A Step-by-step Approach for Specifying & Designing an Engine Overhaul Cleaning System

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When it comes to cleaning engine components, there are many issues that are unique to the aerospace industry: part size, exotic base metals, traceability requirements, aggressive chemistries and the high cost of components, just to name a few. This paper addresses these issues and helps form a guide so that an informed decision can be made when purchasing a new engine-cleaning line or upgrading and improving an existing line. Discussions are included on methods of agitation, spray versus immersion cleaning, material handling options, waste reduction methods and process control issues.

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Overview

As the aerospace industry rapidly changes, overhaul and maintenance facilities need to respond accordingly. Trends in the industry such as increasingly larger aircraft and the need to have tighter process control have forced overhaul facilities to reassess their capabilities and make changes to accommodate the new requirements.

During the engine overhaul process, most engine components require cleaning, even before they can be inspected. Then, after inspection and NDT (non-destructive testing), they may require secondary cleaning. This makes cleaning an intricate part of the engine overhaul procedure. Unless an engine overhaul facility's cleaning is being outsourced, it will have some degree of cleaning capacity.

This paper looks at some of the trends in the industry that may require engine-cleaning lines to be updated or improved. It also touches on some issues that are unique to the industry and require special attention when specifying and designing an engine overhaul line. In addition, it will help provide a basic guideline on some key issues to be considered when making a decision of this magnitude.

Industry Trends

Recent trends in the aerospace industry have prompted engine overhaul and maintenance facilities worldwide to review, update and modify their engine processing and cleaning equipment.

Larger Engine Components

With the advent of larger aircraft, come larger engines and engine components. Existing processing/cleaning systems are being stretched to their limits to accommodate these components. When these process tanks were initially designed, no one would have envisioned that they would one day need to process engines nearly as large in diameter as the entire fuselage of many commercial jet airliners.

Improved Cleaning Methods

Process tanks, commonly referred to as "soak tanks," are more frequently than not, simply large tanks for soaking the engine components. Some systems may incorporate some means of filtration that will introduce some solution movement in the tank, but the actual cleaning is taking place by combining the cleaning chemical action with heat over a specified period of time. An existing cleaning system, which utilizes the "soak method," can be greatly improved by introducing some form of mechanical energy into the process tank. Common forms of agitation are solution agitation, part movement through the solution, or ultrasonic energy. This energy not only improves the cleaning results, but also can greatly reduce the overall cleaning time.

The Reduction and Elimination of Solvent Cleaning

New environmental regulations on certain base solvents have required overhaul facilities to look for new ways of cleaning without solvent-based cleaners.

Example: A common method to clean engine bearings has always been to soak the bearings in a solvent-based cleaning solution. These solvents are very effective at removing the carbon, grease and oils, which are the typical contaminates on an engine bearing. The engine manufactures have updated the cleaning specifications to include procedures that utilize aqueous-based cleaning solutions, with a series of water rinses and a water-displacing oil step. What was once a single-step soak process, is now a three-to-four step process. Pratt & Whitney's SPOP 216 is an example of just such a procedure.[1]

Cleaning times of several hours were quite common in this bearing-cleaning example, when using solvents. The new aqueous methods have improved the cleaning, while significantly reducing the cleaning time. Some bearings, which used to require up to eight hours in a solvent cleaner, are being cleaned in the aqueous process in less than 30 minutes.[2]

Increased Process Control and Part Traceability

A much greater emphasis is being placed on tighter, more accurate process control of the cleaning system's temperature, cycle times, chemical concentrations and rinse water purity. By ensuring that these parameters are in the optimal ranges, the final cleaning results can be maximized.

As an engine is disassembled, its components are closely tracked throughout the entire overhaul process. Detailed records are kept during tear down, NDT and reassemble. One area of record keeping and traceablility in the engine overhaul process that needs improvement is the cleaning phase. With manual transfer systems and outdated control systems, the data being collected usually falls short in quality and quantity compared to what is currently available with today's technology. New control systems and software have the capability to track a hundred or more data inputs per process batch. What was once just a basic log for documenting when a part was cleaned and through what procedure, can now include precise cycle times, temperatures, drip times and transfer times, to name a few.

