Section 10
BASIC HYDRAULICS

Spool centers provide two additional methods of unloading fixed-displacement pumps. An open-center spool (Fig. 52) automatically unloads the pump when centered. Figures 55 and 56 show a tandem-centered spool that does the same thing and holds the cylinder fixed. This kind of spool offers another advantage in tight-space applications, where the tank line of one valve becomes the pressure line of its neighbor (Fig. 57), thus permitting directional valves to be stacked side by side with substantial savings in piping. Payloaders and other hydraulically operated mobile equipment use this arrangement. If more than one cylinder is operating at the same time, however, the downstream actuators slow down because the rod side of one cylinder feeds the cap end of the next.

Another method of unloading a circuit using fixed-displacement pumps is called a "high-low" system (Fig. 58), consisting of a double pump (not a two-stage) feeding into a single pressure line. The double pump has two sections, large and small (usually in a 10-1 or 15-1 gpm ratio), driven by a single prime mover through a common shaft. When the cylinder is to be moved, both pumps provide fluid; but when the cylinder contacts the work or the directional valve is centered, the pressure begins to build. When the pressure reaches the unloading valve setting, the unloading valve is opened by a signal from the pilot line. The flow from the large pump returns to tank through the unloading valve, and the check valve snaps shut to retain the small pump flow. The small pump flow continues to raise the pressure until it reaches the

Fig. 55-Unloading a fixed-displacement pump with a tandem-center valve.

Fig. 56-Tandem-center spool.

Fig. 57-2 tandem-center directional valves on same system.

Fig. 58-"High-low" system.
• ingressed: the mechanic unwittingly dumps it in with the makeup oil; or it comes in through the breather or the cylinder rod seals
• generated: particles shear or wear off during normal operation
• built-in: the system was not properly flushed after construction
• maintenance: the danger of contamination is present every time the system is opened up to be worked on

Contamination comes in three forms—as a solid, a liquid or a gas. Solids include silicon, wear metals, thread tape and many other substances. Though liquid usually means water, it may also denote an incompatible fluid accidentally mixed with the correct fluid. The most common gas contaminants are air and vaporized fluid.

As stated above, ingressed contamination can enter the system during makeup, as dirt in the container used by the mechanic, for example. In fact, the inherent contamination of new oil may be too much for a servo system. To avoid ingressed contamination, mechanics must be trained in the importance of “filter fill,” and designers should avoid the traditional filter-breather apparatus, for the following reasons. When the breather is removed from this device, a screen is exposed that supposedly keeps dirt out as oil is poured into the tank, even when clean, however, these screens are inadequate. Instead, all reservoirs should be equipped with a “filter-fill” filter like the one shown in Fig. 59, with a snap connector that will mate with another on a hose from the fill pump. In the alternative, the snap connector may be placed in the return line ahead of the return line filter to make that filter do double duty. To minimize the possibility of improper filling, it may be necessary to eliminate all of the holes in the reservoir top except the filter-breather. Giving the mechanic the means to pump makeup oil through a filter into the reservoir is an important step in preventing ingressed contamination.

But what if all of the oil added to a system is from new drums—isn’t that clean enough? Why is it necessary to filter the oil before it enters the system? Because new oil from drums is not clean enough for servo and proportional valve systems. Besides, even in conventional systems, too many things can happen between the opening of the drum and the entrance of the oil into the system; a filter on the fill line is excellent insurance.

Generated particles are to be expected in a hydraulic system. In addition to using high-quality anti-wear oil, the best ways to minimize them are to use quality filters and to see to it that all elements are changed as quickly as possible after “DIRTY” shows on the indicator. Such particles are particularly plentiful in hydraulic systems immediately after pump failure, so indicators must be watched more closely for a while and oil samples checked more frequently until the desired equilibrium is reached.

