Coolant Filtration for Automotive Engine Manufacturing

Introduction

The manufacturing of powertrain components including engines and transmissions uses liquid coolants in many of its machining operations to reduce generated heat and move manufacturing debris from the machinedarea. Contaminants introduced into the coolant include metal particles, small amounts of abrasive grit, and traces of tramp oil, lint, and dust.

The reduction of contaminants is critical to keeping coolant streams clean and functioning optimally. Fine particle reduction is especially important in finishing and polishing areas and in through-tool coolant processes. The benefits of clean coolant include increased coolant life, extended tool service life, and improved finished part quality.

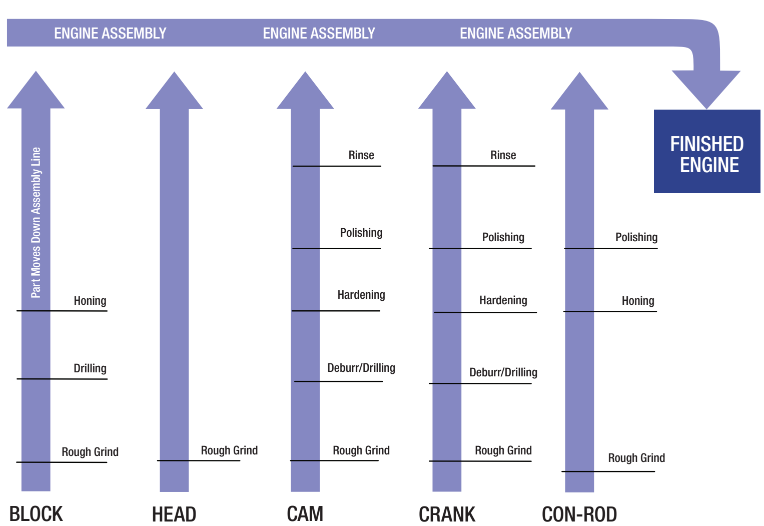
This customer application brief describes coolant use in automotive engine component manufacturing, identifies the benefits of improved coolant filtration, and provides guidelines for selection of the appropriate 3M Purification Inc. filter. Case study examples are presented as illustrations of cost savings that have been achieved.

The Process

Within an automobile engine plant there are several production lines for manufacturing the various components of the engine (block, head, camshafts, crankshafts, connecting rods) and assembling the components into a finished engine (Figure 1). Within these manufacturing lines, there are various machining or cutting operations (grinding, drilling, deburring, polishing, and honing) which remove metal from the parts, creating manufacturing debris (turnings, shavings, fines).

Liquid coolants are typically used with these machining processes for functions including heat removal, debris removal, lubrication, protection of manufactured parts, and protection of manufacturing equipment. A variety of liquid coolant types are used in these processes — aqueous, emulsion, semi-synthetic, oil. The liquids are called by a variety of names (e.g., coolant, emulsion, flushing fluid, lubricant, oil, soap, water, white water). Since virtually all of these systems are recirculating, reduction of contaminants from the coolant liquid stream is necessary to prevent contaminants reaching unacceptable high levels.

Figure 1. Overview of engine plant processes



Typical contaminants found in coolant streams include:

- Metal particles – originating from the production and machining of the metal parts.
- Abrasive materials - generated from grinding wheels or abrasive polishing tapes.
- Oil - introduced from coatings on the parts or small leaks in the machinery.
- Lint, dust, and other contaminants - airborne particles present in the factory setting falling into the coolant baths or onto the semi-finished parts.

Sometimes 'dirty' coolant may be visually clear or only slightly discolored yet the coolant streams can still contain high levels of fine particles.

In an engine plant, there are three common filtration schemes used to remove particulate contamination from recirculating coolant streams:

- A central plant system that services all of the lines in the plant.
- A local system servicing a group or cluster of similar cutting tools.
- An individual device servicing one machining operation.

