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Subject: THROWAWAY FUEL FILTER
OPERATING FUEL LEVELS

It has been brought to our attention that numerous customers have discontinued the use of Cummins-Fleetguard throwaway fuel filters (FF-105, FF-104, FF-4 and FF-5) and have adopted the use of certain competitive filters of inferior structure and efficiency because they have observed that:

1. The Cummins-Fleetguard filters are only partially filled with fuel when removed from engines where the supply tank is below the filter.

2. Certain competitive filters are full of fuel when removed from the engine.

Based on these two observations, the following erroneous conclusions are reached.

1. Full utilization of the paper in the Cummins-Fleetguard filter is not being obtained.

2. The void or air cavity in the Cummins-Fleetguard causes throttle response problems.

The purpose of this letter is to advise of the technical reasons as to why the Cummins-Fleetguard fuel filter is partially filled with fuel when removed from engines and warn of the fuel system damage being caused by use of competitive filters which are full of fuel when removed from engines.

Filter flow tests utilizing transparent windows in the filter can or shell and element, transparent fuel lines and filter structure comparisons reveal that:

1. Operating fuel levels

   During engine operation (all speeds and power settings) the fuel level on the inside of the paper element (clean side) is at the top. The fuel on the inside is solid with no air cavities or voids. The fuel level on the outside of the paper element (dirty side) is 3 to 4 inches below the top of the element as shown in Figure 1.

