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A New Method For Combination Full-Flow And Bypass Filtration: Venturi Combo

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ABSTRACT

The Venturi Combo Lube Filter (VCLF) is a new method for achieving a bypass level of filtration. The new product employs a unique venturi type nozzle with a full-flow and bypass type filter element. Plumbing is much simpler and differs significantly from conventional full-flow/bypass filtration systems. Internally, the VCLF's components are arranged to direct and force fluid through the restrictive/efficient bypass media at a much higher flow rate than conventional systems. The increased flow rate yields improved performance which has been proven via laboratory and field tests. In addition, a parasitic pumping loss (bypass filter flow) is removed.

INTRODUCTION

This paper introduces a new product referred to as the VCLF and its use in a particular application - lubrication systems of internal combustion engines. Specifically, topics covered include why the new product was developed, how its performance compares to a benchmark product, and product benefits.

BACKGROUND

Current engines generally employ one of two forms of filtration to clean the lubricating oil. One method is full-flow filtration and the other is combined full-flow and bypass filtration. Full-flow filtering elements receive and filter 90 to 100% of the regulated oil pump output prior to supplying the oil to the engine's lubrication system. Due to the need to filter a relatively high flow rate of oil, the full-flow is typically designed using more porous media than bypass filters. The higher porosity allows high oil throughput while yielding a desirably low pressure drop. Thus, the full-flow provides continuous engine protection by constantly removing relatively large particles.

Full-flow filters are frequently augmented with bypass filters. Bypass filters, as indicated by their name, are placed in a flow path that bypasses the engine's main oil lubrication system. Typical bypass filters receive only five to ten percent of the regulated pump output, and serve to "superclean" the oil. "Supercleaning" is accomplished by use of a relatively low porosity media. To force oil through this tight media, high pressure oil is supplied to the bypass filter inlet while the filter's outlet is essentially at zero pressure (exit flow is routed to the non-pressurized oil pan). Hence, a high pressure differential drives the flow through the bypass filter. Since the bypass flow is pumped expressly for filtration and does not directly flow to the engine's main lubrication system, it is a parasitic pumping loss. To limit the amount of the parasitic bypass flow, a restrictive orifice is generally inserted between the bypass filter and the oil pan.

Of the two filtration systems discussed, the combination system (both full-flow and bypass filtration) provides the most engine protection, yet it is likely to be more costly than a full-flow system alone. Therefore, the VCLF product was designed to provide the benefits of the combination filtration system while minimizing costs and complexity. The objective was to put the total filtration system in a single container and eliminate the additional plumbing associated with bypass filters.

Considering that the new product was designed to provide a bypass level of filtration (in addition to full-flow filtration), the benefits of bypass filtration are provided for reference in the following section.

ADVANTAGES OF BYPASS FILTRATION

The bypass filter has two basic functions: provide very high filtration efficiency and provide a high capacity for holding contaminant. The design intent is to place the bulk of contaminant removed in the bypass filter while leaving the full-flow filter relatively clean. A "clean" full-flow is advantageous for maintaining easy oil throughput during normal engine operation and especially during cold starts. A restricted full-flow impedes the flow of oil during a cold start. Consequently, there is an increase in the time to get oil to critical engine components and/or an excessive time that the filter bypass valve is open. Both situations (time delays and open bypass valves) are detrimental to engine health.

The quantified merits of bypass filtration are well documented in technical literature. Studies by Stehouwer [1] in Figure 1 demonstrate a key function of bypass filters to be removal of organic material (sludge, varnish, resin, soot, unburned fuel, etc.). His work shows that over 80 % of the contaminant removed by the bypass filter is organic. The values of organic material removal are:

- reduced wear
- protection of the full-flow filter
- reduced deposits (deposits will impede heat transfer in critical areas such as oil coolers)

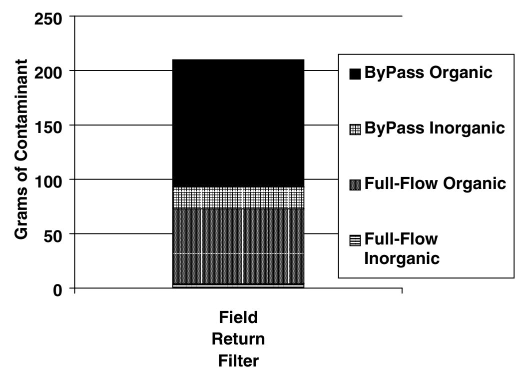

Figure 1: Contaminant Captured in a Field-Return Combination Full Flow and Bypass Filter

A field study [2] confirmed the real world benefits of bypass filtration. As shown in Figures 2 and 3, component wear was reduced over a range of 7% to 64% as a result of adding a bypass filter.