Occasionally there may be combinations of systems (e.g., a coolant supply line from the central system that is further filtered immediately upstream of a polishing tool).

A wide variety of processes are used to remove coarse solids (> 50 microns) in automotive engine coolant systems. Examples of these processes include settling tanks with chip drag out systems, magnetic separators, cyclones and centrifuges, and automatic-indexing nominally rated roll media. For machining operations taking off a relatively large amount of material (grinding…), these systems typically provide for acceptable coolant quality. Fine particulate can accumulate over time in the coolant streams but will typically not detrimentally affect these machining processes.

Machining operations generating fine particulates (polishing tools...) commonly have nominally rated filters (bags…) installed downstream of the coarse solids filters.

Potential Problems

Proper coolant quality is critical for the following machining operations:

1. ***Through-Tool Cooled Drills:*** These drills are used to quickly create precise openings and flow channels in engine parts including blocks, crankshafts, and camshafts. The heat and particles produced by the drilling operation are dissipated by the coolant flowing through the open bore of the drill bit. Small particles in the coolant can 'bridge' together partially blocking the hollow opening to the drill's coolant channel. This can result in restricted flow of coolant through the drill bit, causing localized heat build-up and subsequent premature failure of the bit.
2. ***Polishing Tools:*** (micro-finishing film and honing stones): These tools need to have coolant with low levels of fine particles (1 to 50 microns) as the quality of the finish on the produced part can be affected by the presence of these particles.

For the above processes, the results and impacts of poor coolant quality are summarized in Table 1.

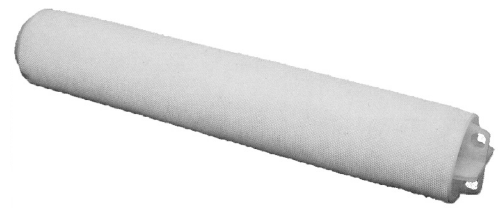
Table 1: Results and Impact of Poor Quality Coolant

Result	Impact
Off-Spec surface finish quality	• Part rework • Rejected parts • Gauging faults • Reduced first time through manufacturing capability
Short tool life (tape breakage, honing stone wear, bit breakage, shoe wear)	• Increased tooling costs • Increased maintenance • Disruptions to production
Increased coolant system maintenance (nozzle plugging, system dumps)	• Higher coolant costs • Increased labor requirements

The previously mentioned processes used to reduce coarse solid levels in coolant systems (automatic-indexing roll media filters, magnetic separators, and centrifuges) do not efficiently reduce the levels of fine solids. Nominally-rated filters (bags…) typically do not provide consistent particle removal efficiencies and have limited particulate loading capacities.

The Solution

For use in machining operations requiring capture of fine solids and consistent coolant quality, the use of 3M™ 740 series cartridges is recommended. Series 740 cartridges provide consistent high efficiency fine particle retention and significant dirt holding capability. This is accomplished by manufacturing a cartridge with a large surface area of meltblown polypropylene micro-fiber media constructed in a radial pleat design. 3M 740 series cartridges include a double o-ring connection that establishes a tight seal while still providing for easy installation and quick change-out.



3M™ 740 Series Cartridge

Features and benefits of the 3M 740 series cartridges are summarized in Table 2.

Table 2. 3M™ 740 Series Cartridges – Features, Advantages, & Benefits

Feature	Advantage	Benefit
• Radial pleat design resulting in high filter surface area.	• High loading capacity • Long run times	• Fewer filter change-outs • Lower overall filtration system cost
• Double o-ring seal	• Reduced chance of by-pass at high pressure	• Consistent filtrate quality
• Rugged core support	• High mechanical strength • Provides guide for filter positioning	• Easy fit installation • User friendly
• 6.5” diameter by 40” length	• Optimized for high flow systems	• Fewer filters to handle

Below are recommendations for the use of 3M 740 series filters in the different machining operations of engine manufacturing. Generally, it is recommended that filters used in abrasive film coolant applications be sized so that the absolute filter rating is approximately one-third to one-half of the abrasive particle size. For example, if an abrasive product with a 30 micron particle is being used, then a good starting point would be a 15 micron absolute rated filter (3M 746B series). Each specific case will vary depending on what existing coarse solids filtration devices exist and the specific fluid particulate quality desired.