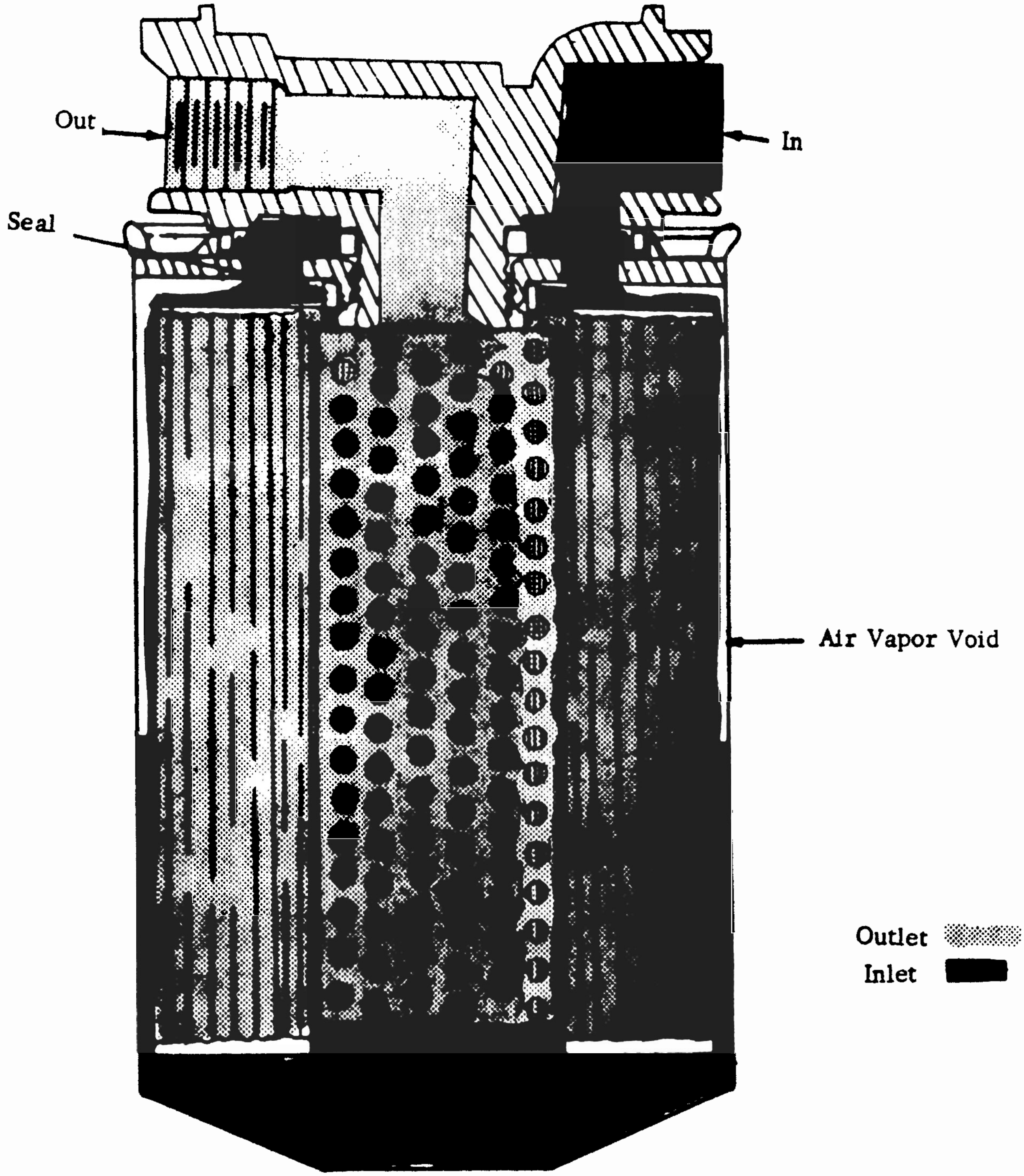


Figure 1

There is no foam in the void.

The void or air-vapor cavity is caused by the phenomenon of wetted porous paper resistance to air or vapor passage. The magnitude of resistance to vapor passage is dictated by paper pore size and fuel film strength or surface tension. Decreasing the paper pore size increases the resistance to vapor passage. Increasing the fuel film strength increases the resistance to vapor passage. Fuel passes readily through the paper in the area where the vapor void exists and fuel can be seen running down the outside of the paper.

The source of the vapor is the fuel itself. Like water, fuel contains a certain amount of dissolved air depending upon the fuel temperature, pressure on the fuel, specific gravity and the amount of aeration to which the fuel has been subjected. Reducing the pressure on the fuel or increasing the temperature of the fuel releases the air. The amount released depends upon the degree of fuel saturation with air and the magnitude of pressure reduction or temperature increase.

To illustrate the phenomenon of wetted porous paper resistance to air or vapor passage, the following test can be conducted:

A. Provide a means of sealing the open end of the paper element and a means of supplying air under low pressure inside the element.

B. Thoroughly wet the element by pushing the element down into a container of fuel, open end up (open end not sealed) such that the inside fills due to fuel passage through the paper and then lifting the element out and let it empty itself by fuel draining through the paper. Do this several times.

C. Lift the element out of the fuel. Let it drain until empty. Apply the end seal and attach the air supply source and a manometer as illustrated in Figure 2.

D. Submerge the element in the fuel until the upper end is 1/8 to 1/4 inch below the fuel surface.

E. Increase the pressure inside the element slowly and note the pressure when the first minute air bubbles appear.

The Cummins-Fleetguard element will withstand a pressure of approximately 10"H_2O before air passage through the paper occurs. This is under static conditions. Under dynamic or operating conditions, this pressure is lower.

Note: The competitive filters tested which were full of fuel when removed from engines would support no pressure when tested as described above because of paper to element end cap bonding leaks (poor bonding). After patching the bonding leaks, the competitive elements would support a pressure of 7"H_2O.