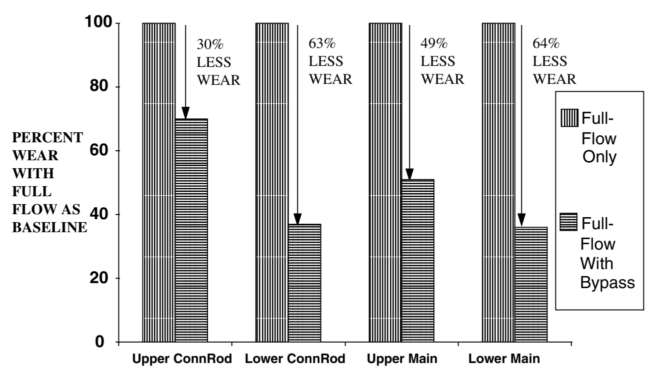

Figure 2: Bearing Shell Wear Reduction via Bypass Filtration

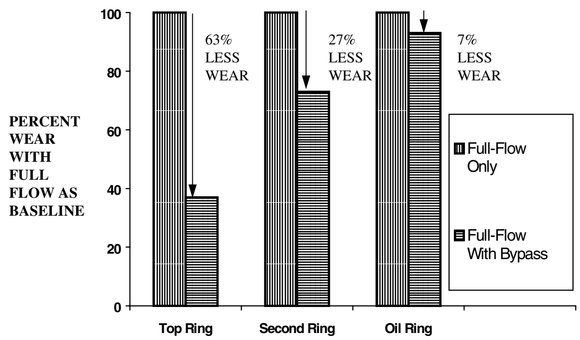

Figure 3: Ring Wear Reduction via Bypass Filtration

In another study [3], engine testing was conducted to compare the wear protection provided by three different filtration systems. The baseline system used full-flow filtration only. The "test" filtration systems included the full-flow filter in conjunction with two different bypass filter designs. The two types of bypass filters were a highly efficient pleated element and a stacked disk element. Wear test results in Figure 4 showed a reduction in wear when using the pleated bypass element over only a full-flow element. However, the use of a stacked disk element virtually eliminated the wear. Therefore, it is demonstrated that using the proper bypass filter design is key to achieving maximum wear protection.

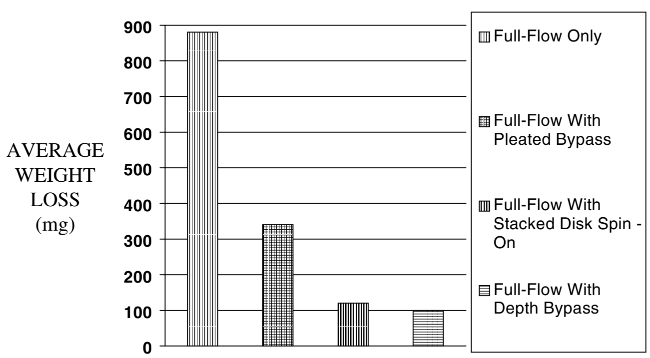

Figure 4: Rod Bearing Wear as Related to Filtration Type

PRODUCT DESCRIPTION

BENCHMARK: COMBINATION LUBE FILTER (CLF, or Fleetguard LF3000) - To facilitate evaluation of the VCLF a benchmark product was selected for comparison. The benchmark is the CLF (Figure 5) which is fully described elsewhere [4]. It consists of a full-flow filter and a bypass filter in a single-container. This product replaced two separate containers and has provided proper engine protection for over 11 years. It is used today on six different diesel engine models ranging from 8.3 to 19 liters displacement. Hence, meeting or exceeding this product's performance is a suitable filtration goal for the VCLF.