3M™ 740 Series Filtration Recommendations

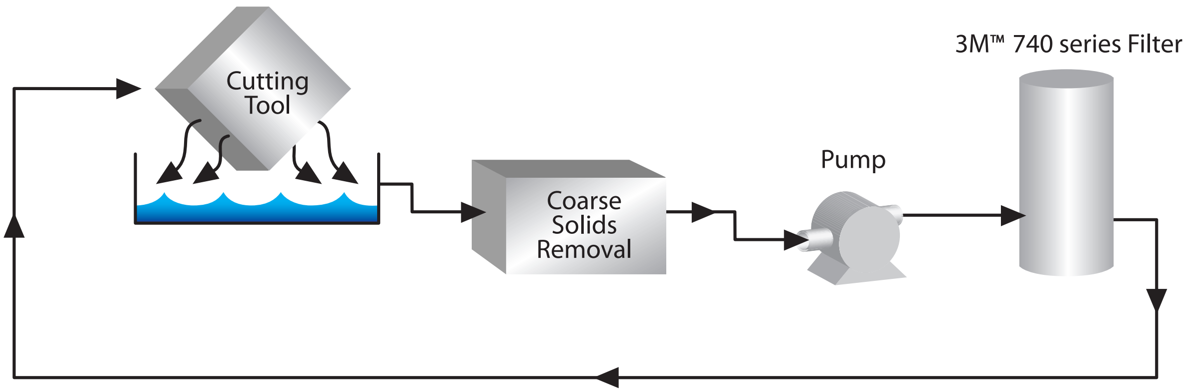
Head, Block, and Connecting Rod Component Production			
	Rough Grind	**Drilling**	**Honing**
Block	Coarse	747B (25µm) or 748B (40µm)	746B (15µm) or 747B (25µm)
Head	Coarse	N/A	N/A
Connecting Rod	Coarse	N/A	746B (15µm) or 747B (25µm)

Camshaft and Crankshaft Component Production				
Rough Grind	**Deburr/Drilling**	**Hardening**	**Polishing**	**Rinse**
Coarse	747B (25µm) or 748B (40µm)	N/A	745B (10µm) or 746B (15µm)	745B (10µm)

The use of coarse solids removal systems upstream of 3M 740 series cartridges will extend the life of the cartridges and is generally recommended for the best overall economic operation. There are two typical process options for including 3M 740 series filters in a recirculating coolant system:

