HY-PRO

What is Dynamic Filter Efficiency?

By now you probably have heard of Dynamic Filter Efficiency (DFE). If not, be prepared to discover an evolution in filter testing and development.

Until now, steady state testing has been the only form of multipass testing available for users and manufacturers for evaluating filter performance. ISO16889, which is the latest standard for such testing, was adopted in December 1999 as an improvement over its predecessor ISO4572. Larson Testing Laboratories of Fishers, Indiana began development of DFE in 1997 as a means to improve performance and efficiency in filter element development for Hy-Pro Corporation. Their research began after a servo valve company began experiencing contamination related failures with a competitor's product. DFE also sparked the attention of a mobile equipment OEM proclaiming they had seen the phenomenon of "unloading" in their lab but couldn't explain it. Other interested parties include several U.S. government agencies and military services. DFE testing is revolutionizing multipass filter testing, allowing the filter development envelope to be pushed. After being made public in 1999, DFE has been proposed to both the NFPA and SAE committees as a new standard for multipass testing.

In order to understand DFE, lets first review the basics of the Multipass test. The test consists of a closed hydraulic circuit in which fluid circulates through a filter while a known quantity of contaminant is gradually introduced into the system. The fluid makes repeated passes through the system and the level of contamination is measured both upstream and downstream from the filter to determine how efficiently the filter element removes the particulate and approximately how much particulate the filter element can retain.

ISO16889 specifies that filter elements will be tested at one flow rate throughout the life of the test. The question is, how many filter elements operate in such a friendly environment? Very few! DFE bridges the gap between ideal lab simulation and real world operating conditions by cycling the flow rate up and down between two flow values throughout the test. Thus DFE combines the concepts of flow fatigue and multipass testing to truly show the vital signs of a filter element in a real life system. In addition, vibration analysis is included. (This is another feature of DFE testing that is not addressed by current multipass test methods.) Every hydraulic system is subject to vibration generated either by the pump in the form of pressure pulsations (pump ripple) or actuation and movement of equipment. Vibration can have an adverse effect on filter element performance especially if one or more of the frequencies in the system coincide with the harmonics of the filter element. If this occurs, the excited element can resonate and release most of the contaminant previously captured. The DFE test procedure monitors the vibration characteristics of the filter element throughout the life of each test to assure that an element does not operate at a harmonic frequency across the performance envelope.

Test

A series of tests on similar elements from different manufacturers were performed to compare performance under ISO16889 and DFE. The results were surprising! Filter elements developed and tested under current ISO standards did not perform as well when subjected to DFE testing (for test assumptions see table 1). Depending upon the manufacturer, there were different phenomenon that occurred including unloading, media breakdown, and reduced capacity.

Table 1. ISO16889 & DFE multipass parameters

Flow rate	30gpm (15gpm low flow for DFE)
Gravimetric injection rate	3mg/l
Test temp	100f
Viscosity	150 SUS
Test contaminate	ISO medium test dust
Test fluid	MIL-H-5606
Terminal DP	60 psid
Filtration Ratio (Beta Ratio)	$\beta 5_{[c]}$ = 200

a. Unloading. When the flow was cycled up and down a range from 15gpm to 30gpm there was a tendency for the elements to unload particles during the transitional periods releasing clouds of contamination downstream from the filter. Shortly after a flow change the fluid cleanliness would stabilize, but there were noticeable decreases in efficiency (dynamic efficiency). The unloading was most drastic when increasing the flow from 15gpm to 30gpm, but also occurred when reducing the flow from 30gpm to 15gpm (see figure 2). These clouds of contamination can move the cleanliness level in and out of the acceptable ranges required by manufacturers to minimize component failure. The clouds typically consisted of very high concentrations of silt with larger particles that would never pass during the steady state conditions of ISO16889. The unloading phenomenon can be attributed to a combination of circumstances. The compression/relaxation of filter media related to flow velocity variations could cause changes in the fiber matrix of the media related to either the internal support structure of the media or the substrate and pleat support structure that is critical to filter element performance. There is also the element design itself related to pleat count, pleat spacing, and pleat height.

b. Media Breakdown. Some of the test elements showed integrity problems when simultaneously challenged with contamination and cyclical flow rates. As the test went on, not only was there a decrease in efficiency at flow change sequences, some elements displayed a continual decay in overall filter efficiency (see figure 3). The element illustrated in figure 3 was true to it's rating of B10[c] = 200 (99.5% removal efficiency) at a clean pressure drop of 2psid, however at 34psid and after several flow changes, the same element had a filtration ratio of B10[c] = 7 (85.8% removal efficiency). The frightening result was, a filter element that starts out providing a rated cleanliness level becomes an inferior performing filter element once the system subjects it to real world conditions. (The DFE test affords the opportunity to look at snapshots of the filter element's performance without being skewed by time-weighted averages.)

