Technical Paper

FILTRATION FT 106 TECHNICAL PAPER

Modern Centrifugation and the Maintenance of Wire Drawing Lubricants

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OVERVIEW

The paper will address the merit of incorporating a centrifuge into a filter system to maintain coolants. Much depends on the application and system requirements relative to design variables such as type of coolant, flow rate, tank sizing, solids loading, expectations of coolant life, available capital, existing equipment, and daily production requirements.

Media filtration has long been the accepted means of removing contaminants from coolants. Centrifuging has always been an alternative; however, the flow limitations of centrifuges require that a considerably larger number of units would be required to do the same job as a single media filter. This added significantly to the cost of the systems and required additional plant real estate.

Today's centrifuge technology has led to a heightened interest in centrifuging as a means of coolant maintenance. Whether the application utilizes viscous mineral oil, soluble oil or plain water, the centrifuge plays a larger role in coolant package maintenance than in the past.

The paper also addresses the role of the centrifuge with other filtering equipment and how they complement one another is important to the overall system success. Also reviewed are conveyors, cone bottom tanks, and both gravity and vacuum media filters.

To understand the new role that centrifuges have in today's equipment selection, the following will be covered:

- Reasons for filtering
- Internal dynamics
- Modern centrifuge operation including controls
- The applications and appropriate system designs
- Recent system developments
- Upgrading present systems

WHY FILTER

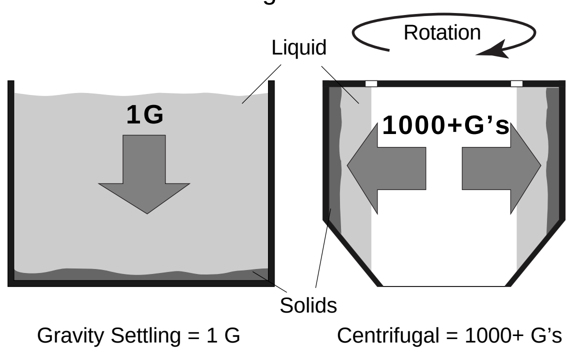
In order for drawing machinery to perform at maximum efficiency, producing the very best quality wire with minimal die and capstan wear and still maintain the longest coolant life, filtration plays a vital role in the overall success. The removal of copper or aluminum particulate and related harmful by-products of production in emulsion or oil applications is vital in achieving these goals. Many times this can be accomplished best by including a centrifuge in the mix of equipment necessary to do the job right.

- High Production Rates
- Lubricant Life
- Wire Quality
- Die and Capstan Life
- Fewer Wire Breaks

INTERNAL DYNAMICS, (what is happening inside the centrifuge)

A centrifuge is a device that magnifies the forces of gravity in a gravity separation (settling) process. Figure 1 illustrates this. In the static tank, 1 G exists and is the reason solids settle and collect on the bottom. The rotating vertical bowl depicted creates the same results but in a much shorter time and in a much smaller package due to the increase in G-force, which could be over 2000 G's.

Gravity vs. Centrifugal Force
Figure 1



The factors that improve gravity separation also improve centrifugal separation.

In the settling tank, an outside disturbance could stir the contents and lengthen the time it will take to separate the solids from the liquid, and the same is true with a centrifuge. By minimizing turbulence within the centrifuge bowl, the ability to separate solids will improve.

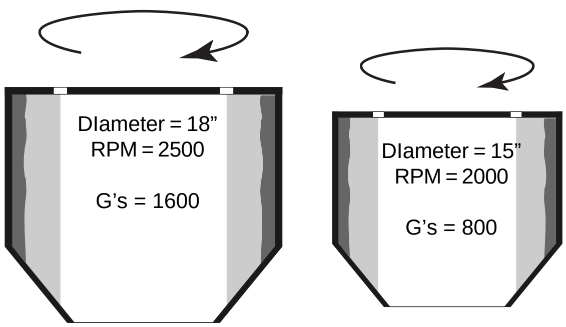
Another factor for improved separation in both a settling tank and centrifuge is the residence time or the amount of time the combination of solids and liquid are in the tank or centrifuge. In a centrifuge, this is controlled and limited by the diameter and length of the bowl.