Cellular Cleaning

Many overhaul shops are investigating the feasibility of moving from a single large central cleaning line, where all components flow through, to independent cellular cleaning systems within a given work cell or component area. This reduces the load on the central cleaning line, brings the control back to the cell and usually reduces costs (in time and dollars) associated with in-process material handling.

This sounds like a great concept. However, it is simply not practical for every application and can be extremely cost prohibitive. For example, an APU's (Auxiliary Power Unit) cleaning requirements and procedures are very comparable to other much larger engine components such as an engine gearbox housing. There are many steps and the number of process tanks required can be numerous. In this example, most of the processing stages in the gearbox line would need to be duplicated in the APU work cell to have true independent cellular cleaning overhaul.

Cleaning Issues Unique to the Aerospace Industry

The aerospace industry is very unique in every aspect. This also holds true when discussing issues specific to aircraft engine overhaul.

Large and Variable Part Size

Overhaul facilities need to be extremely flexible when it comes to component part size. As passenger and military aircraft grow in size, everything from hangers, jetways and cleaning capacities/capabilities need to increase in size accordingly. As major assemblies are broken down into their smaller components, the overhaul shop has to have the flexibility to process extremely large parts, as well as small components such as turbine blades and fittings.

Exotic Materials

High operating temperatures combined with high stress loads and lightweight requirements are a few factors that require many engine components to be designed using exotic metals and alloys that are unique to the aerospace industry. While these metals are soiled with build-up that requires very aggressive chemicals, they also require unique cleaning chemistries so as not to damage their integrity.

Component Cost

The cost of the materials of construction combined with the OEM manufacturing costs and the liabilities which follow the part throughout it's operating life, correlate to engine components with extraordinary price tags. A single engine bearing can cost $50,000 or more. For this reason, it is imperative that process times and material handling techniques are closely monitored. For the costs associated with one damaged or scrapped part, a buyer could purchase a new cellular cleaning line.

Because of these high dollar values, reducing engine overhaul turnaround time has a significant and direct effect on the bottom line. Faster turnaround time results in reduced inventory requirements, in entire engines and spare parts. Increasing the efficiency and speed of cleaning in the overhaul process will indirectly equate to significant cost savings. With commercial engine costing exceeding $12,000,000 or more, one can see how much potential cost savings exists.

Traceability

Part traceability is pertinent in engine overhaul. As the components are broken down into smaller components, they are cleaned and inspected. All of these procedures are well documented and follow the part throughout its operating life. More of an emphasis is currently being placed on better record keeping and traceability of a part's cleaning history. In a high profile case, 8,200 engine blades that were improperly cleaned were recalled. It was found that an improper cleaning process caused fatigue cracks in the blades. Because of the high degree of traceability, the actual day that the blades were cleaned was identified and notices were sent to all airlines affected. As a result, new procedures and regulations have been implemented for cleaning this engine component.[3]

Basic Cleaning Formula

When designing or upgrading a cleaning system, it is helpful to understand the basics of the Cleaning Formula. The four factors of the Cleaning Formula are: time, temperature, chemistry/concentration and the method of cleaning. Common methods of cleaning include, spray, soak, hand wipe and immersion agitation. When one of these factors is changed, it has a direct and sometimes exponential effect on the others.

Time

Tank time is usually one of the first variables to be set. Typical cleaning times can range from 2 minutes to upwards of 30 minutes. Reducing the cleaning time can increase the cleaning system's volume capacity. However, there are strict guidelines that are provided by the engine OEM detailing these parameters. These are typically referred to as overhaul standard practices. In the case of Pratt & Whitney, they use the term "SPOP."