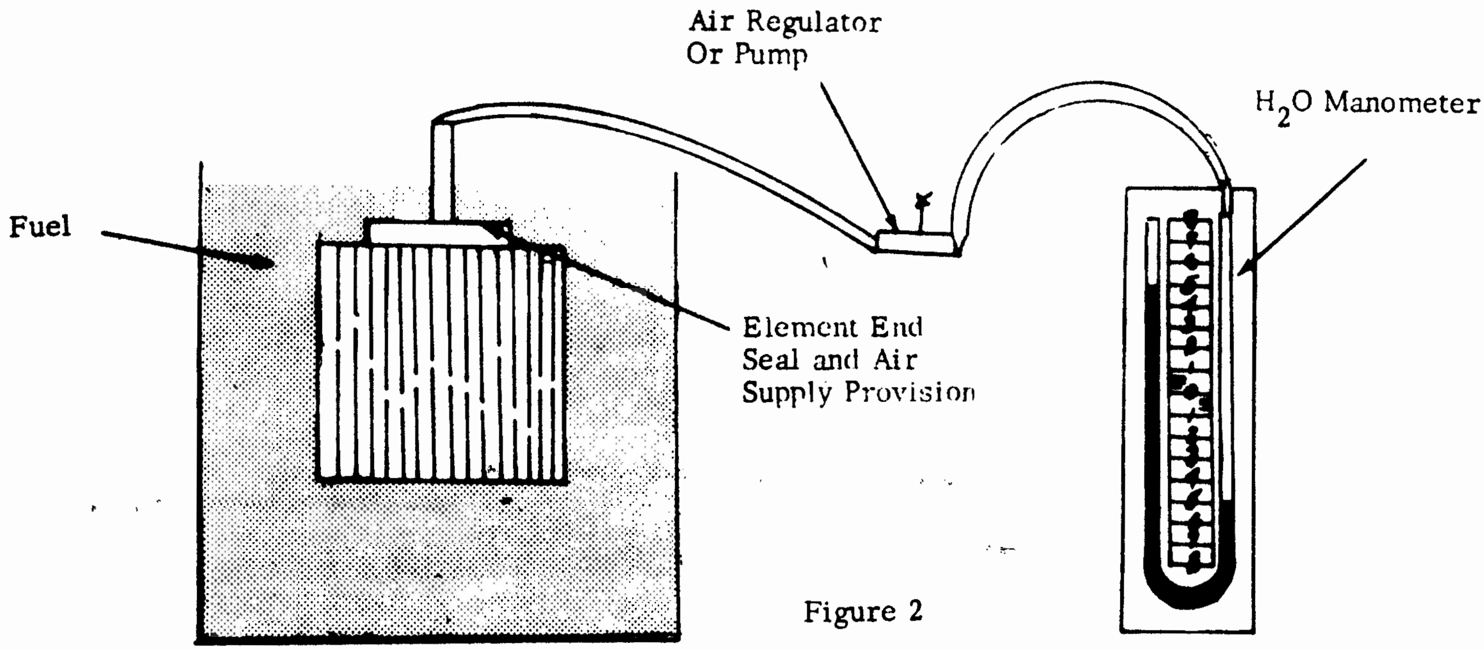


Figure 2

The reasons why certain competitive filters are full of fuel when removed from engines are:

A. No paper element resistance to air or vapor passage. This absence of resistance is due to dirty side to clean side leakage points in the element to end cap bonding. Such leakage points prevent the formation of the void or vapor-air cavity but they render the filter virtually useless from a filtration standpoint.

Note: Tests show that a Cummins-Fleetguard filter operating with a low fuel level on the dirty side, will instantly operate full of fuel if a small puncture is made in the paper at the top.

B. No or inadequate seating between the element and cap and can end plate as illustrated in Figure 3.

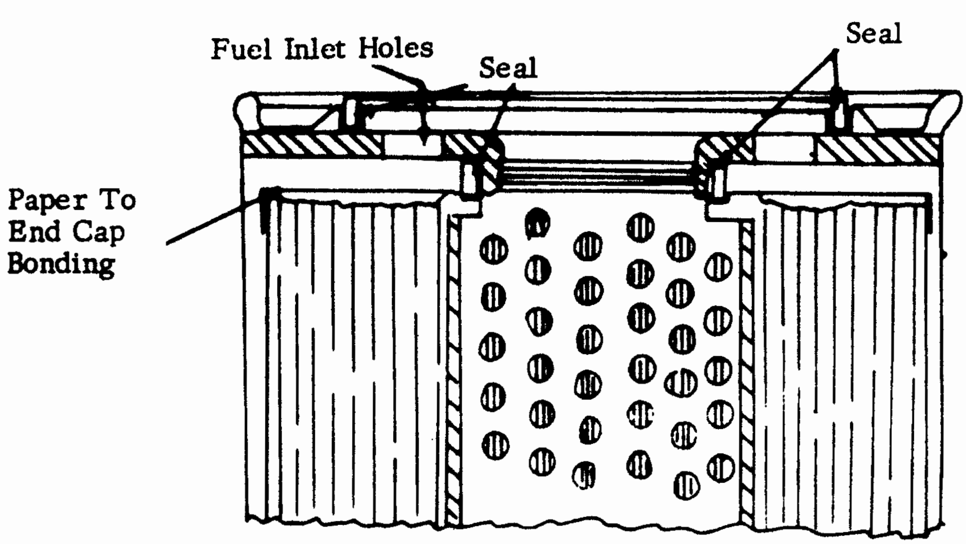


Figure 3

The result of this dirty side to clean side leakage or filter paper bypass is the same as above. There will be no air or vapor void but the filter is useless from the standpoint of filtration efficiency.