Increased G-force, as previously mentioned, is the primary factor in improved liquid/solid separation. The factors that determine G-force or centripetal acceleration are rotational speed and bowl diameter.

G-force or centripetal acceleration is calculated in a centrifuge as follows in Figure 2.

Bowl Size vs. Centrifugal Force
Figure 2

$$G's = (RPM \times 3.14 \times DIA/60)^2 \times 1/(32 \times R)$$

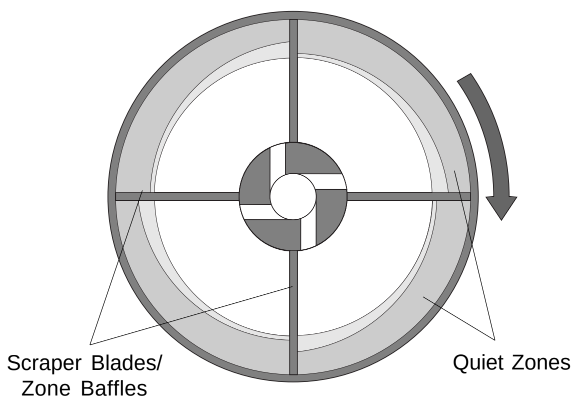


Where:	G’s =	Gravitational Force
	DIA =	Bowl Diameter (ft.)
	R =	Bowl Radius (ft.)
	RPM =	Revolutions per Minute in s^{-1}

In modern centrifuging, the control of turbulence within the centrifuge is possible by the addition of design features as seen in Figure 3, showing four quiet zones created by the plow blades that are also used during the discharge cycle.

On the centrifuge depicted, the plow blades are locked, via a special clutch mechanism, and establish the same rotational speed as the centrifuge bowl. This furthers the ability to maintain the four quiet zones thus allowing the most efficient solids separation and distribution of solids within the centrifuge bowl.

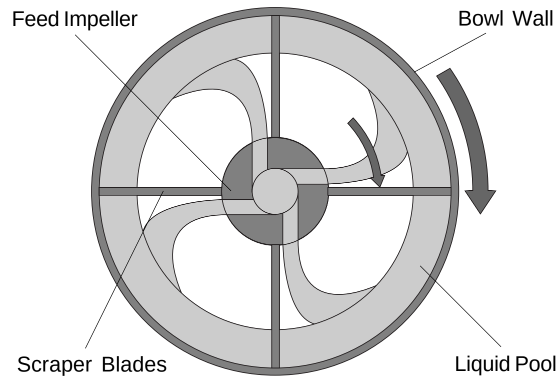
Centrifugal Bowl Quiet Zones
Figure 3



It is important to note, as mentioned previously, the centrifuge is a type of settling tank. If the plow blades are free to travel within the centrifuge bowl, the efficient separation of solids will be affected. This would be analogous to moving a paddle back and forth in a settling tank as solids were settling. The efficient settling would be disrupted.

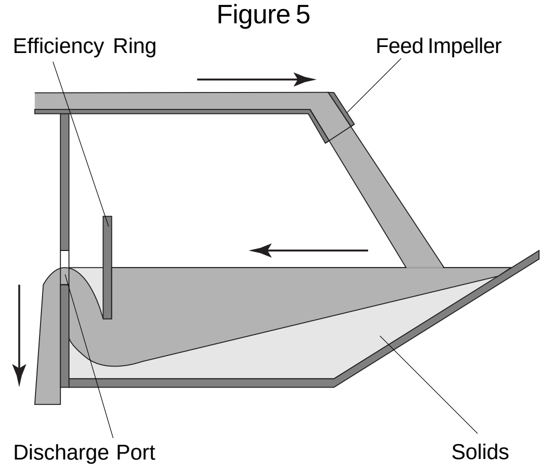
Another important dynamic to consider as shown in Figure 4 is the delivery of solids-laden liquid to the established quiet zones. This is accomplished by the rotating feed impeller that is synchronized to the rotating bowl and centrifuge plow blade that create the quiet zones. The dirty liquid enters the centrifuge bowl and each quiet zone simultaneously.