These "practices" are more than just guidelines. Exposing a part to some of the cleaning chemicals for an extended period of time can be detrimental to the part's integrity. For this reason, it is quite common to have maximum cleaning cycle time specifications.

The overall process time, which includes cleaning, rinsing and secondary chemical applications is the period of time the part is in process from loading to unloading. The total time is usually dictated by the initial cleaning cycle time, which tends to have the longest wet process time requirement. If the system incorporates a forced air drying stage, depending on the part configuration or the number of parts in a process batch, this could also be the "bottleneck" in the overall process time.

Temperature

The manufactures of the cleaning compounds recommend operating temperatures. These are specific to each product, as they are frequently formulated with surfactants or a combination of surfactants, which are most effective in certain temperature ranges.

An increase in temperature usually will have a direct effect on the cycle time and can reduce the required chemical concentrations. Too much of an increase (over the recommended operating temperature) can have an adverse effect on the cleaning chemistry and can actually "split out" the surfactants in the cleaners, leaving the bath "dead." Depending on the formula, the bath may or may not be able to be revived by lowering the temperature back to the recommended operating range and mixing the solution.

Chemistry/Concentrations

A significant percentage of cleaning chemicals used in engine overhaul applications are water-based. Their recommended concentrations can range from 5% to 50%. In general, cleaning in a 5% to 10% concentration range is quite common. In more aggressive applications, such as those using permanganate-based cleaners, percentages of 40% to 50% concentrations are quite common. Again, the cleaning chemical manufacturer specifies these ranges.

In addition, the engine OEM has its recommended ranges that may differ slightly from the data sheet provided by the cleaning chemical supplier. Please note that in most aerospace cleaning applications, the engine OEM not only has recommended operating times, temperatures and concentrations, but they also have a list of approved products. If the product is not on the approved list, it cannot be used in the cleaning line.

Method of Cleaning or Mechanical Energy

Due to the complex geometries of numerous engine components, the most common form of cleaning is to immerse the part in a cleaning solution. Other methods of cleaning such as spraying or hand wiping can be and may need to be incorporated into the cleaning process. For purposes of discussion, this paper is limited to immersion cleaning, as it represents the most common method used in a typical engine overhaul facility.

Large soak tanks, which are quite common in the plating industry, are also quite common in engine overhaul facilities and are frequently used as cleaning tanks. By introducing some form of mechanical energy into the process tanks, the cleaning results can be improved and cycle times reduced. When specifying the method of introducing mechanical energy into the cleaning process, the engine OEM standard practices manuals may provide several options with no preferred method. This enables the overhaul facility the flexibility to choose the preferred method, specific to their needs.

There are basically three methods of creating mechanical energy in a cleaning tank: liquid agitation, part agitation through the solution and ultrasonics. All three will be discussed in greater detail in the next section of this paper.

Designing a New Cleaning Line

When designing a new cleaning system from the ground up, several factors need to be addressed.

Number of Process Tanks

If the operation requires overhauling of a single manufacturer's engine or engines, then determining the number of process stages is simplified. The OEM will have recommended procedures, which will dictate how many process stages are required. You may have the flexibility to add a second wash stage or extra rinses, but rarely can you eliminate a stage or step.

When reviewing recommended process times, you most likely will note that there are one or two steps that require significantly more process time than the other steps. If this time requirement is seen as a potential volume limitation for the cleaning system, a second or even a third stage maybe justifiable. For example, if one stage requires 30 minutes and the others are 15 minutes or less, by adding a duplicate stage, the limiting process time can be reduced to two steps of 15 minutes. The total process time of 30 minutes is still met, yet the volume capacity of the system has doubled for the cost of one more process tank.

If your overhaul facility processes engines from different manufacturers, you will need to design a hybrid system, or have a cleaning line for each style/type of engine. Dedicated cleaning lines are not always practical for obvious reasons.

It is quite probable that each manufacturer will have slightly different procedures and approved cleaning chemicals. The goal would be to find as many shared similarities, so as to reduce the total number of process stages required. There tends to be a great deal of overlap between different manufacturer's procedures.