Since built-in particles originate during system construction, the user should consider having any large, complicated system flushed by an experienced contractor before it is put into use. Actually, companies whose sole business is flushing new systems should be consulted early in the design phase.
because of the need for access taps at certain locations and the desirability of eliminating dead spots that naturally accumulate dirt. As a customer, the user must take an active role: flushing should never be delegated to a contractor without the user’s continuing involvement because errors made at this point can haunt the system user for years. The flushing contractor should be held to the cleanliness standard established for operations. Determining the point at which flushing is complete is best left to a lab capable of automatic particle counting and rendering the cleanliness level in the International Standards Organization (ISO) format; but portable particle counters can perform this task in the field with reasonable accuracy.

Maintenance contamination can be minimized by properly training the mechanics who are responsible for opening up systems. They must understand the consequences of allowing dirt and water to enter a system during maintenance, especially if such contaminants remain there. Invisible contamination (smaller than 40 micrometers) can also cause extensive damage to system components. At the very least, rags should be taped around open lines and components should be flushed before re-installation. Because slight ingestion during maintenance is inevitable, more frequent filter changes should be anticipated for a while.

Until recently, industry had no effective way to measure the cleanliness of a hydraulic system against a standard. Now, however, the ISO has devised a system based on two numbers: the number of particles greater than five micrometers in size and those greater than 15 micrometers (one micrometer is one millionth of a meter or 0.000039 inches). Figure 60 is a logarithmic chart on which these numbers can be plotted. Since various types of hydraulic systems require different levels of cleanliness, the new ISO contamination rating system facilitates specification of those levels.

Figure 60 is used by first obtaining the number of particles above a certain size, X, plotted on the horizontal axis in one ml of fluid. Automatic particle counters can provide this information, based on either light transmitted or pressure drop across a sample; both methods afford reasonable accuracy. That number is plotted where the number of particles on the left vertical scale (remember, the scale is logarithmic) intersects the vertical particle size line. This procedure is followed for the 5- and 15-micrometer sizes and the corresponding numbers noted on the range code line (the numbers 0-30). You will notice that with each increase in range number, the number of particles/ml doubles. The combination of two range codes separated by a slash (/) identifies the contamination level. For instance, let us say that the particle counter found 1500 particles five micrometers and larger in a one-ml sample. On the left side of the chart in Fig. 60, 1500 is the unmarked line between 1000 and 2000. If you follow that line to the right, it will intersect range number 18 directly above the five-micrometer line. Now, let us say that the particle counter found 60 particles 15 micrometers and larger in the same sample. Again, locate 60 on the left-hand scale and follow it to the right until it intersects range number 13 directly above the 15 micrometer line. The sample, therefore, has a cleanliness level of 18/13.

Though the procedure described above tells the user how clean a hydraulic system is, it does not explain how to make the system cleaner. This led naturally to an international system for rating the efficiency of filter elements. The Multipass Filter Performance Beta Test (ISO 4572) expresses results as the number of particles of a given size that get through a filter under test compared to the number in the same size range that were introduced upstream. The Beta ratio would report, for instance, that a filter had a Beta_{50} equal to 75, meaning that for every 75 particles of 10 micrometers or larger upstream, only one got through; thus, the filter had

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\frac{(75-1)}{75} \times 100 = 98.7\% \text{ efficiency.}
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The next logical questions are: Once you have determined the ISO standard that you want to reach, how do you use the Beta system to achieve it? How long will it take? Though no such procedure has yet been developed, filter manufacturers are working closely with universities and independent labs to devise objective recommendations. In working toward a specific level of cleanliness, the following factors should be considered:

- the micrometer size of the filtration element,
- the Beta rating of the element,
- the placement of elements in the system,
- how clean the system was initially and
- how rapidly dirt ingestion occurs during use.

All of these factors affect the time required to reduce system contamination to the desired level.

The ISO has made no formal recommendations on these points as yet, perhaps because of the many variables involved. However, Fig. 81 presents one manufacturer's recommendations for reaching target cleanliness levels (plotted on the vertical axis) with various types of filtration arrangements (plotted across the bottom axis). Reading the text of this chart substantiates the difficulty of the problem. This author recommends no less than Beta > 100 for any filter on a critical system.¹

Reference