Rotating Feed Impeller
Figure 4



To aid in providing the best performance within the quiet zone, a controlled diversion of the liquid flow takes place with another design feature referred to as an efficiency ring. As seen in Figure 5, a stable liquid level is maintained by the efficiency ring which forces the liquid to travel to the outermost diameter of the bowl where the G force is the greatest and maximum separation takes place. This feature also increases the residence time of the solids within the quiet zone of the centrifuge.

Centrifugal Efficiency Ring
Figure 5



All of the described design features combine to shorten the distance of particle travel within the bowl and assure the best opportunity for removal with the least amount of turbulence.

So it is true that with the highest rotational speed, the largest diameter bowl, good solids distribution, and the longest residence time with the least amount of turbulence, the most efficient solids/liquid separation will take place.

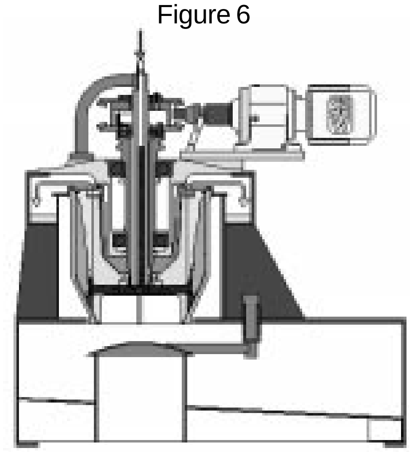
CENTRIFUGE OPERATION

AUTOMATIC CENTRIFUGE OPERATION

The basic operation of all centrifuges is the same; however, there are many variations to design features such as liquid introduction, internal component design, solids discharge, and controls that make the centrifuges available in today's market quite diverse.

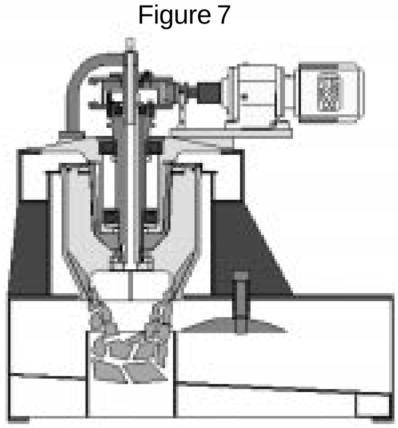
The unit depicted in Figures 6 & 7 shows a centrifuge with a top liquid inlet and internal feed tube inside the main centrifuge drive assembly.

Centrifugal Process Cycle
Figure 6



Liquid is pumped down the feed tube at low pressure to the rotating feed impeller at the bottom of the centrifuge bowl. The solids-laden liquid is then distributed within the four quiet zones, and the solids are separated as the liquid travels back up the outside of the centrifuge bowl. The clean liquid then exits the bowl and drains out through the inside housing into the base and back to the process tank. On some applications such as light oil, the liquid can discharge tangentially from the top of the housing and bypass the base. This design eliminates potential misting by segregating the clean liquid from the spinning bowl.

Centrifugal Cleaning Cycle
Figure 7



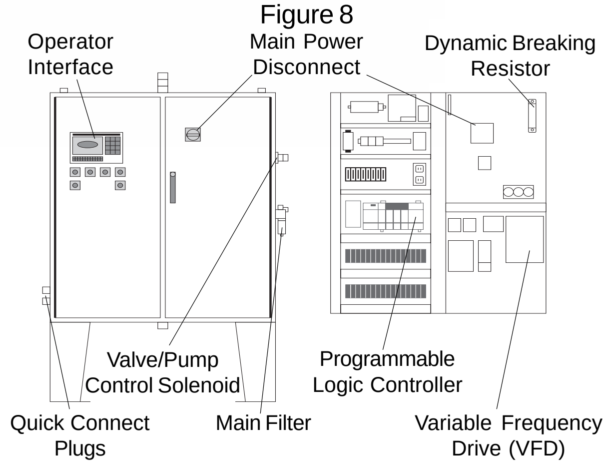
As solids are separated, the bowl will begin to fill. The unit will begin the cleaning cycle by either a PLC timed control or a load sensor that monitors any excess vibration produced due to a full bowl. The PLC will stop the liquid feed and stop the centrifuge. Once the centrifuge has stopped, a predetermined time is programmed to allow the drainage of any free liquid left in the bowl.