When reviewing the OEM standard practices and procedures, it is likely that some of the cleaners have been approved by more than one engine manufacturer. By specifying products that have the widest range of approvals, the number of process tanks can be minimized. If the process tanks cannot be "shared," or if it is preferred to have dedicated cleaners, then it will be necessary to have dedicated tanks for each individual supplier's requirements.

If recommended times and temperatures overlap, an internal operating range can be written which incorporates only the overlapping ranges. The most significant range is the upper operating temperature limitation. If one manufacture has a slightly lower maximum operating temperature for the same cleaning solution, the procedure can be written with the lower temperature for both applications. The same concept holds true for the recommended chemical concentration parameters.

You will also have some flexibility when specifying the number of rinse tanks. Some procedures may have a minimum requirement, but rarely will you see a maximum requirement. It is quite common to have at least one rinse stage between chemical stages, with one or more rinses for the final rinsing. Keep in mind, your parts will only be as clean as your final rinse.

One simple method of waste reduction or minimization is to have a series of two or more final rinse tanks counterflowing. This not only reduces rinse water usage, but also helps to ensure a cleaner final product. This theory holds true whether the process incorporates treated water or tap water.

Table 1: Water Required to Dilute One Gallon of Dragout[4]

Dilution Ratio	One Rinse (gal)	Counterflowing Rinses 2	3	4	5
100:1	99	10.0	4.3	3.0	2.3
1,000:1	999	31.0	10.1	5.4	3.8
5,000:1	4,999	70.0	17.0	8.2	5.3
10,000:1	9,999	100.0	21.0	10.0	6.1
20,000:1	19,999	141.0	27.0	12.0	7.0

For two gallons of dragout, multiply water figures by two, for 1/2 gallon multiply by 0.5 etc.

Sizing Process Stages

The process tank size is directly related to the maximum part size to be processed in the tank, in the orientation that promotes the best cleaning. Some parts will clean better in a particular orientation.

First, determine the maximum part size to be processed and the “envelope” it occupies in the desired orientation. This will dictate the maximum basket or carrier size to be used for material handling. Second, there will be minimum recommended tank clearances, space for ancillary equipment and a desired liquid level above the part during processing. This will give you a baseline for starting. Each individual cleaning system manufacturer will have their own requirements and recommendations, specific to their equipment.

One basic principle commonly used in the cleaning industry is the 80/20 rule. To apply this rule to this application, one must first closely review the mix of parts and the range of sizes. If a very small percentage of the parts are much larger than the majority, it may be more practical and cost effective to design the system’s size around the larger percentage of parts. The larger parts could then be cleaned with alternative means such as hand scrubbing or spraying.

Materials of Construction

Due to the aggressive nature of the cleaning chemicals and the high operating temperatures utilized in an engine overhaul application, highly chemical resistant materials of construction are required. The most common is 304 stainless steel. The chemical supplier may recommend other series of stainless such as 316. It is common to have the support structure fabricated out of mild steel with a chemical resistant paint and all wetted parts fabricated in the recommended stainless steel series.

One design feature to consider, is to specify that all support structures that come in contact with the floor, should be fabricated out of a series of stainless steel. It is inevitable that chemicals will come in contact with the support structures and over time, may have a detrimental effect on the integrity of the process tanks. If a stainless steel base is designed into the support structure, these chemicals can be periodically rinsed down without any ill effect on the tanks. This also helps facilitate a safe and clean working environment.

One other common method to make the process tanks more chemical resistant is to line them with a chemical resistant material such as polypropylene. If an alternative material is considered for liners, consider not only its chemical resistance characteristics, but also its temperature limitations.