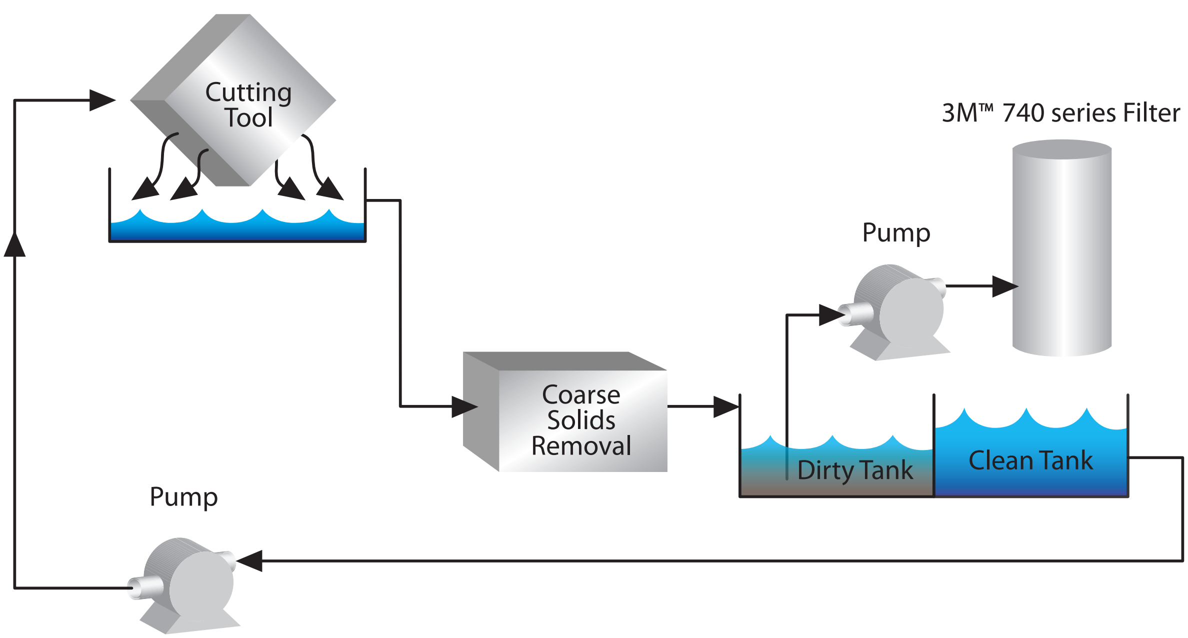
1. ***3M™ 740 series cartridge located immediately upstream of the cutting tool*** (Figure 2). This arrangement provides the cleanest possible coolant directly to the tool. In this configuration, two filter vessels can be duplexed to provide continuous filtered coolant to the process during cartridge change-outs.

Figure 2. Filtration Immediately Upstream of Cutting Tool.



2. ***Series 740 filters located in a separate filtration circulation loop*** (Figure 3): This setup is beneficial when coolant flow to the machining operation cycles often or the flow rate changes rapidly. Also, if the main loop's pump capacity is limited, then coolant flow to the machine will not be diminished when pressure drop increases as the filters load. In this arrangement cartridges can be changed with minimal disruption to production.

Figure 3. Separate Filtration Circulation Loop.



Case Study Examples

Below are three examples of automotive engine component manufacturing where the addition of 3M Purification filtration provided for process improvements and cost savings.