The PLC then opens the cleanout chute door pneumatically. A pinion gear engages two opposing ring gears that drive the centrifuge bowl and plow assembly in opposite directions and cleans the sludge from the bowl. The solids drop through the chute to a container below, and the process cycle begins again.

The heart of the centrifuge system is the programmable logic controller or PLC.

The PLC can be programmed to customize the process to the special needs of the application. For example, with lower percentage of solids or smaller particle-sized solids, the time required to separate the solids may have to be lengthened. In some cases, with heavy solids the process time may be shortened. The PLC gives the operator the flexibility to fine-tune their process needs. Another example is by shutting off the flow to the centrifuge but still allowing the unit to spin. This programmed "spin cycle" allows any free liquid to be forced out of the bowl providing dryer solids in the bowl.

Electrical Control Features
Figure 8



Devices within the typical controls package found on an automatic centrifuge include:

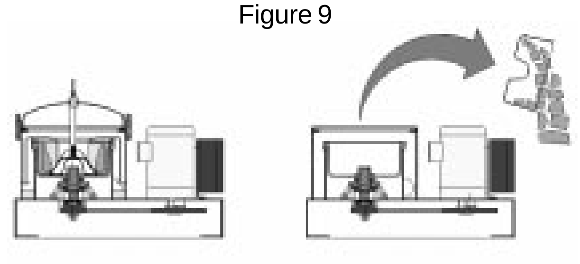
- Variable frequency drive control
- Plow over-current sensor
- Load sensitive dump sensor
- Dynamic braking resistor
- Pneumatic chute and plow actuator

MANUALLY CENTRIFUGE OPERATION

For smaller processes a manual centrifuge may be all that is needed to provide solids separation. Unlike the automatic centrifuge, the manual centrifuge requires monitoring and hands-on cleaning.

As seen in Figure 9, the manual centrifuge separates solids generally the same way as the automatic unit. As solids and liquid enter the centrifuge, they are evenly distributed within the bowl. At a predetermined time, the flow to the centrifuge is stopped, and an indicator beacon will notify the operator that the centrifuge should be cleaned. The operator then dumps the bowl and restarts the unit after replacing the bowl. The obvious concern with this process method is that the reliability of an operator which will determine the overall system efficiency and success.

Manual Centrifugal Process and Cleaning Cycles
Figure 9



Applications and Appropriate System Designs

Applications we will discuss

- Copper wire drawing with water soluble emulsions
- Aluminum drawing with mineral oil
- Aluminum drawing with an emulsion

Copper wire drawing with emulsions

When considering a centrifuge as part of the system design mix or a "stand alone clarifier" for this application, the important variables to consider are the flow rate and delivery of coolant to the centrifuge and expected daily production. The primary advantage for using centrifuges is the elimination or reduction of filter media and subsequent disposal costs.

Regarding flow rate, typically a media filter would have to be considered first when flow rates are in excess of 200 GPM. Media filtration systems are sized for 110% of system flow requirements (24 / 7).

Figure 10 shows a typical system concept with properly-sized vacuum filter, tanks, pumps, heat exchanger, and tank heater.