c. Reduced Capacity. In analyzing the dirt capacity of the test elements, some displayed a reduction in capacity when tested to DFE standards. The test elements showed the dirt capacity using the ISO16889 test was 32 grams and the dirt capacity using the DFE test on similar test elements was 26 grams. A reduction of about 23%. (See table 2)

d. Performance Summary. There were a variety of characteristics displayed during the comparison between DFE and ISO16889 that include fluctuating (dynamic) efficiencies, lower aggregate/time weighted efficiencies, clouds of contamination, and media breakdown (integrity) issues. Throughout the testing one fact rang true, the performance of every element tested was worse when tested under DFE than it was under ISO16889.

Table 2 DFE and ISO16889 performance comparison of figures 1 and 2

	DFE % efficiency	ISO 16889 % efficiency	DFE Ratio	ISO 16889 Ratio
Ave. $\beta 5_{[c]}$	99.28% *	99.59%	140 *	247
High $\beta 5_{[c]}$	99.14% *	99.59%	117 *	247
Low $\beta 5_{[c]}$	99.56%	N/A	229	N/A
High to Low flow change $\beta 5_{[c]}$	98.69% *		76	N/A
Low to High flow change $\beta 5_{[c]}$	97.71% *	N/A	45	N/A
Dirt Capacity	26 grams	32 grams		

* Note: $\beta 5_{[c]}$ = 200 is considered to be absolute 99.5%

Table Summary Observations
The DFE test element had a lower average efficiency for all high and low flow sequences, that was actually below the manufacturer's element rating.
The DFE test element was least efficient during flow change sequences.
The DFE test fluid showed higher fluid contamination per the ISO cleanliness codes at all sequences, and was most contaminated during flow changes.
The test element had a reduced capacity vs. the steady state test.

This latest filtration discovery goes a long way in supporting the argument that all filter elements are not created equally. Often driven by cost reductions, users agree to integrated supply contracts committed to hard cost (price) reductions each year without specific knowledge of how they will achieve such a goal. For example, when a list of filter elements goes out for bid and several suppliers submit quotations there may appear to be an opportunity for hard cost savings based on price. However, if the replacement elements save 10% on unit cost but have only half the life, where are the savings? Filtration is a compromise and the true cost of filtration is not necessarily the price of the filter element. Shorter life means more frequent element servicing, which requires more elements and more maintenance hours. With more frequent servicing, there are more shutdowns and more equipment downtime. Also, if filter efficiency is sacrificed because of integrity issues, there is a greater possibility of contamination related component failures. These soft cost issues can be difficult to measure, but are important components of the life cycle cost equation. What is the value of saving a few dollars on an inferior element when the result might be expensive repairs or replacement and equipment downtime? Despite an increasing perception, high performance hydraulic and lube filter elements are not a commodity item. With more domestic and foreign manufacturers entering the North American filter market and a move toward synthetic filter element components for disposal by incineration, the performance characteristics of filter elements in real world conditions can only be defined by DFE testing.

> The bottom line is that filter elements not tested to DFE standards may neither deliver their rated performance nor maintain desired minimum required system cleanliness at all times. When a valve or pump manufacturer specifies a fluid cleanliness level this means at all times, not most of the time.

DFE testing affects everyone who comes in contact with a hydraulic or lube filter element. For more information on Dynamic Filter Efficiency testing contact Larson Testing Laboratories or Hy-Pro Corporation (filter manufacturer)

Figure 1. ISO16889 Steady state efficiency curve.