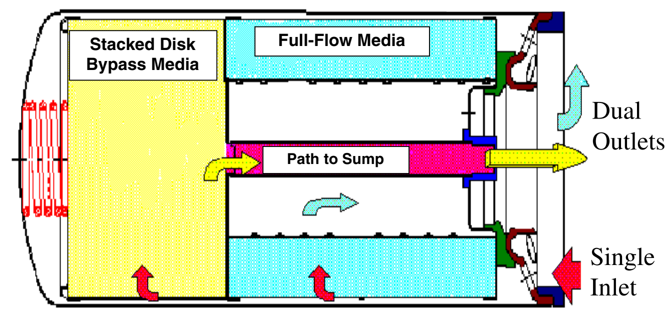

Figure 5: CLF Reference/Control Dual Element Filter with Single Inlet, Dual Outlets

The CLF operates as follows: fluid flows from the engine through the filter inlet, and part of the flow passes through the full-flow section while the remainder passes through the bypass section. Approximately 90% - 95% of the fluid flow passes through the full-flow section and then to the engine's main lubrication system. The bypass flow exits the filter and passes to the engine oil pan via a secondary flow circuit which includes a flow-limiting orifice (Figure 6). The complexity of having a secondary flow circuit adds cost (vs. a full-flow only filter circuit).

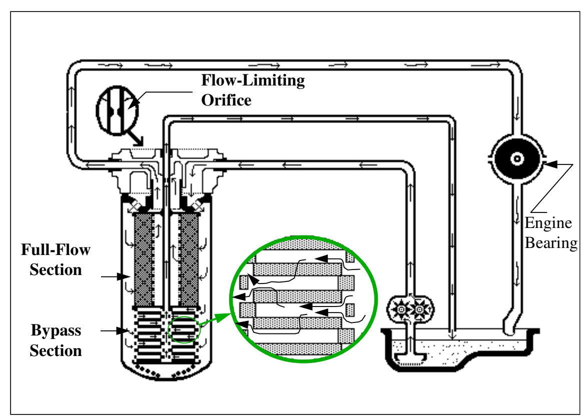

Figure 6: Combination Lube Filter Circuit

NEW PRODUCT: VENTURI COMBINATION LUBE FILTER (VCLF) - Considering the proven performance of the benchmark product, the VCLF was developed [5-7] to retain or exceed CLF filtration performance while eliminating the special engine plumbing (separate bypass circuit). Like the CLF, the new product contains both full-flow filter media (FFM) and bypass type filter media (BPM) in a single container (Figure 7). A key feature of the VCLF design is the increased utilization of the high capacity, high efficiency BPM. Specifically, the intent is to capture the bulk of the contaminant in the BPM while allowing the FFM to remain relatively clean. Thus, the FFM can provide continuous low-pressure-drop filtration.

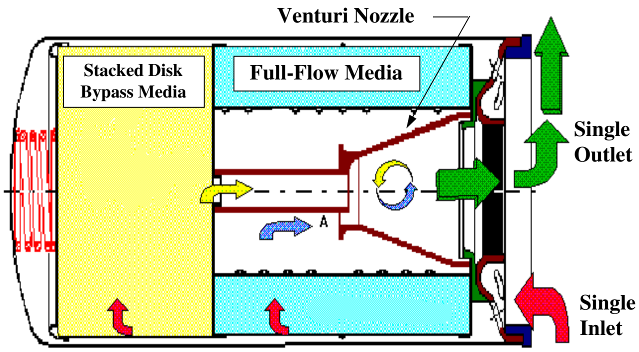

Figure 7: VCLF with Single Inlet, Single Outlet, Venturi Nozzle
Patent Pending

To achieve design objectives, the VCLF forces considerable flow through the BPM. It flows approximately two to three times the rate of conventional BPM's as shown in Figure 8.

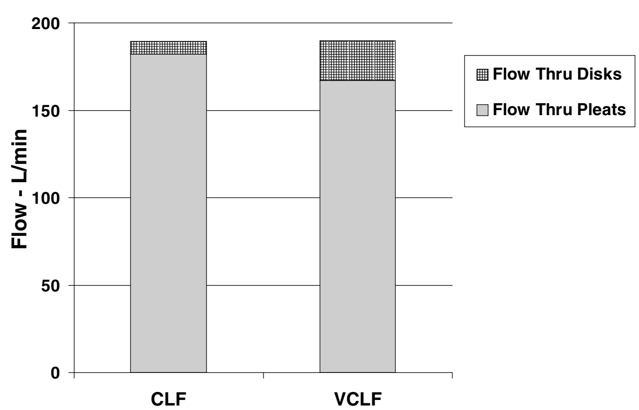

Figure 8: Flow Split: CLF Vs. VCLF @ 189 L/min

The operation of the VCLF is as follows: similar to the CLF, the FFM and BPM share a common inlet. However, the VCLF employs a venturi nozzle (patent pending) to direct and force/pull oil through the BPM at a high flow rate. The higher flow rate is accomplished via these flow mechanisms: the flow through the freer-flowing full-flow element is restricted by the nozzle throat at nozzle inlet "A" (Figure 7), forcing more flow through the bypass type media. A low pressure zone in the throat of the nozzle generates a suction at the outlet of the bypass media, pulling more flow through the tight bypass section.