Typical Filtration System with Vacuum Filter
Figure 10

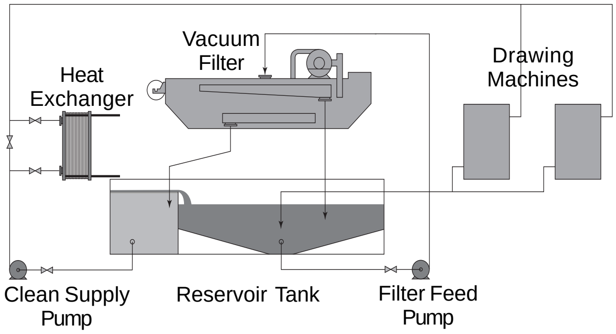
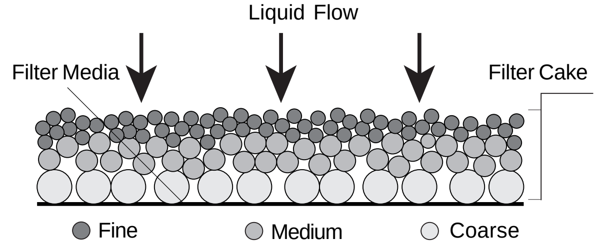


Figure 11 shows how with the production of "cake" on the media the most efficient filtering and removal of the fines is possible. As solids contact the media, the larger particles are trapped first, which in turn entrap smaller and smaller particles. The media is the support for the filter "cake" while the filter "cake" removes the finer particles.

Filter Cake Formation
Figure 11



Due to the physical size of centrifuges, design and capacity will limit the flow rate thus limiting clarification effectiveness. As flow rates increase, the number of centrifuges required to do an equivalent job increases. Although large centrifuges can handle upwards of 60 GPM, their effectiveness to remove solids diminishes as flow rates increase.

Solids Bypass in Centrifuge
Figure 12

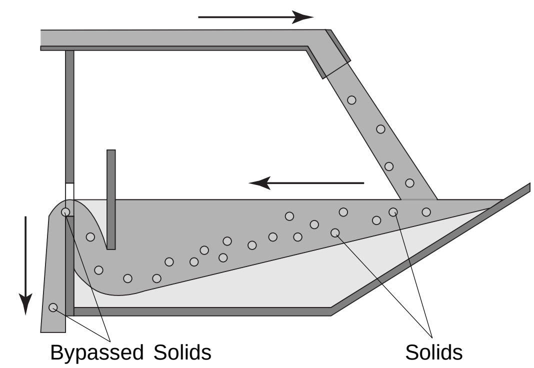
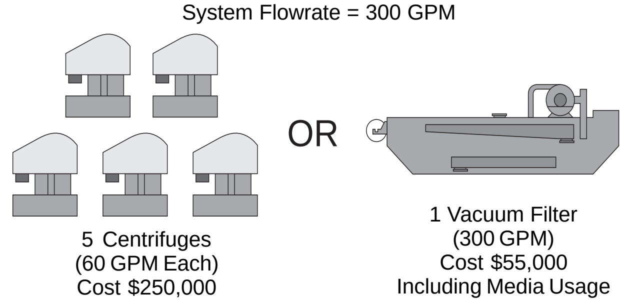


Figure 12 shows how centrifuges operate on a bypass basis requiring multiple passes to eliminate dirt. With media filtration, dirt is removed more effectively in a single pass with the production of filter "cake".

Depending on the increase in flow rate, the cost effectiveness of the system quickly diminishes when multiple centrifuges are implemented to acquire full flow filtration.

Centrifuge vs. Vacuum Filter
Capacity and Capital Cost
Figure 13
System Flowrate = 300 GPM



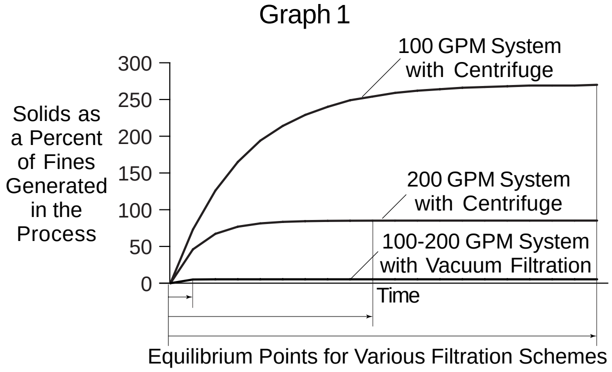
In lower flow rate requirements, typically 200 GPM and less, it may be an option to consider a centrifuge system design incorporating a single or double unit and applicable tank design to assure the most efficient solids delivery to the centrifuge as seen later in the recent developments segment.