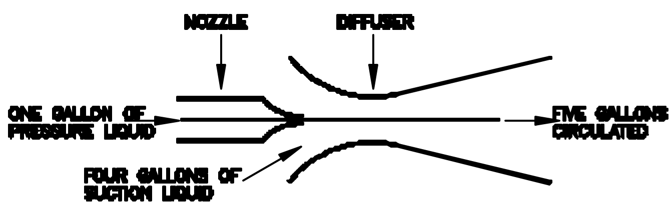
A major airline overhaul and maintenance facility currently has process tanks that are fabricated out of ¼ inch plate, 304 stainless steel. They have been in operation for close to thirty years. Due to the integrity of the tank itself, these process tanks, with a little refurbishing, could quite conceivably last another 30 years.

Method of Agitation

If you have an existing system utilizing simple soaking process tanks, the addition of agitation will greatly enhance the cleaning results and reduce the average cleaning cycle time. If you are starting from square one with a new process line, there are three basic methods to consider. If you were attempting to modify your existing process tanks, not all methods would be practical without significantly reducing the working envelope of the system.

Liquid agitation is one of the least costly methods, especially if it is a retrofit for an existing cleaning line. The most simplistic form is a circulation pump, which will create liquid movement in the tank. This method can be greatly improved upon by using a series of eductors connected to a manifold header. The eductors enable smaller pumps to circulate large volumes of tank solution. Due to their venturi design, they can have a circulation rate of four to five times the pump rate.[5] This greatly increases the mechanical energy, thereby increasing the cleaning action. If these eductors are mounted on ball joints, they can be positioned in such a way to create an efficient circulation pattern or a whirlpool-like effect.

Theory Behind Eductor Agitation



When specifying the actual pump size, the materials of construction and the flow rate, one must first consider the aggressive nature of the cleaning chemicals. As with the tank construction, the pump will need to be highly chemical resistant. In addition, its seals will need to compatible with the solutions. One way to ensure that the seals are compatible, is to eliminate them altogether with a seal-less vertical pump design. This not only eliminates the seal, but also reduces the amount of external plumbing and therefore, the potential for leakage at pipe joints and unions.

The flow rate requirement is very subjective. If the tanks are already existing soak tanks that are being retrofitted, any flow rate will be an improvement. When specifying the pump flow rate for a new process tank, it needs to be enough to enhance the cleaning but not so much that it creates the potential for part damage. Several turnovers of the solution per hour are recommended for best results.

Vertical part agitation is also an efficient method to introduce mechanical agitation in the solution tank. By moving the part through the solution, you create a scrubbing action that is very effective at removing soils. In addition, this method is very effective at ensuring that the intricate part configurations are thoroughly drained and flushed numerous times in the cleaning cycle.

When designing a system with vertical part agitation it is highly recommended that all mechanical parts, such as a pneumatic or hydraulic cylinders, do not come in direct contact with the aggressive chemicals. This will reduce the required maintenance and extend the system's operating life. If properly designed, vertical part agitation systems are very dependable and will last for years or even decades.

In addition, insist on a method of part agitation that enables you to control both the speed of the agitation (the frequency of stroke), as well as the length of stroke. Some part configurations clean better at different stroke lengths and some parts may be damaged if the stroke speed/frequency is too aggressive.

Another type of agitation that is an option, is ultrasonic energy. Ultrasonic transducers operate at a high-frequency range above the upper range of human hearing. In aerospace applications, operating frequencies between 20 kHz and 40 kHz are quite common and effective.

Ultrasonic pressure waves propagate through the solution causing alternating high and low pressure areas at the part surface. The low pressure causes a cavitation bubble to occur. The high pressure then causes the bubble to implode. Temperatures inside the cavitation bubble can reach 5,482°C (9,900°F) with pressures up to 500 atm. The implosion event creates a jet stream that travels up to 400 km/hr.[6] The combination of pressure, velocity and temperature create very effective cleaning energy.

When specifying the ultrasonic frequency, it is best to consult the experts. They will need to know details such as part size, weight, cleaning solution, soils and base metals.