C. Large pore paper which has less wetted porous paper resistance to air or vapor passage (7"H_2O on competitive element and 10"H_2O on Cummins-Fleetguard). The large pore paper of course passes much larger dirt particles and a much greater total quantity of dirt than the Cummins-Fleetguard and fuel system life is reduced accordingly.

Note: Prior to 1960 the filters marketed by Cummins Engine Company contained structural defects as indicated in paragraphs A and B, plus large pore paper similar to that in the competitive filters today. High fuel system wear necessitated that the structural defects be eliminated and high efficiency paper be employed. Those competitive filters which are full of fuel when removed from engines contain those weaknesses Cummins eliminated in 1960.

Some competitive filters tested during this investigation had low operating fuel levels on the dirty side similar to that of the Cummins-Fleetguard. These filters had quality details approaching that of the Cummins-Fleetguard.

Characteristics of air or vapor void formation:

Assume that we have installed a new filter filled with fuel. When we begin cranking the engine, the gear pump begins evacuating air from the fuel plumbing. Air evacuated from the tank to filter plumbing passes through the paper at the extreme top. The filter remains full of fuel. Fuel rises from the supply tank as the vacuum increases. Fuel begins entering the filter and begins passing through the paper. At this point, the filter is full of fuel on both sides of the paper. When fuel begins passing through the paper at the top where air was formerly passing, the phenomenon of resistance to air-vapor flow becomes evident. Air-vapor which is released from the fuel due to vacuum are prevented from passing through the paper. As this vapor accumulates, it displaces fuel on the dirty side of the paper and the fuel level drops slowly. While the vapor cavity is increasing in volume, more fuel is being discharged from the filter than is entering. The fuel level on the dirty side drops until the equilibrium point is reached where the pressure differential across the paper is equal to the wetted paper resistance to air passage. For instance, in actual operation the absolute pressures in the filter would be as illustrated in Figure 4.

When the equilibrium point is reached, any further air or vapor released from the fuel or brought in with the fuel through an air leak passes through the paper immediately at the extreme top.

