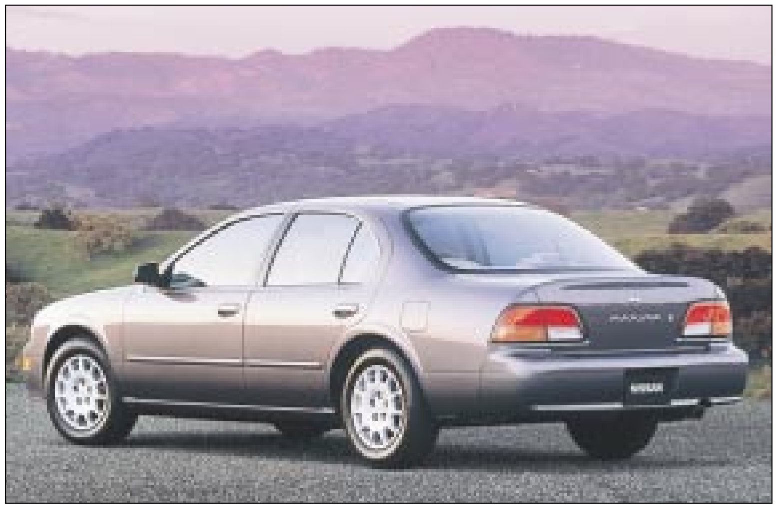
Filtration focus fixes faults

By S. Hanawa

In 1996 and 97, I and other engineers and technicians at Nissan Motors of Japan performed field tests in an attempt to analyze and rectify oil contamination problems in our assembly plant that manufactures our Maxima and Blue Bird models. Final results of the year-long study showed that installing off-line filtration systems reduced hydraulic equipment breakdowns by 86.7% and failure of servovalves by 92.4%. We were so impressed with the results that we now specify this type of filtration system on all new hydraulic machinery equipped with servovalves. Following is a condensed version of a report summarizing our work and what we learned.



Nissan North America, Inc.

The 1998 Maxima GXE, shown, and other models are manufactured at Nissan's Kanagawa Plant, which has begun widespread use of off-line filtration in conjunction with in-line filtration to reduce hydraulic failures overall, and especially those related to servovalve operation.

Laying the groundwork

Because hydraulic fluid contamination can come from many different sources, we first set out to identify all potential sources of contamination from within our plant before actually beginning the tests. The standard interval for oil sampling and analysis was every four months for critical equipment, every six months for less-critical equipment, and annually for general-purpose equipment. Among the characteristics analyzed in these routine tests were oil color, kinetic viscosity, total acid numbers, and water and particulate contamination. These analyses enabled us to narrow down the sources of contamination into five categories:

Contamination from the workplace environment — We found sources of contamination surrounding hydraulic equipment to include dirty air, metal particles from nearby machinery, extraneous oil, weld spatter, and sanding by-products. We found hydraulic fluid to be contaminated with sand and iron powder in our forging shop; water, oil, chips, and dust in our machine shop; and weld spatter and fiber scrap in the assembly shop.

A recent study by Nissan Motors of Japan attributed 85% of hydraulic equipment failures to contamination. Better filtration slashed these failures by nearly 90%.

Contaminants produced within the hydraulic system — Friction from sliding motions inherent to hydraulic components eventually generates wear particles that get carried through a hydraulic system. We found that abraded iron particles and packing material debris became wedged between sliding surfaces, further aggravating the abrasive wear. Eventually, the abraded surfaces caused internal leakage in the affected components, which degraded performance and caused operational malfunctions.

Water from oil cooler cracks — We found that water-cooled heat exchangers in some of equipment sometimes developed cracks in the thin walls separating the water from the hydraulic oil. This allowed water to enter the hydraulic system, which eventually led to emulsified fluid. Emulsified fluid often caused pump cavitation and rust on internal surfaces of components.

Contaminants resulting from fluid decomposition — Hydraulic oil is composed of hydrocarbon compounds combined with small amounts of oxygen. When heated or continuously exposed to light, the fluid becomes more susceptible to oxidation, which can lead to sludge formation. We found that a gel-like sludge formed at

Seijiro Hanawa is a senior engineer, Equipment Check Engineering Group, Engineering Experimentation Div., Third Engineering Dept., Nissan Motor Co., Ltd., Kanagawa, Japan. The off-line filtration systems described in this article are manufactured by Triple R Corp. For more information on these systems, ***Circle 398*** *on a reader service card.*

low temperatures. This sludge often stuck to control valves and caused oil blockages. At higher temperatures, the sludge broke up and became fluid-suspended contamination.

Contaminants from additive decomposition — We had been using a hydraulic fluid containing the additive zinc zialkyldithiophosphate (ZnDTP) in some equipment to reduce wear, oxidation, and abrasion. However, we discovered that ZnDTP is easily hydrolyzed, which compromises mechanical properties of the fluid. Moreover, if heated, its anti-oxidation capabilities deteriorate rapidly, sometimes actually shortening the longevity of the fluid.

