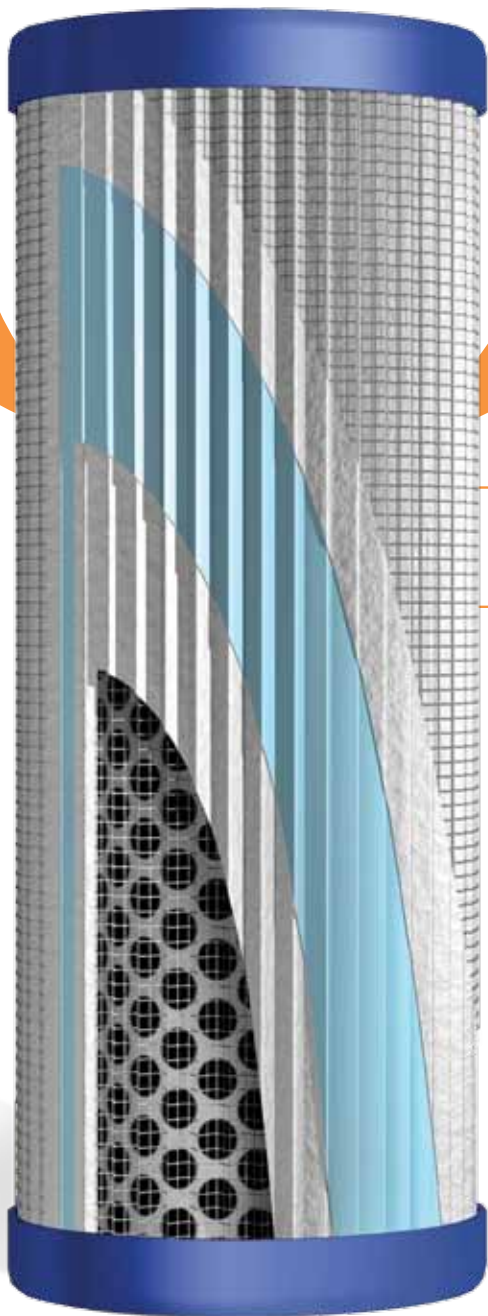


Figure 1.



OPTIMIZED OIL AND FLUID FILTRATION

BY MARTY BARRIS, ENGINEERING DIRECTOR, DONALDSON INDUSTRIAL HYDRAULICS

Optimizing the design of fluid filters requires consideration of structural requirements, chemical compatibility requirements and thermal requirements. To support these important filter design specifications, Donaldson Industrial Hydraulics Group reviewed and redesigned its line of fluid filter elements. The end result was a product line that better met the needs of its customers. This article describes the process.

The correlation between particulate contamination and hydraulic or lube oil system component wear is well known. Every fluid system has suspended particles in its fluid. These contaminants cause wear through a variety of mechanisms, resulting in even more suspected particles. It is frequently quoted that such contaminants are the cause of more than 70% of all hydraulic system downtime.¹

Fluid filtration has long been used to reduce the levels of particulate contamination down to acceptable amounts for the benefit of improved lubricant and hydraulic fluid effectiveness, extended component life and improved system uptime. The level of performance demonstrated by fluid filtration systems, however, still has room for further optimization. Ideally, a filter would remove all particulate matter while creating no pressure loss and last forever. The goal for optimizing the product line was the combination of high efficiency, low initial restriction and long filter life.

Maximizing Media Area

Providing the most in terms of filter media area for contaminant collection and storage is not simply a matter of adding more pleats but a process of optimizing the combination of pleat depth, pleat count, media thickness, thickness of media support layers and thickness of structural screens. The filter media must be as thin as possible, consistent with:

- A design that is low in initial flow restriction
- A media that exhibits a strong contaminant capacity on a per-area basis
- A high and stable in Beta ratio of 1,000 minimum, start to finish
- No Beta ratio fall-off during the end of its life
- No Beta ratio shortcomings at the initial use of a filter

The media support layers, used for media structural support and flow drainage, must also be as thin as possible while performing their design function. In addition to added protection and physical support, these layers assist in enabling the fluid flow to reach the entire media surface and allowing the filtrate to flow through to the inner pleat spaces. They function in concert with the structural screens, which provide the major portion of physical support. In order to maximize available filter media area, the media support layers also need to be as thin as possible, consistent with this structural benefit.

Such an optimization routine has led to a design that exhibits a 47% increased media area over our standard products. Further, this new design provides a media area 15 to 35% more than many of the top-level competitor designs and over 60% more than other competitors' media area. It was determined that polymer screen-based solutions could not compete with this newly optimized design in terms of filter media packaging versus strength.

Improving Structural Support

It was concluded that a steel screen is unsurpassed in terms of physical strength relative to the space consumed, consistent with the design of the filter element. It must have the ability of pleat shape retention in light of physical load changes due to fluid viscosity, fluid flow, contaminant loading and dynamic interactions. The best structural support will space pleats evenly and maintain a uniform

"V" pleat shape, thereby exposing the entire media area to the contaminated fluid flow. As a pleat support, steel wire provides for pleat stiffness, shape retention and uniform spacing in a thin package, leading to higher media area capability, lower initial flow restriction and higher contaminant capacity (Figure 1: Element Construction).

The inner liner of a fluid filter element provides for the



Figure 2a.



Figure 2b.