Determining how many watts/liter of ultrasonics are needed can end up being a budgeting factor. In aerospace applications, it is possible to have process tank volumes in excess of 7,500 liters (≈2,000 gallons) and operating ranges of 2.6-4.0 watts/liter (≈10-15 watts/gallon) are quite common. Factoring in a very conservative cost of $5/watt and a single 7,500 liter tank, fitted with 19,500 watts (2.6 watts/liter) of ultrasonics, will cost $97,500.

If the process tanks are existing soak tanks and they are being upgraded with a form of agitation, certain styles/types of ultrasonics are designed as drop-in retrofit units. In addition to the ease of installation, they also are low profile and do not require a great deal of space, so the tank's working envelope size may not be compromised. The ultrasonic supplier should review the tank design to determine the ultrasonic installation location that will provide the greatest cleaning effectiveness.

It is important to note that the process tanks that are retrofitted with ultrasonics must be fabricated out of stainless steel, because over time, mild steel will not hold up to the aggressive nature of the ultrasonic cavitation bubbles' scrubbing action.

The engine manufacture's standard practices and procedures of cleaning for particular components may dictate ultrasonic power, frequency and time limitations. For example, GE Aircraft Engines' Standard Practices Manual on engine bearing cleaning is very specific on time limitations for cleaning with ultrasonics. In section 70-22-01, dated November 1997, it states, "ultrasonic agitation is allowed for only one five minute interval for each bearing cleaning cycle."[7]

Pratt & Whitney's SPOP 216 has similar requirements on the frequency and the total wattage of optional ultrasonics. "A 20 or 40 kHz frequency ultrasonic unit is recommended with an intensity of 6-11 watts/square inch."[8]

Method of Heating and Heat Requirements

Not all of the process tanks will require heat. For those that do, they may have operating ranges between 50°C and 94°C (≈120°F-200°F). A common mistake is under-sizing the watt (BTU) capacity of the heating system. When specifying the watt (BTU) requirements, factor in:

- Tank volume
- Operating temperature requirements
- Anticipated kgs./lbs. product per hour
- Type of metals being processed
- Temperature of incoming parts
- Heat loss due to evaporation
- Desired heat up times
- Make up water temperature and volume/hour
- Plant humidity
- Velocity of air across the tank (exhaust system)
- Ambient air temperature
- Tank insulation value

Steam, gas and electricity are the most common methods to heat process tank solutions. The method chosen is usually made based on usage costs, availability and the corrosive characteristics of the solution.

A large percentage of overhaul shops are equipped with central steam. Therefore, steam heated engine cleaning lines tend to be the most common. Steam coils are made of pipe embossed metal plates with steam passages as the heat transfer surface. With steam heat coils, the heat can be spread out over a large surface area. This is referred to as "low heat flux density," which is the amount of heat transferred per unit area of the heating surface. Low heat flux density (also known as low watt density) is desirable, as it reduces the frequency in which the steam coils need to be cleaned and the tank has a limited maximum input temperature (i.e. maximum steam inlet temperature). In addition, they can be designed in such a way that they can be easily removed for routine cleaning and maintenance and they allow for a great deal of flexibility in shape and size to fit a variety of tank requirements. The disadvantages are the requirement for a boiler system, steam and condensate piping and the efficiency of the steam-heated systems will vary depending on the type of boiler and steam system selected.

When specifying the materials of construction for the steam coils, factor in which chemicals will be used in the process tank. Stainless steel 316 series is recommended for all steam coils and for some chemical solutions, more corrosive resistant materials and exotic metals maybe warranted.

Gas heat is probably the second most common form of heating for these applications. Gas, usually natural or propane, is burned in a chamber or immersion gas coil. The efficiency of the heating is based upon the firing rate of the burner and the length of the gas coil. Maximum efficiencies are usually about 80% (above 80% there will be condensation in the gas coil). The heat flux density can vary depending on the surface area of the gas coil and the firing rate. Some of the newer pressurized burner systems are capable of firing into small diameter gas coils and achieving very high heat transfer rates (high heat flux density) especially near the burner entrance where the gas temperature is the highest.