The best way to measure the performance of a system with either a centrifuge or a vacuum filter is to determine the point at which the system reaches a state of equilibrium.

Equilibrium is the point at which the rate of solids generated equal the rate they are being removed and the remaining percentage of solids within the system stabilize. This graph shows a comparison of performance from vacuum filters to a centrifuge at 100 and 200 GPM system flowrates.

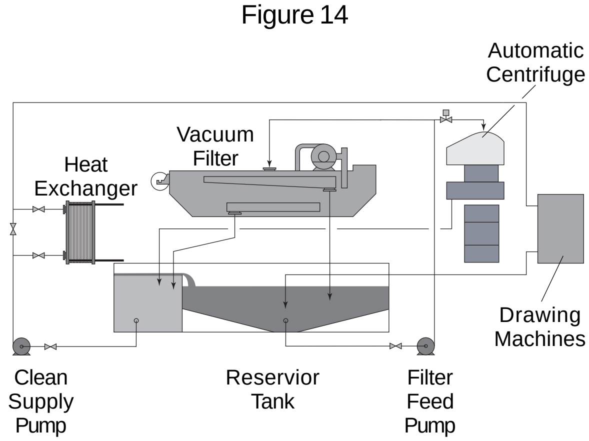
The vacuum filter reaches a state of equilibrium very quickly and maintains a low percentage of fines in the system. The centrifuges in both 100 and 200 GPM applications show a higher percentage of fines in the system due to bypass filtration. Also, the time to reach equilibrium increases as the flowrate of the system increases.

Filtration Equilibrium Based on Time and Percent Solids
Graph 1



A system concept alternative including a centrifuge would be as previously described in Figure 10 but now with a centrifuge incorporated to continually polish the emulsion. Along with the obvious benefit of cleaner emulsion due to the continuous polishing, a reduction of media will be realized.

Filtration System With Both Vacuum Filter and Polishing Centrifuge
Figure 14

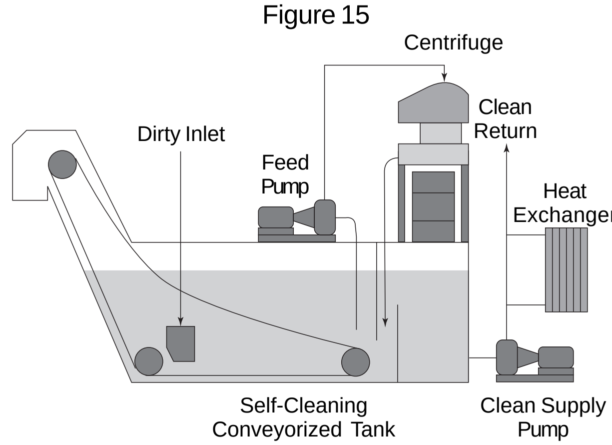


ALUMINUM DRAWING WITH VISCOUS MINERAL OIL

An application best suited for centrifuging is the clarification of mineral oil used in both rod breakdown or intermediate aluminum wire drawing. The aluminum particles stay in suspension in the viscous oil for a long enough time to provide the centrifuge the opportunity to remove them. Although these systems are working on a bypass basis, the centrifuge is the most efficient means of removing these particles from the oil.

Figure 15 shows the typical Aluminum /oil system with two compartment conveyorized tank, centrifuge, pumps, heat exchanger and system heater. Care must be taken to design the tank for proper retention. The centrifuge or centrifuges are sized for a percentage of the flow rate.