The BPM and FFM flows then merge inside the filter, thereby sending 100% of the filtered flow to the engine's lubrication system. The system is made energy efficient by the use of a nozzle diffuser which reduces the fluid's velocity to recover a portion of the pressure drop lost in the nozzle throat (ref. Bernoulli's equation).

Note the VCLF has only one outlet versus two in the CLF. The single outlet simplifies engine plumbing. Also, elimination of the companion engine bypass flow circuit eliminates parasitic bypass flow. Having one filter inlet and outlet means existing applications which use full-flow-only filters can easily apply the VCLF with no equipment/engine modifications.

Since the fluid passing through the VCLF's bypass-type medium is not returning to the engine oil pan, bypassing the engine's lubrication system, the VCLF cannot technically be called a bypass filter. The VCLF is an enhanced "two stage" full-flow filter. The enhancement is the increase in flow rate through the tighter "stage" by the use of the venturi nozzle.

PRODUCT PERFORMANCE

LABORATORY RESULTS - One of the laboratory test methods used to evaluate the CLF and VCLF, the multipass test, is an industry standard [8]. The multipass laboratory tests were conducted at a flow rate of 189 L/min and a terminal pressure drop of 172 kPa. A minimum of eight tests was run on each product. Results presented are averages.

The products were also evaluated via field testing combined with a unique laboratory procedure for used filter analysis. The unique procedure entails removing a section of filter material, extracting the used oil, then determining unit weight gain. That weight gain is then extrapolated to total filter weight gain (i.e., total contaminant trapped by the filter). Subsequently, the filter section is incinerated in a controlled manner to determine contaminant make-up. Contaminant which will not burn (spent oil additives, wear metals, dirt, core sand, etc.) is referred to as inorganic. The contaminant which does burn (resin, unburned fuel, soot, sludge, varnish, etc.) is referred to as organic.

Laboratory test results are shown in Figures 9 through 12. Figure 9 shows the multipass efficiency. The VCLF slightly out-performs the CLF. Figure 10 shows multipass capacity. Again, the new product outperforms the control product. Flow versus restriction is shown in Figures 11 and 12. Whether high or low viscosity oil is used, the VCLF has the lowest restriction to oil flow. The lower pressure drop is attributable to the added flow through the tight filter stage and the pressure recovery nozzle.

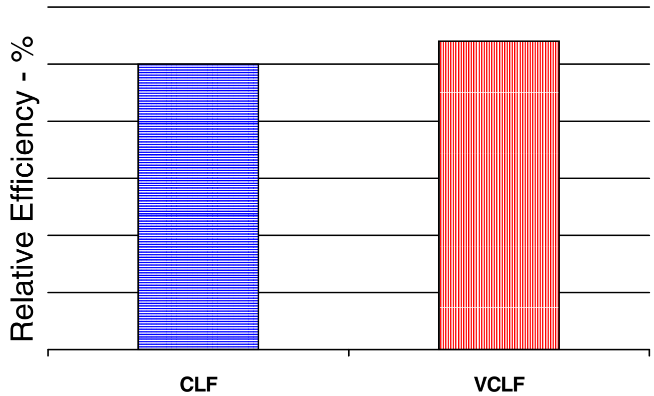

Figure 9: Laboratory Dust Efficiency
(Removal of Particles > 10 Micrometers)