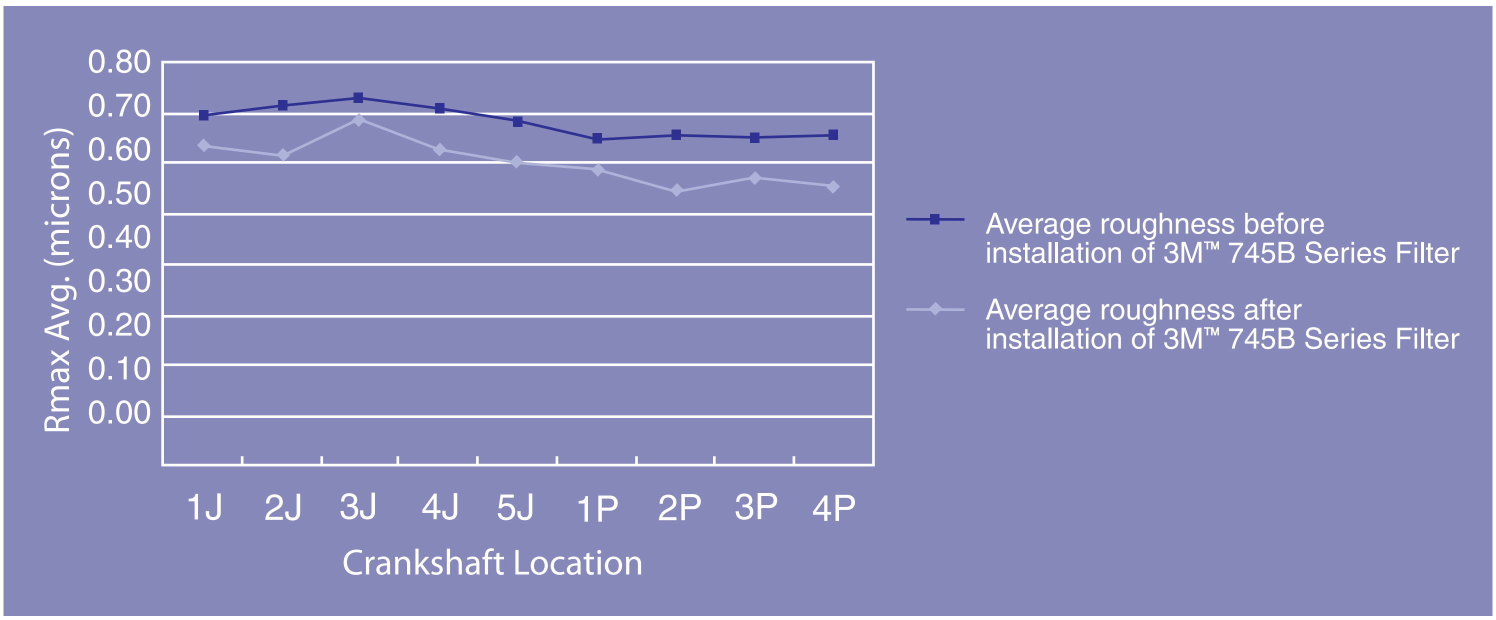
Case Study #1 – Crankshaft Polishing Line

Process: Coolant system servicing a single micro-finishing film tool polishing crankshaft parts. A separate pump circulates coolant at 20 - 30 gpm from the dirty tank through the filters into a clean tank. The existing coolant solids removal system consisted of a magnetic separator, centrifuge, and five, 20" length, 10µ nominally rated string-wound cartridge filters.

Problem/Solution: The customer was experiencing dirty coolant which was addressed by frequent coolant change-outs and system cleaning. To address the situation, the string-wound filters were replaced with one 3M™ 745B series filter (7" OD by 40" length, radially pleated polypropylene, 99% efficient at 10µm).

Results: Installation of the 3M 745B series filter resulted in a reduction in system coolant change-out frequency from eight times per year to once per year and an improvement in crankshaft finish quality (Figure 4).

Figure 4. Surface Roughness Chart



Case Study #2 – Engine Block Honing Operation

Process: Coolant system flooding multiple stations of honing stones where block cylinders are cut to final dimensions. The coolant flow rate is approximately 500 gpm. The existing coolant solids removal system consisted of roll media filters (4 ounce).

Problem/Solution: The customer was experiencing dirty coolant which was addressed by frequent coolant change-outs and system cleaning. To address the situation, the customer installed duplexed eleven round vessels with 3M 747B series filters (6.5" OD by 40" length, radially pleated polypropylene, 99% efficient at 25µm) to provide full flow filtration immediately upstream of the block hones (Figure 5).

Results: Installation of the 3M 747B series filter resulted in a reduction in system coolant change-out frequency by a factor of four and longer honing stone life. Direct annual net savings associated with the less frequent coolant change-outs and reduced replacement tooling costs was ~ $44,000 (Table 3).