Typical Aluminum Wire Drawing Filtration System
Figure 15

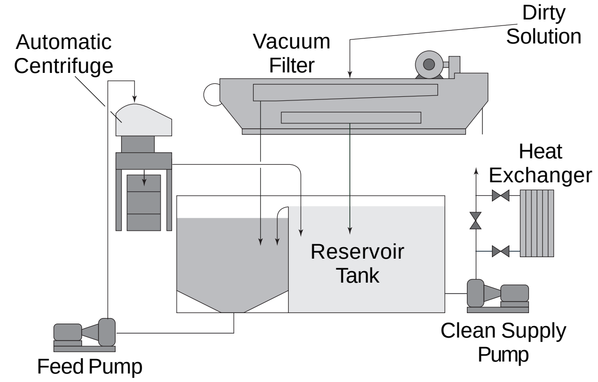


ALUMINUM WIRE DRAWING WITH EMULSION

The combination of media filter and self-cleaning centrifuge with proper tank design seen on Figure 16 is recommended for this special application.

When drawing aluminum with an emulsion, the fines produced will react exothermically with the water to produce aluminum oxide. The heat generated from this reaction could ignite combustible materials such as media.

Pyramid Bottom Tank With Automatic Centrifuge and Vacuum Filter
Figure 16



Dirty emulsion is pumped to the vacuum media filter where contaminants and some fines are removed.

When the accumulation of solids is formed, they will settle readily within the dirty compartment of the pyramid bottom tank. The solids will be efficiently transferred to the centrifuge, concentrated and removed. In this concept, we have removed the solids from the coolant and also eliminated the potential contact with combustible media.

The liquid and solids enter the cone bottom tank tangentially creating a rotating current, driving solids to the bottom, and optimizing delivery to the centrifuge. The heavy concentration of solids is pumped to the centrifuge and is separated. Clean liquid drains to the center cylindrical clean section of the tank where a pump will deliver the coolant back to the drawing machine.

FILTRATION PERFORMANCE DATA
TABLE 1

Clarifier Type	Age of Oil	Volume Gals.	No. of Machines	Total HP	% Fines	Viscosity SSU	Draw
Centrifuge Conveyor	5 Years	4,500	1	250	7.1	1,673	Rod
Centrifuge Conveyor	5 Years	8,000	11	1,480	6.5		
Conveyor	3 Years	5,000	1	600	1.5	1,258	Rod
Conveyor	2 Years	7,000	4	1,200	1.8	1,060	Rod
Conveyor	2 Years	2,250	1	500	0.5	1,292	Rod
Vacuum Filter	3 Years	14,000	4	1,200	5.9	864	Rod/Int
Centrifuge	6 Years	17,500	4	1,900	7.7	860	Rod/Int
Centrifuge	2.5 Years	5,000	1	400	6.75	750	Rod

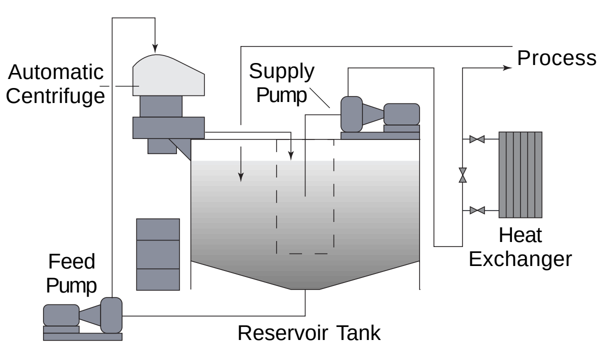
This chart shows actual aluminum wire drawing installation data and how the combination of a centrifuge and conveyorized tank is an effective means of maintaining oil viscosities and low "fines" level greatly extending oil life.

Recent Developments

Some water-soluble drawing operations with flow rates of 200 GPM or less, and have sporadic or part time production may be tolerant to a centrifuge filtering system. With this concept much is dependent on expected daily production. For example, an 8-hour production day would give the centrifuge system a chance to catch up and keep the coolant clarity at acceptable levels. Should daily production increase to 16 hours or even higher, the system would be taxed, and coolant clarity would suffer.

Figure 17 shows a system concept with a centrifuge on top of a cone bottom tank with a centrifuge feed pump, clean supply pump and heat exchange package.

