($\approx$ 1·4 lbf/in.^{2})	To be used if a pressure drop of 1 bar cannot be achieved.
0·01 bar ($\approx$ 0·14 lbf/in.^{2})	To be used if a pressure drop of 0·1 bar cannot be achieved.

Note: The pressure drop selected is to be stated in the code in brackets after the specific flow rating in litres per minute, e.g. 136(1).

(*D*) *Filter Rated Flow*

The maximum acceptable flow through the filter (in litres per minute) when using a fluid at 30 centistokes kinematic viscosity and 0·9 specific gravity is to be stated, e.g. 225.

(*E*) *Filter Particle Penetration* (*or Transmission*) *Rating*

To indicate the contamination control of the filter on large and small size particles, the filtration ratio and information on the largest particle penetrating the filter are given:

(*i*) The minimum filtration ratio on particles larger than a specified size when using test contaminant approved for this purpose under standard test conditions is to be stated. The appropriate particle reference size given in Table II is to be selected and stated in brackets, e.g. 35(15).

TABLE II—*Reference particle size to be used*

Reference Particle Size (*micrometres*)	*Applicability*
5	When Filtration Ratio at 5 micrometres is greater than 25.
15	When Filtration Ratio at 5 micrometres is less than 25 but is greater than 10 at 15 micrometres.
25	When Filtration Ratio at 15 micrometres is less than 10.

It should be noted that the values given in the above table will need to be re-examined in due course when more data on performance over a wider range of filters has been obtained.

(*ii*) The size of the largest particle of an approved test contaminant which penetrates the filter under standard test conditions is indicated by giving the largest size range in which particles are counted downstream as shown in TABLE III.

TABLE III—*Size range of largest particles passed*

Code	*Range in which the largest particle lies* (*micrometres*)
5	less than 5
10	5–10
15	10–15
25	15–25
50	25–50
100	50–100
>100	larger than 100

The complete filter particle penetration rating should then be expressed in the following form, e.g. 35(15)25, where (15) refers to the reference particle size for the filtration ratio.

(*F*) *Filter Contaminant Capacity*

This will give the weight of specified test contaminant (in grammes) which is required to be added upstream of the filter to produce an increase of pressure drop across the filter as shown in TABLE IV:

TABLE IV—*Pressure drops across filter for contaminant capacity rating*

Increase in pressure drop (bar)	*Remarks*
5·0 ($\approx$ 73 lbf/in.^{2})	Recommended for high pressure line filters.
2·0 ($\approx$ 30 lbf/in.^{2})	Recommended for medium pressure line filters.
0·5 ($\approx$ 7 lbf/in.^{2})	Recommended for low pressure (suction) line filters.

The pressure drop selected for each filter should be stated in the code in brackets after the contaminant capacity, e.g. 2·5(5).

Note on Particle Penetration and Contaminant Capacity:

The following conditions need to be standardized and, in the case of any departure from the standard, the actual condition used should be stated:

(*a*) Test contaminant. The ratings are related to specified test contaminant(s). The effect of varying the test contaminant needs to be established. However, the variation should be insignificant if test contaminants exhibit the same order of particle size distribution and shape factor.

(*b*) Either the rate and method of adding contaminant, or the details of the upstream contamination level which is to be maintained.

(*c*) Method employed for particle counting.

(*d*) Flow Rate. (If the filter is tested at its rated flow, this should be stated).

The Filtration Performance Rating Code could be given in the filter manufacturer's catalogue as shown opposite. The example given would provide the following information on the performance of the filter under the test conditions stated:

A Rated Pressure—The filter is suitable for use in system lines where the operating pressure does not exceed 200 bar. (Note that overpressures and transients must also be taken into account).

B Rated Pressure Drop—The maximum acceptable pressure drop across the filter arising from the normal direction of flow is 20 bar. The filter element should, therefore, be changed before this pressure drop is reached. Significantly higher pressure drops could lead to structural failure of the element or to significant contaminant or media migration. If a bypass valve is fitted, it should be set to open at a pressure lower than the rated pressure drop.

C Specific Flow Rating—A flow of 136 litres per minute of fluid at 30 centistokes viscosity and 0·9 specific gravity is required to produce a pressure drop of one bar across the filter fitted with a clean element. At the rated flow of the filter, the normal pressure drop across the filter would, therefore, be of the order of 1·8 bar.

D Rated Flow—The filter is suitable for use in lines with flow rates up to 225 litres per minute when the fluid has a kinematic viscosity of 30 centistokes and a specific gravity of 0·9.

E Particle Penetration Rating—The filter has a minimum filtration ratio of 35 for particles of BS 1701(fine) test contaminant larger than 15 micrometres when tested at the filter's rated flow with contaminant injected at a rate of 10^6 particles larger than 5 micrometre per 100 millilitre volume of circulating fluid. In addition, under the same conditions the largest size of particle transmitted through the filter medium is in the 15–25 micrometre size range.

F Contaminant Capacity—2·5 grammes of BS 1701 (fine) test dust are required to be added upstream of the filter to achieve a rise in pressure drop of 5 bar across the filter at its rated flow. Comparison of this rating with that of other filters will indicate the comparative life expectancy before the filter element needs changing or cleaning.

	Filter Performance Characteristic	*Rating*	*Units*
A	Rated Pressure	200	bar
B	Rated Pressure Drop	20	bar
C	Specific Flow Rating	136(1)	l.p.m.
D	Rated Flow	225	l.p.m.
E	Particulate Penetration Rating	35(15)25*	—
F	Contaminant Capacity	2·5(5)*	grammes
G	Test conditions and procedures:		
	Test Contaminant	To BS.1701 (Fine)	
	Particle counting by	Back Projection Microscope	
	Test procedure	Multi-pass	
	Test Fluid	Kinematic viscosity 30 cSt Specific gravity 0·9	

*Filter tested at rated flow for these tests.