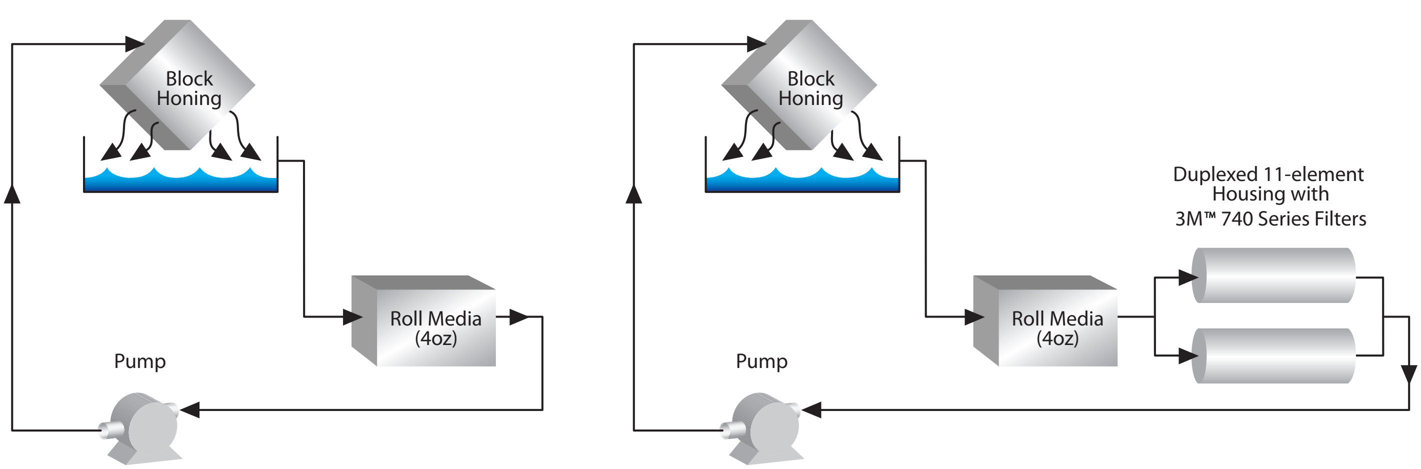
Table 3. Engine Block Honing Savings Summary

System Data	Previous System	Previous System
Filter Changes per Year	0	Filter Changes per Year
Cost per Filter	$0	Cost per Filter
Filters per Change	0	Filters per Change
Coolant Changes per Year	10.4	Coolant Changes per Year
Labor per change-out (Hours)	0	Labor per change-out (Hours)
Labor Cost ($ hour)	$50	
Amount of Coolant per change-out (gallons)	1000	
Coolant Cost per Gallon	$6	
Labor Time per Coolant change-out (hours)	16	
Calculation of Annual Costs*		
Filter change-out		
Filter Costs	$0	$44,845
Labor Costs	$0	$260
Coolant Life		
Coolant Costs	$62,400	$15,600
Labor Costs	$8,320	$2,080
Replacement Tooling	$36,000	
Total	**$106,720**	**$62,785**

* Savings due to part quality improvement or increasing production line uptime are not included in the above calculations

Figure 5 Process schematic of original system and improved system

Original System **Improved System**



Case Study #3 – Through-Tool Cooled Drills

Process: Coolant system servicing a station of through-tool cooled drills that produce oil flow openings in crankshaft parts. The drills have hollow central shafts where coolant is pumped to reduce generated metal swarf particles and heat. Overall coolant flow rate for this unit is approximately 200 gpm. The existing coolant solids removal systems consisted of a centrifuge, six 30” length, 30µm nominally rated string-wounds and twenty stacked disk filters (Figure 6).