Concentrations of all these contaminants exceeded acceptable limits. As the contaminants were carried by the hydraulic fluid between sliding surfaces, a variety of problems resulted, including abrasion, clogging of narrow passageways, and oxidation. These actions were responsible for the malfunction of many different components, including pumps, directional-control valves, servovalves, and actuators. We concluded that these contaminants caused 85% of hydraulic equipment failures. We predicted that keeping hydraulic fluid free of debris would extend its longevity and significantly lower the frequency and severity of breakdowns. To achieve this, much more aggressive filtration would be needed to protect equipment from the ravages of fluid contamination.

Plotting a strategy

We evaluated the effectiveness of every component of our hydraulic filtration systems to determine the best course of action. The preliminary work to determine the types and sources of contaminants proved especially valuable in showing us ways to improve the filtration systems.

Breather-filters — Most reservoirs had been fitted with an air breather-filter to exclude airborne contaminants drawn into the reservoir when fluid level decreased. These filters did not adequately prevent water vapor and small particles from entering the system. These filters also became easily clogged, causing oil surges or breakdowns to occur. In most instances 300- to 500-mesh filters were used. Possible solutions would be to use a breather with a bladder interface to prevent ambient air from coming in contact with fluid. Another possible solution would be to use a finer mesh filter and possibly incorporate a desiccant-type air drying element with the filter.

Suction filters — Pumps are almost always protected from contamination by inlet filters. They usually are installed by fitting a suction strainer directly into a pipe submerged in the tank. We found this method to be somewhat ineffective because the filter easily becomes clogged. This starves the pump of fluid, which causes cavitation and subsequent pump breakdown. This method also requires the machine to be shut down to replace filters.

A much more effective method would be to place the suction filter in a separate housing along with by-pass valves, a clogging alarm, and other accessories. The bypass prevents cavitation when the filter becomes clogged, and the indirect piping makes it easy to change filters — without having to shut down the machine. Even better yet would be to remove contaminants from the reservoir altogether, which would greatly extend life of the suction filter.

High-pressure filters — High-pressure filters (usually rated 3 to 10 μm) had been installed just upstream of most critical control devices, such as servovalves, as a last-chance protection filter. We found that this practice must be done with great care to prevent possible valve damage. Also, these filters must be cleaned regularly to prevent them from clogging, which could increase backpressure, reduce response by restricting flow, or both. Again, reducing overall contamination within the entire system would go a long way toward extending service life of these filters.

Low-pressure filters — Case-drain filters, bleed-off filters, and return-line filters are intended to prevent contaminants from entering the reservoir. However, high pressure surges often occur in these circuits, so filters must be carefully sized for each application. Incorporating bypass valves with all return-line filters helps alleviate this potential problem by preventing clogged filters from causing excessive backpressure in

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Type of component	Working pressure — kg/cm³	Acceptable degrees of contamination				
		NAS degree ≤25 μm	NAS degree ≥25 μm	Contamination concentration — mg/100 ml	Water concentration — % volume	Ferrography WPC
Vane pump	≤70	10	9	10.0	0.10	≤50
	≤140	10	8	8.0	0.10	≤40
	≤140	10	8	5.0	0.05	≤40
Gear pump	≤70	11	9	10.0	0.10	≤50
	≤70	10	8	8.0	0.10	≤50
Piston pump	≤140	9	6	5.0	0.05	≤30
	≤140	8	5	3.0	0.05	≤25
High-performance hydraulic motor	≤210	9	6	5.0	0.05	≤25
Electrohydraulic servovalve	≤140	6	5	3.0	0.03	≤25

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return lines. Contaminants in case-drain lines, in particular, readily accumulate in the bottom of pump and motor housings, so it is extremely important to clean case drain filters regularly to prevent equipment breakdowns. As case-drain filters become clogged, contaminants accumulate even more rapidly, therefore we prefer to use only about a 50- to 100-µm mesh filter for case drain lines. So instead of trapping the majority of them in the filters in these lines, we allow the contaminants to flow into the reservoir, where they can be removed more readily.

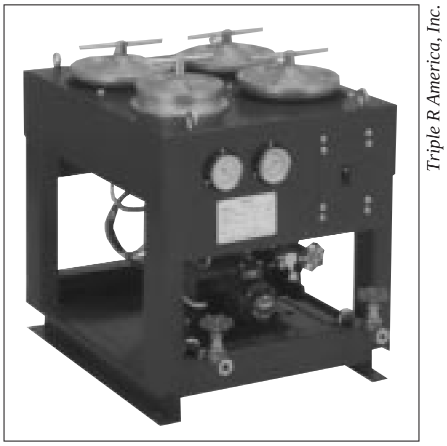
Off-line filtration - Many applications used an off-line filtration system with its own circulating pump and network of filters to separate and remove contaminants from the reservoir. We found that off-line filtration solved many of the problems just described with some additional advantages. First, because they are isolated from the main hydraulic circuits, these systems are not subjected to surge pressures and cannot cause cavitation. Also, they are easy to service and maintain, often without having to shut down the machine.