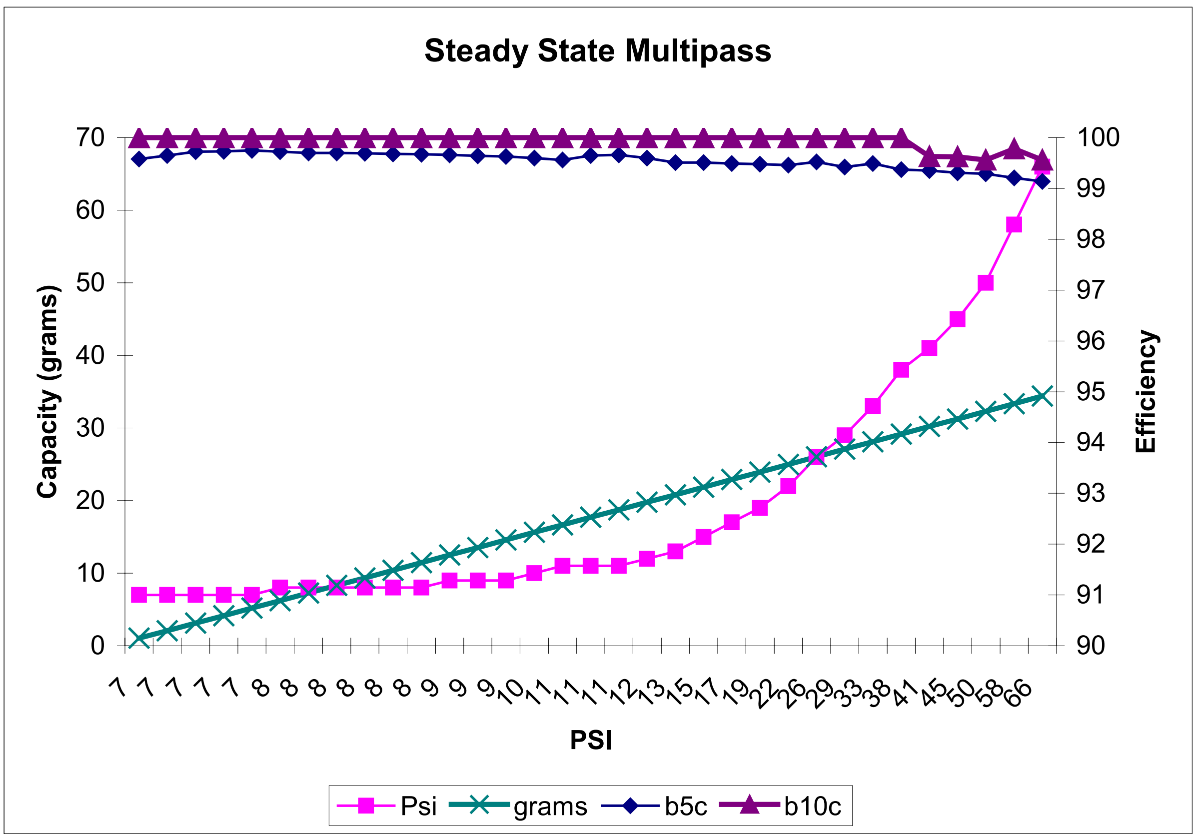


Figure 2. DFE efficiency curve that reflects unloading.