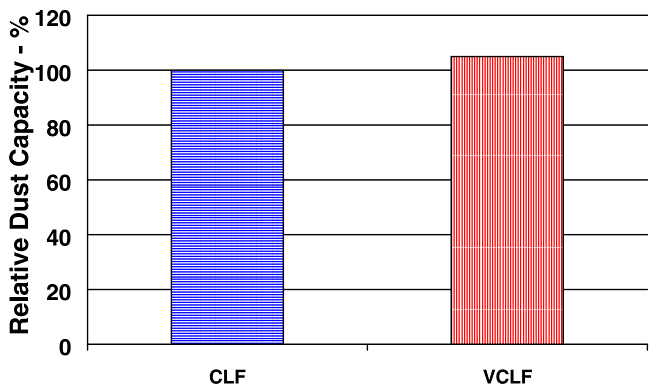

Figure 10: Laboratory Dust Capacity

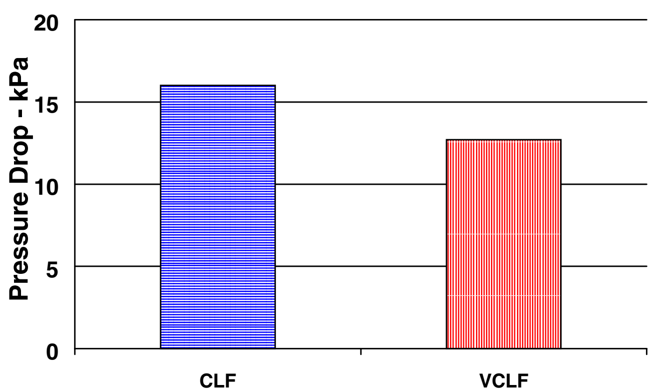

Figure 11: Resistance to Low Viscosity
(6.5 cSt) Oil Flow at 114 L/min

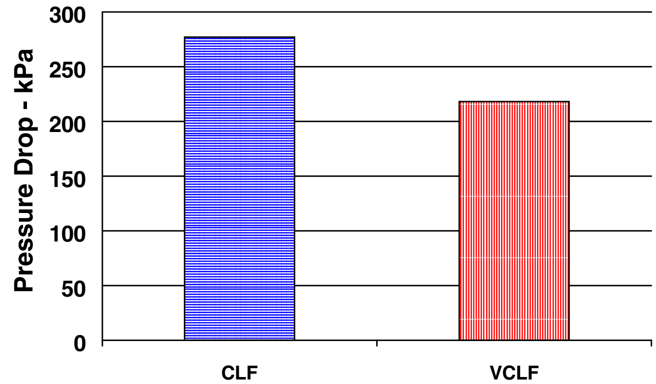

Figure 12: Resistance to High Viscosity
(3500 cSt) Oil Flow at 23 L/min

FIELD RESULTS - Field tests were conducted on 20 engines [9] at two on-highway trucking fleets. At each fleet five engines ran control product (CLF) and five were modified (attachment/plumbing) to run test product (VCLF). Fleet A engines were Cummins 430 N14 Celect. Freight loads were generally the maximum legal limit of 176,000 kg. Filter and oil change intervals were approximately 40,000 km. Fleet B engines were Cummins 350 N14 Celect. Freight loads were generally less than 100,000 kg. Filter and oil change intervals were approximately 50,000 km. At both fleets, engines were plumbed to permit pressure drop measurements across the filters. The test duration was nine months.

Since filtration differences based on filter hardware design were the main interest areas of the field test, all filters (control and test) were produced from the same media lots (for full-flow and bypass types of media). Product durability was also measured in the test, and all products were equally durable.

Field test results (shown in Figures 13 through 15) for Fleets A and B are much more meaningful than laboratory tests. Each data point shown is an average of 5 data points. Also, to take into account different change intervals, the data are normalized to grams per 10,000 kilometers.

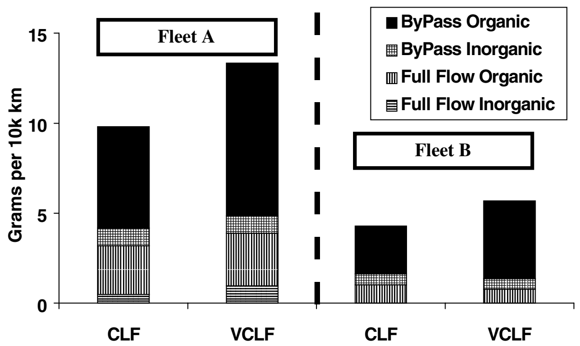

Figure 13: Filter-Captured Contaminant
(Type and Location within Filter)

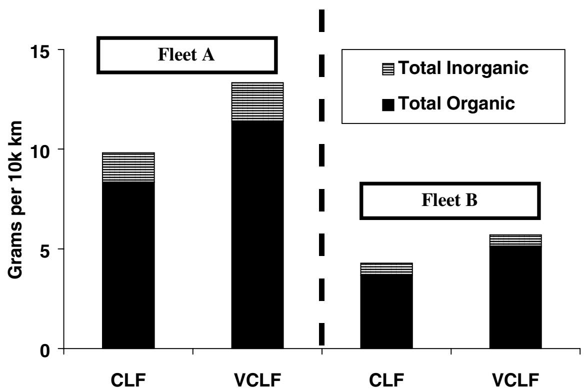

Figure 14: Filter-Captured Contaminant
(Organic Vs. Inorganic Values)