The plot thickens

It became clear that much finer filtration throughout our hydraulic systems was essential to reduce the frequency and severity of equipment breakdowns. The problem, however, was that as filters become finer, resistance to flow increases. These flow restrictions can slow down machine operation, cause sluggish response, and produce pressure variations that cause operational malfunctions. The challenge then became to implement a filtration system that would provide high contamination protection without sacrificing system dynamics.

To find a solution, we carefully evaluated the two generally accepted methods of filtration for hydraulic equipment: surface and depth filtration. Surface filtration is widely used in the conventional applications just described and relies on pleated elements to trap contaminants on the surface area of the filter media. Among its strong points, surface filtration:

- offers little resistance to flow when elements are relatively clean
- exhibits a large contaminant containment area, and
- is relatively easy to apply and maintain.



Triple R America, Inc.

Self-contained off-line filtration unit, which augments in-line filters, has filters piped in parallel to match flow capacity with application requirements.

However, as the amount of contamination removed from fluid increases, surface filtration becomes much less effective. As explained above, the more contaminants in the fluid, the more quickly elements become clogged. This means filter condition must be carefully monitored and maintained by changing elements frequently.

Depth filtration uses layered roll-type rather than pleated elements — much like a roll of paper towels. Compared to surface filtration, depth filtration:

- captures a larger percentage of contaminants
- removes free water from hydraulic oil, and
- can provide finer filtration to achieve a higher degree of cleanliness.

On the other hand, as roll-type elements capture contaminants, resistance to flow increases more rapidly than with pleated elements. This makes it even more important that roll-type elements be kept clean and explains why pleated elements are more widely used for in-line filtration. However, pressure differential is not as critical with off-line filtration, because off-line filtration circuits operate at low pressure with low flow independent of the hydraulic system. So excessive pressure drop across a filter only affects flow in the off-line filtration circuit and not in the main hydraulic system. We concluded that an off-line filtration system used in conjunction with conventional in-line filters was the most practical method to provide cleaner fluid with minimal restriction to fluid flow.

Results and conclusions

Combining our findings from past machinery breakdown records with fluid analysis results allowed us to determine the degree of filtration necessary to reduce breakdowns. We developed a standard level of contamination removal for each application. Then we implemented a plan to identify and test filtration systems that could meet these standards.

We conducted in-depth field studies in the most troublesome area — our Carrosserie Shop. This is an automated area that assembles press-worked panels by inserting them into a jig. They are then formed by hydraulically powered equipment and welded by robots. Almost all of the equipment involved is hydraulic, and the 26 welding robots and auxiliary equipment produce an abundance of weld spatter. The Carrosserie Shop suffered 158 breakdowns in an 8-month period — an average of nearly 20 per month. Of the total, 117 of the breakdowns — about 74% — were attributed to lock-ups and other malfunctions of servovalves.

Each time we examined failed equipment we found that the fluid contained large amounts of weld spatter from the robotic welders. Despite our use of suction and return filters, weld spatter continued to plague the systems. Changes had been made, including sealing parts of the air breathers and cylinder heads, but these changes failed to halt the ingression of contaminants and resultant breakdowns.

Because we had been unsuccessful in keeping weld spatter out of the system, our goal became identifying a purification system that would remove these contaminants as quickly and effectively as possible. After evaluating all the necessary information, we conducted preliminary tests of three off-line, depth-filtration methods. The most effective of these would then be used in an extensive 8-month field test. One system was only 38.2% effective at removing contaminants, another was 41.9%, and a third, provided by Triple R, was 63.7% effective. The Triple R system also proved to be the most energy efficient.

We then incorporated various Triple R filtration systems into the 8-month field tests by incorporating them into all hydraulic power units in the Carrosserie Shop. During the tests, hydraulic fluid contamination was carefully documented, and breakdown rates and maintenance problems were closely monitored. Results revealed that, as a whole, 93.3% of the contamination had been removed. Not surprisingly, this was accompanied by an 86.7% reduction in machinery breakdowns — from 158 in eight months to only 23, which is less than three per month. Of the total 23 malfunctions, only nine were attributed to servovalves — a reduction of over 92%. The less frequent breakdowns resulted not only in higher production rates, but greatly reduced maintenance costs as well.

We now routinely install these off-line types of filtration systems on all new hydraulic machinery equipped with servovalves before putting into production. We also found that because fluid is so much cleaner, we now check filter elements on critical equipment every six months instead of every four. And filters in less-critical equipment is checked only once a year instead of every six months. H&P