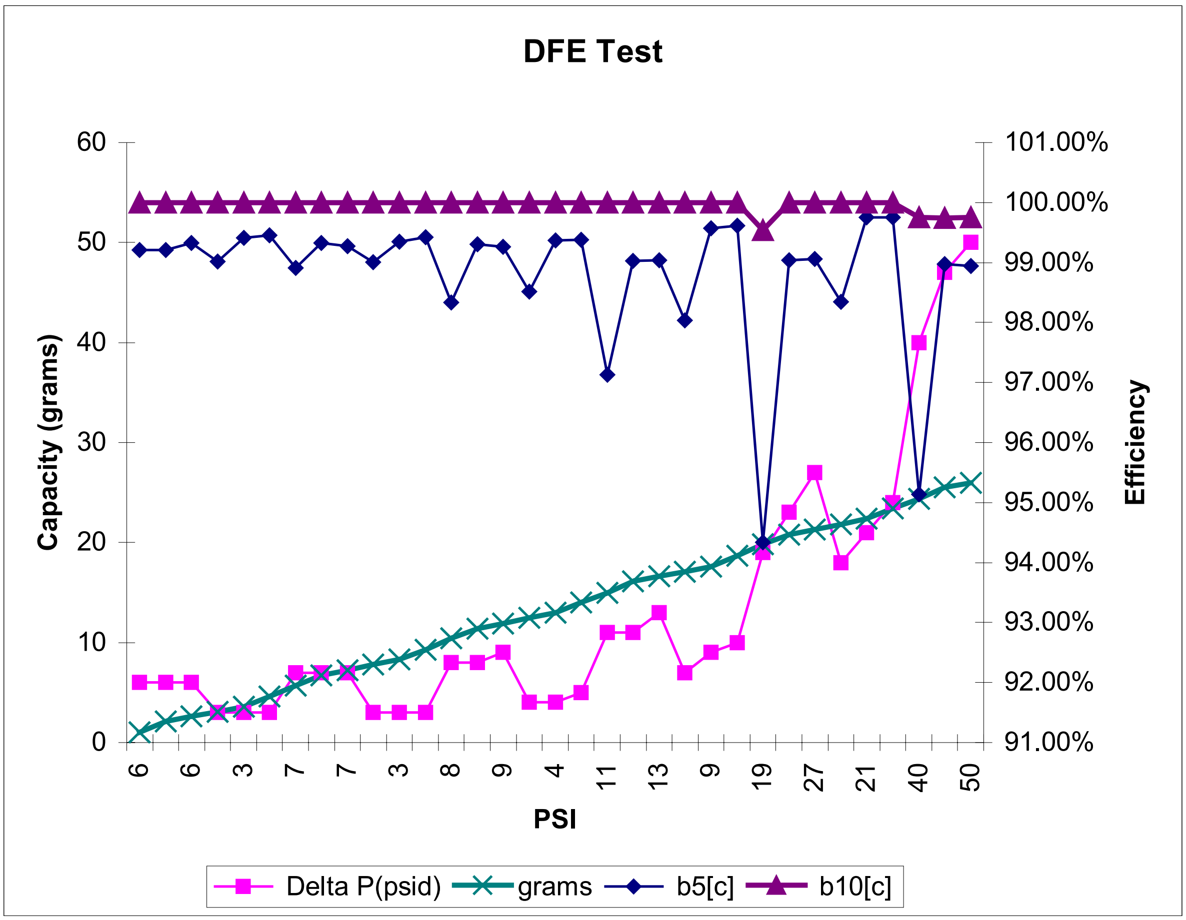
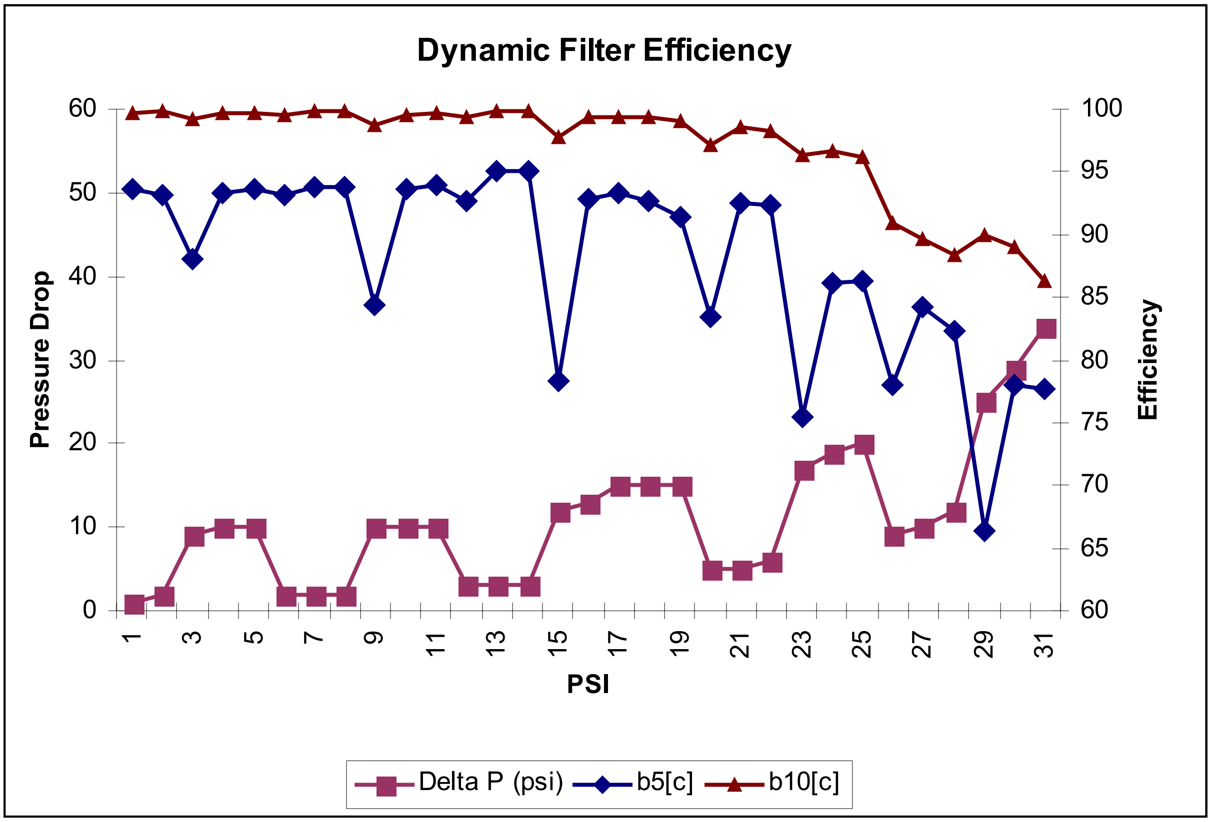


Figure 3. Unloading with media breakdown.



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