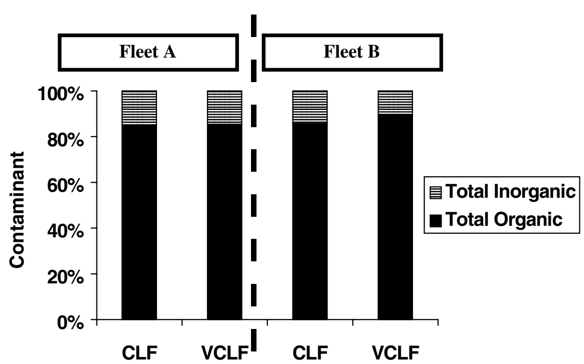

Figure 15: Filter-Captured Contaminant
(Organic Vs. Inorganic Percent)

The data shown compare the total amount and type of contaminant trapped by the two filter types and the location in which the contaminant was captured (pleated full flow type section or stacked disk bypass type section). Five key points can be made from the figures:

1) For both fleets, the VCLF removed substantially more contaminant (Figures 13 and 14).

2) The additional contaminant removed by the VCLF was trapped primarily in the stacked disk section. This is logical, considering the flow rate through the VCLF stacked disks was more than twice that for the CLF stacked disks.

3) Figure 15 shows the majority (over 80%) of contaminant trapped by both filter types was organic (sludge, soot, unburned fuel, varnish, resins, etc.) in nature.

4) Although the stacked disk media occupies only about one-third of the filter volume, it has captured (for both filter types) two-thirds of the total contaminant trapped by the filter (Figures 13 and 14). Hence, the concept of using a bypass-type filter medium to protect the full-flow medium from premature plugging is well demonstrated.

5) The amount of contaminant captured by the filter appears to be related to engine rating and duty cycle. Specifically in Fleet A, with higher horsepower engines and higher loads, the quantity of contaminant removed was substantially more than for Fleet B.

As a matter of documentation, the pressure drop across the pleated and stacked disk filter sections (all filters) was monitored during the field test. None of the filter sections had any substantial increase in pressure drop.

PRODUCT ADVANTAGES FOR THE ENGINE MANUFACTURER

The VCLF design offers three key benefits to an engine manufacturer interested in providing a bypass level of filtration for engine protection:

1. Plumbing Reduction: With the VCLF design, engine plumbing can be simplified from designs currently using full-flow and bypass filters. The new design eliminates the need for two filter heads (if using separate filters). It also eliminates the need for a bypass loop returning oil to the pan. Elimination of a bypass loop or filter head can simplify engine design and reduce manufacturing costs.

2. Parasitic Loss Removal: Engine manufacturers can eliminate the parasitic losses associated with a bypass filter, thereby increasing engine operating efficiency.

3. Easy Filtration System Upgrade: Engine manufacturers currently using only full-flow filters can begin offering a bypass level of filtration without design changes or added cost to the base engine.

PRODUCT ADVANTAGES FOR THE ENDUSER

Obviously, any advantages gained by the engine manufacturer are also benefits to the enduser. Additionally, the VCLF provides the enduser with a simple upfit option as he can apply the new unit without engine changes. Hence, he gains a simple means of achieving the benefits of bypass level filtration.

SUMMARY

A new product (VCLF) has been developed that offers benefits over conventional filtration systems in two categories:

1. Hardware/Design: In systems where bypass filters are applied (often in diesel engines), the VCLF provides these advantages:

   a) Simplifies filter and system plumbing with substantially reduced system complexity and costs
   b) Removes a parasitic oil pumping loss (engine bypass fluid pumped to pan)
   c) Permits users to install the new product anywhere a full-flow-only filter is installed, thereby easily reaping the benefits of bypass level filtration

2. Filtration Performance: The VCLF outperforms the proven control product in the following ways:
   a) Laboratory capacity and efficiency
   b) Field tests comparing quantity of contaminant removed

The filtration benefits are achieved via increased utilization of high capacity, high efficiency bypass-type media.

ACKNOWLEDGMENTS

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