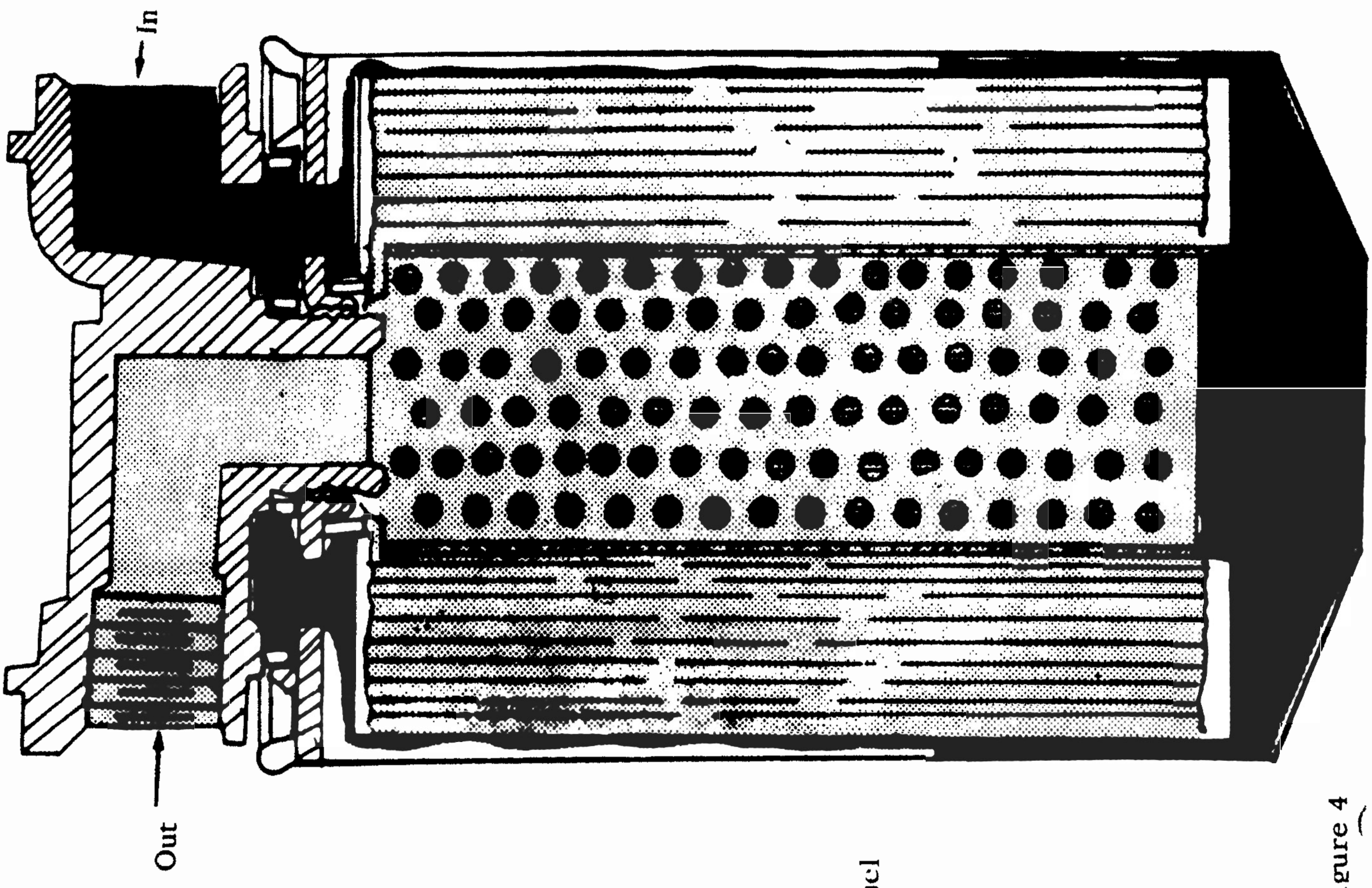
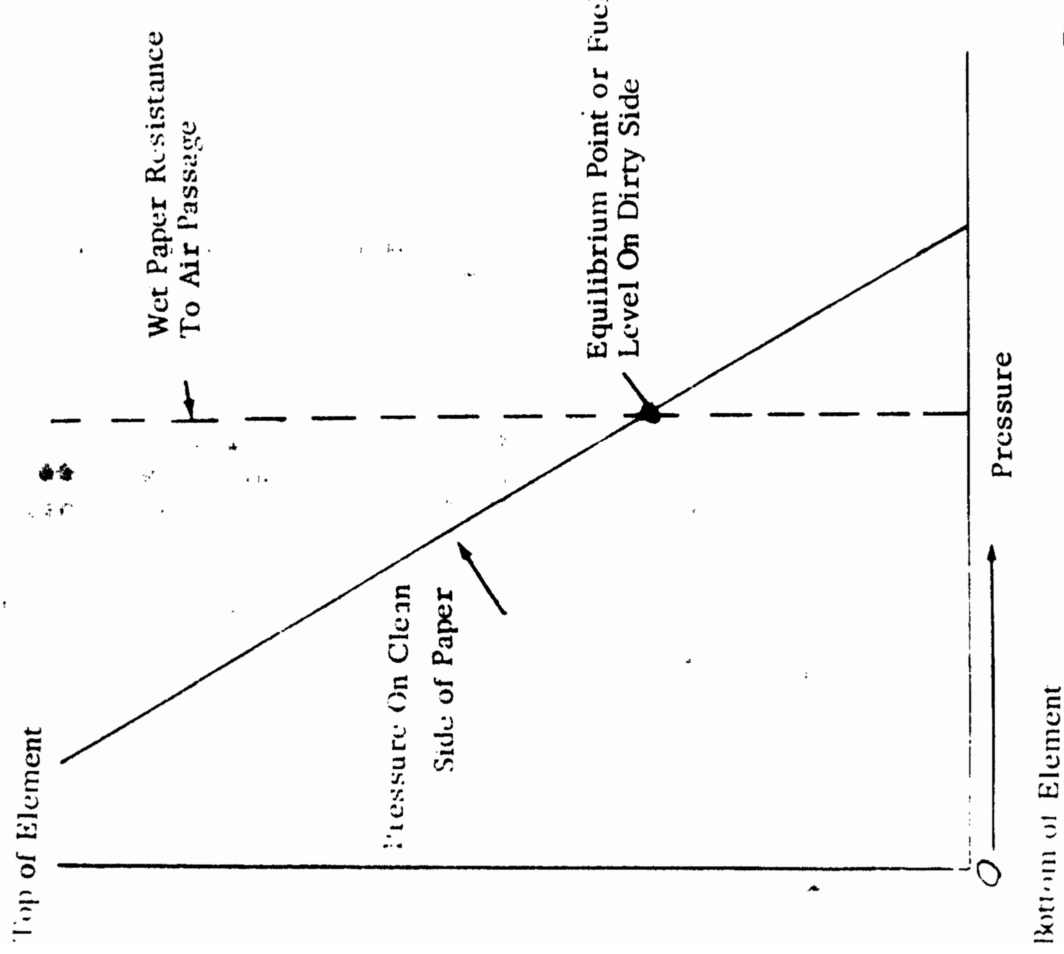