Typical Centrifuge Filtration System
Figure 17



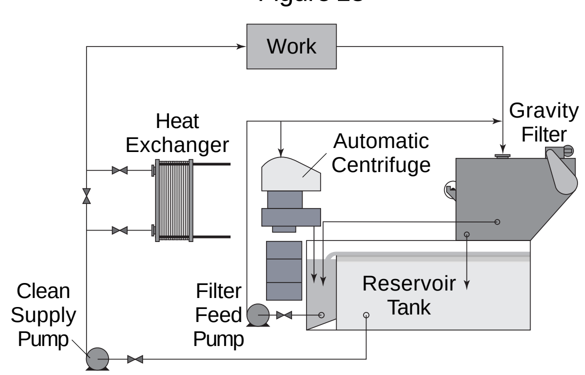
As a bypass system, this concept would work well given a grace period during the production day to catch up. If production continues, dirt would soon overtake the capabilities of the system, and dirty coolant would be sent back and the solids deposited in the dies of the drawing machine. Another centrifuge could be added but then the system cost would increase and may make this concept less attractive.

Should production increase and additional drawing machines be added, this type of system would not be well suited to implementing design changes to accommodate the increased capacity.

Upgrading Present Systems

In many cases, additional drawing machines may have been added to a filter system that was designed years before for a much lower flow rate. To help keep the system balanced, a centrifuge may become a cost effective solution.

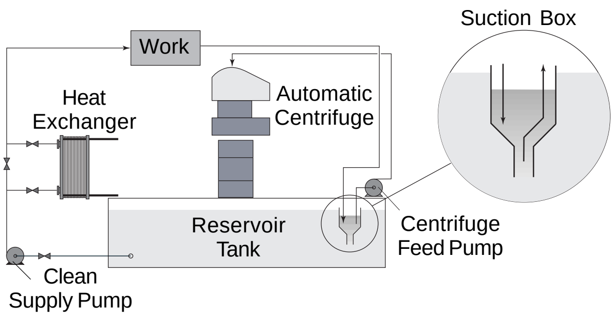
Filtration System With Both Gravity Filter and Polishing Centrifuge
Figure 18



With careful consideration of the existing filter system design, the proper sizing and placement of a centrifuge will help take the load off the media filter and help reduce media usage while continually polishing the coolant.

In cases where there was only tank retention and the flowrates are under 200 GPM, a centrifuge can be a viable option. The centrifuge and pump suction line placement should provide the best opportunity for the delivery of solids to the centrifuge. A suction box as shown in Figure 19 could be added submerged in the tank to help deliver the highest concentration of the dirty coolant to the centrifuge. Special flexible lines can be moved to different parts of the system tank where settled materials tend to accumulate.

Suction Box
Figure 19



Summary

The cost-effective maintenance of coolants is always a challenge. Each drawing machine filtration requirement should be approached individually and considered a custom design. The system design variables stated at the beginning such as type of coolant, flow rate, tank sizing, solids loading, expectations of coolant life, daily production requirements, existing equipment and available capital all should be considered when developing a new system concept including a centrifuge or adding a centrifuge to an existing installation.

The modern centrifuge is a great piece of equipment when applied correctly; however, a centrifuge has limitations too, and is not a substitute for positive barrier filtration. As time goes on and technology advances, the limitations ordinarily found with centrifuges such as bowl size and RPM's produced at reasonable costs may disappear. Then the centrifuge could become the equipment of choice for more filtering system applications.

Bibliography:

Figures 15, Table 1 and general concepts of aluminum wire drawing with emulsion in oil were taken from the technical paper authored by Joe Scalise of Filtertech and Kathy Helmetag of Houghton, "Aluminum Wire Drawing Filtration" presented at Interwire 1999.

Many drawings depicting the centrifuge internal workings and design features were supplied by U.S. Centrifuge, Inc.,

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The paper was presented by the author at Wire Expo 2002 in Chicago, IL, June 2002.

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Printed in U.S.A. 6/02