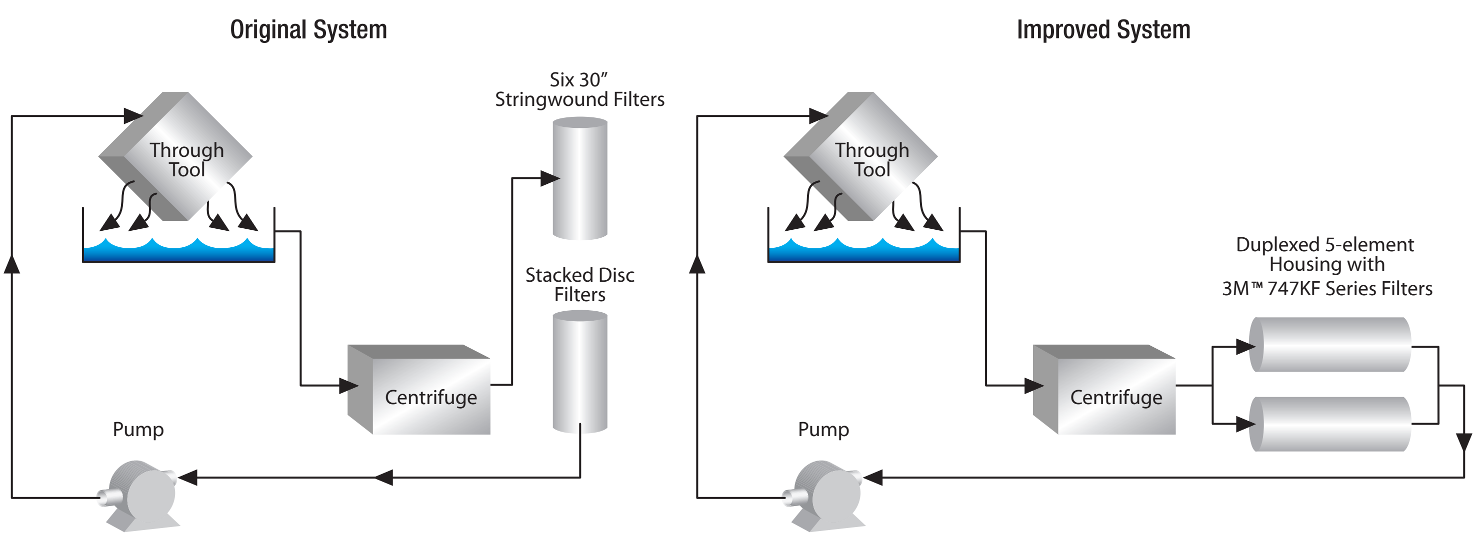
Problem/Solution: The customer was experiencing unacceptably high drill breakage rates as a result of dirty coolant. To address the situation, the customer removed the existing string-wound filters and installed duplexed 5-round vessels with 3M™ 747KF series filters (7” OD by 40” length, radially pleated polypropylene, 99% efficient at 25µm) to provide full flow filtration upstream of the crankshaft gun drills (Figure 6).

Results: Installation of the 3M 747KF series filters resulted in a reduction in drill breakage rate by 80% and less frequent filter change-outs. Direct annual net savings associated with lower replacement tooling costs and reduced labor during the tooling change-outs was $48,000 (Table 4).

Table 4. Through-Tool Savings Summary

System Data	Previous System	3M™ 747KF Series System
Drill Breakage (repairs per month)	12.5	2.5
Drill Repair Cost ($ repair)	$207	
Calculation of Annual Costs		
Filter change-out		
Filter Costs	$35,196	$46,524
Labor Cost	$38,400	$3,600
Replacement Tooling Costs	$31,050	$6,210
Total	**$104,646**	**$56,334**

Figure 6 Process schematic of original system and improved system



Conclusions / Benefits

For automotive engine manufacturing system, proper reduction of contaminants from coolant streams through filtration is critical for proper part quality. Installation of 3M™ 740 series high efficiency filters will significantly improve coolant quality. Use of 3M 740 series cartridges offers the most benefits for precise cutting operations such as polishing and honing and has also been shown to be beneficial in through-tool coolant processes. Generally high efficiency filtration works best following existing coarse solids removal devices.

The potential benefits of improved filtration of automotive engine coolants using 3M 740 series cartridges include:

- Improved product surface finish quality
- Increase in first time throughput manufacturing rate
- Longer tool life
- Longer coolant life
- Reductions in labor/maintenance requirements

In many cases, additional benefits of cleaner coolant are realized after the system is cleaned up and unexpected operational improvements reveal themselves.

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