In
Out

Figure 4


Wet Paper Resistance
To Air Passage
Equilibrium Point or Fuel
Level On Dirty Side
Pressure On Clean
Side of Paper
Top of Element
Bottom of Element
Pressure
0

2. Full utilization of filter paper

Full utilization of the paper in the Cummins-Fleetguard filter is achieved.

Fuel enters the filter through the circle of holes in the can end plate. The fuel drops on the top of the element inside the can and flows down the paper pleats. Fuel passes through the paper as it flows down the pleats.

Starting with a clean element, flow through the paper is greatest at the extreme top and decreases progressively from top to bottom even though an air void exists on the dirty side. As operational time accumulates, the filter paper plugs progressively from the top to the bottom. This was confirmed by introducing dye into the filter inlet during operation and noting the flow through windows in the filter can and element. This characteristic of the filter is due to:

A. Fuel flows through the wetted porous paper much more readily than air or vapor. For instance, when the paper element is partially submerged open end up, it fills rapidly by fuel flow through the paper. The Cummins-Fleetguard and competitive filters fill under this condition at approximately the same rate even though the Cummins-Fleetguard paper has much smaller pores. This is due to the fact that the Cummins-Fleetguard has considerably more paper area (length and width of paper is much greater).

B. After the air or vapor cavity forms on the dirty side of the paper, the pressure differential across the paper is greatest at the top and decreases from top to bottom as in Figure 5.