Classification of Filters for Hydraulic Systems

To facilitate selection of a filter for any application, filters may be classified into groups based on the following characteristics:

System Operating Pressure
System Fluid Flow Rate
System Contamination Control

A broad band classification suitable for application to R.N. hydraulic systems could be as follows:

TABLE V—*Operating Pressure*

Pressure	*Filters suitable for line operating pressures:*
High	Higher than 200 bar (≈ 3000 lbf/in.^{2})
Medium	In the range 14–200 bar (≈ 200–3000 lbf/in.^{2})
Low	Less than 14 bar (≈ 200 lbf/in.^{2})

TABLE VI—*Fluid Flow*

Flow	*Filters suitable for fluid flow:*
High	Greater than 250 litres per min (≈ 55 gallons per min)
Medium	In the range 50–250 litres per min (≈ 11–55 gallons per min)
Low	Less than 50 litres per min (≈ 11 gallons per min)

Note: The fluid flow should be stated for a fluid at a kinematic viscosity of 30 centistokes and specific gravity of 0·9.

TABLE VII—*Contamination Control* (*Based on Filtration Ratio*)

Classification	*Filtration Ratio at Reference Particle Size stated*		
	5 micrometre	*15 micrometre*	*25 micrometre*
Very fine	Greater than 25	—	—
Fine	—	Greater than 100	—
Medium	—	Greater than 10	—
Coarse	—	—	Greater than 25
Very Coarse	—	—	Less than 25

TABLE VIII—*Presentation of Filter Performance Data for R.N. Hydraulic Systems*

Contamination Control (See Table VII and Note 1)	*System Operating Pressure (See Table V)*								
	High Line Pressure >200 bar			Medium Line Pressure 14–200 bar			Low Line Pressure <14 bar		
	Filter Rated Flow (See Table VI)			*Filter Rated Flow (See Table VI)*			*Filter Rated Flow (See Table VI)*		
	High	Medium	Low	High	Medium	Low	High	Medium	Low
	>250 lpm	50–250 lpm	<50 lpm	>250 lpm	50–150 lpm	<50 lpm	>250 lpm	50–250 lpm	<50 lpm
Very Fine FR >25 at 5 µm									
Fine FR >100 at 15 µm									
Medium FR 10–100 at 15 µm									
Coarse FR >20 at 25 µm									
Very Coarse FR <20 at 25 µm									

Notes: (1) Contamination Control based upon the Filtration Ratio (FR) at particle size stated.
(2) The information given succinctly by the Filter Performance Rating Code could be included in the above Table in addition to the filter manufacturer's catalogue reference.

ANNEX B

DEFINITION OF SOME FILTRATION TERMS USED IN CONTAMINATION CONTROL OF HYDRAULIC SYSTEMS

(1) *Filter*—A device whose primary function is the retention by a porous medium of insoluble particulate contamination from a fluid.
Note: The filter consists of a housing, an element, and the seals between the housing and element. It may incorporate a pressure relief valve assembly and/or a pressure drop sensing device.

(2) *Filtration*—The process of removing a proportion of the insoluble particulate contamination held in suspension in a fluid by passing the fluid through a filter.

(3) *Filter Element*—The sub-assembly of a filter containing the filter medium.

(4) *Filter Medium*—The porous material that performs the process of filtration.

(5) *Filtration Ratio*—The ratio of the number of particles larger than a specified size per unit volume in the influent to the number of particles larger than the same size per unit volume of the effluent fluid as determined under specified test conditions.

(6) *Filter Particle Penetration Rating* (*or Filter Particle Transmission Rating*)—A measure of the ability of a filter to remove from a fluid a specified test contaminant under specified test conditions expressed quantitatively in terms of the contaminant penetrating (or transmitted through) the filter.

(7) *Filter Contaminant Capacity*—The weight of a specified contaminant which must be added upstream of a filter to produce a given increase in pressure drop across a filter under specified conditions.

(8) *Filter Rated Flow*—The maximum recommended flow rate when using a fluid at a specified kinematic viscosity and density.

(9) *Filter Specific Flow*—The flow required through a filter containing a clean element when using a fluid at a specified kinematic viscosity and density in order to produce a specified pressure drop across the filter.

(10) *Filter Element Flow Fatigue*—An indication of the ability of a filter element to resist structural failure of the filter medium due to a flexing caused by cyclic system flow conditions.

(11) *Filter Element Material Compatibility*—The compatibility of the materials which comprise a filter element (but not the seal material) with a designated hydraulic fluid under specified fluid temperature conditions.

(12) *Filter Rated Operating Pressure*—The maximum steady-state pressure at which a filter is designed to operate without structural damage to the filter body or element. An adequate margin is to be allowed for overpressures due to component failure and for transient conditions.

(13) *Filter Element Pore*—An opening in a filter medium to allow the passage of fluid.

(14) *Filter Proof Pressure*—The non-destructive test pressure that a filter shall withstand without permanent deformation, external leakage, or other malfunction.

(15) *Filter Pressure Drop*—The difference in pressure across the filter at any time.

(16) *Filter Rated Pressure Drop*—The recommended maximum pressure drop across a filter arising from the normal direction of fluid flow. The filter rated pressure drop is to be related to the filter element collapse (or burst) pressure.

(17) *Filter Element Collapse Pressure*—The least pressure drop across a filter element arising from outside-to-inside flow that causes failure of the structure or medium of a filter element.

(18) *Filter Element Burst Pressure*—The least pressure drop across a filter element arising from inside-to-outside flow that causes failure of the structure or medium of a filter element.

(19) *Fluid Filterability*—An indication of the ease with which a fluid can be filtered.

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