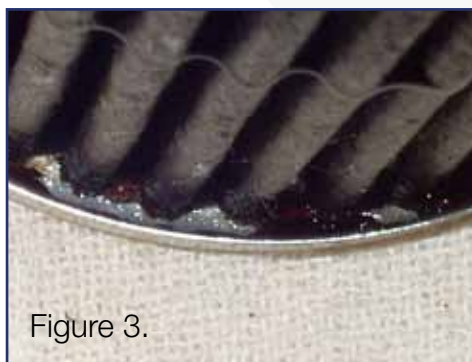


Figure 3.

structural support for collapse resistance in a standard, forward flow (outside to inside) configuration, as per ISO 2491. For high collapse designs (3,000 PSID, 207 bard), a heavy wall cylindrical tube inner liner is used. For standard collapse designs (150 PSID, 10 bard), a spiral wound and interlocked steel tube is used.

To accommodate the higher stresses involved in the high collapse resistant designs, machined aluminum endcaps are utilized. This provides an added level of stiffness and structural support required for filtration integrity in high-stress situations. Coated stamped steel endcaps are used for standard collapse resistance designs (Figure 2: High Collapse and Standard Collapse Endcaps).

Extending Thermal and Chemical Compatibility Considerations

The chemical and thermal compatibility of fluid filters is an increasingly difficult design challenge due to the complex variety of fluid systems. Today's fluid systems are

often tailored towards the special needs of fire resistance, biodegradability and electrical insulating ability. Media utilizing a blend of borosilicate glass fiber whose matrix is bonded together with an epoxy-based resin system was found to provide the best available chemical resistance for the broadest array of hydraulic, fuel and lube oil filtration applications. Conducted surveys revealed that not all filter media resin systems make use of this more chemically resistant material.

Potting material should fully engulf the ends of the filter media to prevent leaks but also be made of a material that can withstand the rigors of the application--structurally, thermally and chemically. This continuous use of epoxy for bonding and sealing provides the best chemical compatibility for the broadest array of fluid filtration applications. As described in Table I, epoxy is compatible with most fluids.

Chemical incompatibility can lead to filter degradation and leaks. The sealant that is used to join the filter media to the endcap can literally be dissolved with a chemical mismatch. Figure 3 (Chemical Damage To Endcap Sealant) shows the degradation caused in the potting compound (polyurethane) when exposed to Polyalkylene glycol fluid.

Whereas polyurethane for potting and other seals work fine in applications such as petroleum-based fluids, water glycols (HFC fluids), polyol esters (HFD fluids), it does fall short, specifically in HFA, HFB, PAG, phosphate ester and diester applications. Plastics similarly are fine for petroleum-based fluids but fall short for other more severe applications. Epoxy bonding, potting and seaming are necessities for higher-temperature applications and for use with phosphate esters and the high water-based fluids listed above.

The other major area of chemical compatibility is the seal material choice, typically in the form of an o-ring. While the most common material used is Buna N rubber, it is less chemically compatible with certain fluids. These include phosphate esters, diesters and some higher-temperature applications. Chemical and thermal compatibilities are listed in Table II (Chemical Compatibility of Seals).

Specifically, fluorocarbon seals are recommended for diesters, phosphate esters and higher-temperature applications. *EPR (Ethylene Propylene Rubber) is recommended for certain phosphate esters used in Skydrol/Skydrol 500 fluid. The thermal range is -65 to 300°F (-54 to 149°C).

Results

Industry standard ISO tests were conducted on the optimized filter element design to gauge its performance relative to its peers. Both particle contamination capacity and initial flow restriction tests were performed. The evaluations confirmed an average of nearly 80% improvement in particulate capacity over the standard product, and as much as a 58% improvement over the top-level competitors' capacity.

Regarding the initial restriction, the new designs reflected the decisions for low pressure loss and were even more dramatic, averaging only 53% of the standard product and about 76% of the competitors' restriction over the range of filter media grades offered.

References

1 Rabinowicz, E., "Friction and Wear of Materials," 2nd ed., July 1995, John Wiley and Sons (ISBN 047-1830844)

* Skydrol® is a registered trademark of Solutia, Inc.

TABLE 1

PETROLEUM BASED FLUIDS	FIRE RESISTANT FLUIDS	BIODEGRADABLE FLUIDS
Straight oils Automatic transmission fluids Military hydraulic fluids	Phosphate esters (HFD fluids for electrical insulating/fire safety) Polyol esters (HFD) High water based fluids (fire and environmental concerns) Oil/water emulsions (HFA fluids: 5%/95% oil/water) Water/oil invert emulsions (HFB fluids: 60%/40% oil/water) Water glycol (HFC fluids: 60%/40% glycol/water)	Vegetable based oils (natural esters) Sunflower, rapeseed oils Synthetics – water-free, HFD fluids Diesters Polyalkylene glycol (Plurasafe® EnBio TC® S fluid*) Polyol esters (HFD)

* (Plurasafe® and EnBio TC® S are registered trademarks of BASF and EnBio Industries, respectively.)

TABLE 2
Chemical Compatibility
of Seals

FLUID	FLUORO-POLYMER (VITON®)	BUNA N RUBBER
Petroleum based fluids	×	×
Oil/water emulsions (HFA: 5%/95% oil/water)	×	×
Water/oil invert emulsions (HFB: 60%/40% oil/water)	×	×
Water glycol (HFC: 60%/40% glycol/water)	×	×
Water	×	×
Most Phosphate esters* (HFD: electrical insulating/fire safety)	×*	Not recommended
Polyol esters HFD	×	×
Diesters	×	Fair only
Ethylene glycol	×	×
Polyalkylene glycol (Plurasafe® EnBio TC® S fluid)	×	×
Temperature range	-20°F to 350°F -29°C to 177°C	-65°F to 250°F -54°C to 121°C

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