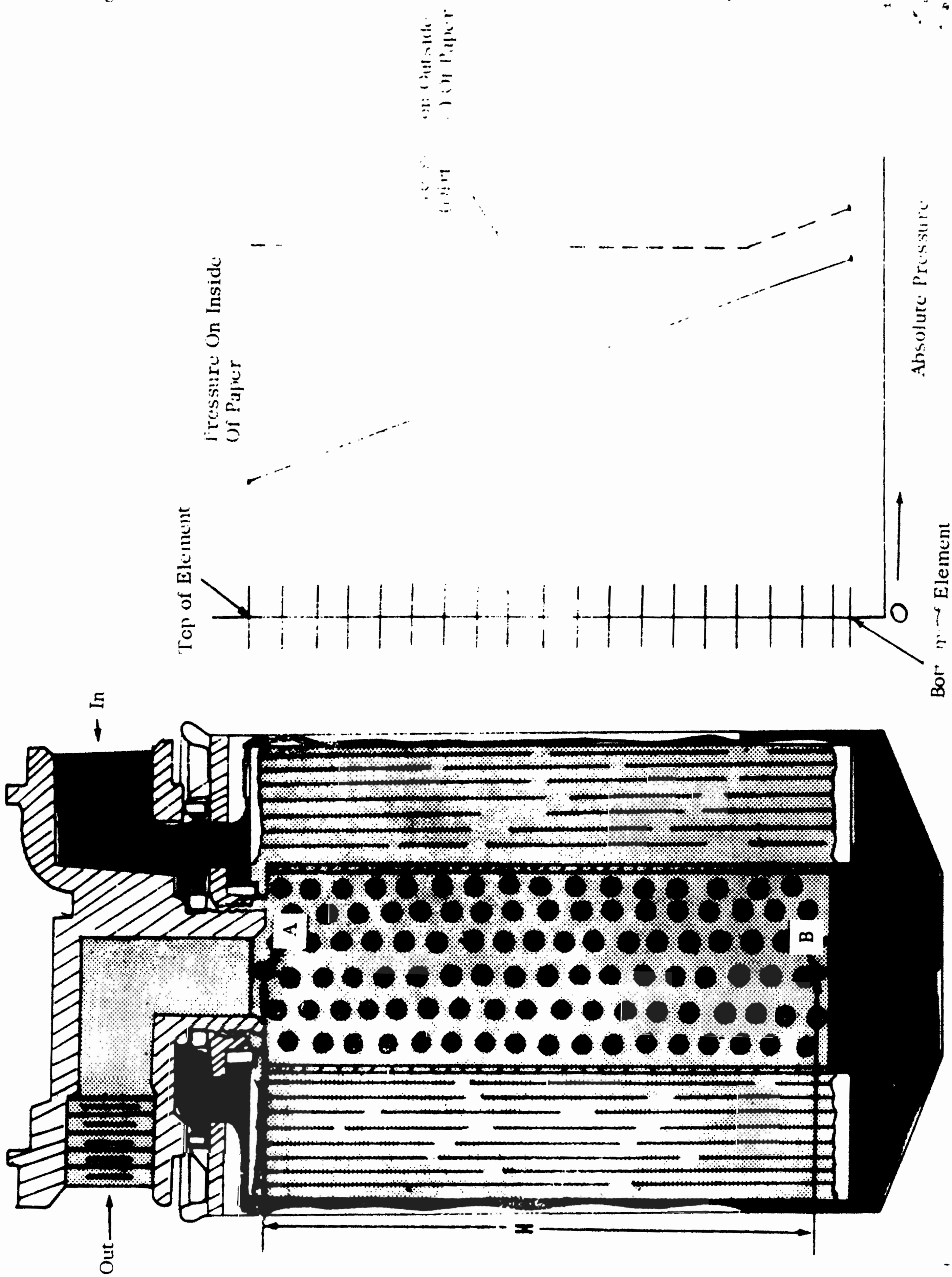
Note: If the pressure at "A" is X psi absolute, the pressure at "B" is X psi + the weight of the column of fuel of height "h" in psi.

Absolute pressure is atmospheric pressure ± the gauge pressure. For instance, if the vacuum at "A" is 2"Hg. and the barometer is 29"Hg., the absolute pressure at "A" is 27"Hg. or 13.5 psi since 1"Hg is equal to approximately 0.5 psi.

3. Throttle response

TRUE ~~The Cummins-Fleetguard fuel filters cause no throttle response problems.~~

TRUE The filter operates full of fuel, free of air inside the paper element. The fuel ~~pump and engine do not know there is a void on the dirty side.~~ Closing the throttle during engine operation does not create an air cavity or void on the clean side of the paper. During periods of prolonged down hill closed throttle motoring, the inside of the paper remains full of solid fuel. When the throttle is opened, there is no charge or shot of air discharged to the engine.


Pressure On Inside
Of Paper
Top of Element
Absolute Pressure
In
Out
A
B
H
O

When the engine is shut down, the inside of the paper element (clean side) remains full of solid fuel and the air cavity on the dirty side remains at it's equilibrium level.

When the filter is removed from the engine, the fuel level on the inside and outside of the paper equalizes instantly when the vacuum or pressure differential across the paper is broken, thus after the filter is removed, it appears that both levels were the same when on the engine and a void or cavity existed on the inside of the paper.

Air or vapor does not accumulate or build up in the void and pass into the fuel pump intermittently. The void is always under the same vacuum as that of the filter inlet.

With a given supply tank to filter plumbing arrangement, the vacuum at the filter inlet to obtain a given flow into the filter (for instance 500#/Hr.) is the same regardless of whether it is a Cummins-Fleetguard, a competitive brand or a can with no element in it. For this reason, there is no tendency for one to introduce or produce more air than another from a functional or design standpoint.

Conclusion

The main differences between the various brands of throwaway fuel filters are those features which cannot be seen or appraised by an external visual examination. The filters must be subjected to detailed structural and physical tests to determine whether they will be an asset or liability.

The cost of destroying a few filters for your own examination and bubble test as described under item 1 above, will be more than offset by extended fuel system life.