If the gas tube gets fouled and the heat transfer is restricted, the temperature of the heat transfer surface will rise and the efficiency of the heater will go down (flue gas temperature will increase). With high heat flux densities, the burner tube may be damaged or burn out as a result of fouling. Gas burner controls should be specified based on insurance carrier requirements and local codes.

The advantage of gas, in some case, is lower fuel costs and possibly low heat flux density. Disadvantages are lower efficiency than electric heat, the need to vent combustion gasses and burn out potential.

Probably the least common method to heat a large process tank is electrically. In an electric system, an electric current is passed through a resistance element resulting in heat. The heat is conducted through a sheath material that separates the resistive heating element from the solution. A contactor controls the flow of electric power to the heating element in response to tank temperature and set point. Electric heaters are made in a variety of watt densities and sheath materials. Unlike steam, the maximum heater temperature is not limited to the nature of the energy supply. The electric heater will supply a constant amount of heat. If the heat transfer is restricted, the temperature of the heat transfer surface will be forced up until the heat does transfer or until the heater burns out due to over temperature.

The advantages of electric heat are the relatively small size, easy installation, ease of control, and low capital costs. The disadvantages are generally higher heat flux density and burn out potential due to no natural limit of maximum heat transfer surface temperature. Electric heaters are 100% efficient in that all energy supplied to the heater is released to the tank as heat.

Material Handling and Degree of Automation and Controls

Due to the large part sizes, overhead hoist systems tend to be the most common method of transferring loads from stage to stage. These systems can range from simple manual hoists to fully-automated three-axis systems where all movements are computer controlled and monitored.

If it is a low volume cleaning operation and advanced measures of process controls and documentation are not required, then a manual transfer system maybe sufficient. All transfers are timed and controlled via an operator. This basic system has the greatest operator objectivity and potential for operator error. However, the advantage is that the operator interfaces directly with the system and can visually inspect the parts between each process. If more process time is required and the recommended maximum process time has not been exceeded, the operator has the ability to increase the cycle time by putting the parts into the tank for additional cleaning.

When a higher degree of automation, process control and documentation are required and/or the anticipated cleaning volumes are high, fully automated transfer systems can meet these requirements. The more advanced systems utilize a control process commonly referred to as “dynamic scheduling.” Dynamic scheduling features greatly enhance the process engineer’s capability of performing complex recipe mixing with high production and/or high flexibility requirements. Hundreds of recipes can be intermixed. With databases of several thousand part numbers, the user can run any combination of racks or loads in any sequence and get consistent quality on every part, automatically. Simple to fill out menus for immersion times, drip times and desired min/max times can be employed.

With the proper software, detailed logs are automatically saved and customized reports can be generated. This greatly enhances the traceability of each part as it is processed though the cleaning system.

Ancillary Equipment & Waste Minimization

One method to reduce waste treatment volumes is to extend the chemical bath’s operating life. By removing suspended solids and floating contaminates, one can reduce the frequency of having to dump or waste treat thousands of gallons of chemical solutions.

Suspended solids can be efficiently removed with basic cartridge or bag-type filtration. Recommended total tank turnover rates of 2-5 times per hour are common. With process tanks that see excessive soil loading (usually the first wash stages), higher LPM volumes are recommended.

Filtration in these types of applications commonly takes place at the macro particulate range of the filtration spectrum. Sand and grit fall into this range. The smaller the filtration media's micron rating, the greater the amount of soils which can be removed. Most filtration systems are designed with enough flexibility to enable the user to use a wide range of filtration media sizes. "Polishing" filtration systems operate in ranges as low as 50-100 micron (about the size of a human hair), while the systems designed for large soil loads may operate well above 1000 microns. When specifying the desired level of filtration, it is best to work closely with the equipment manufacturer and the chemical supplier. In addition, some engine manufacturer's standard procedures may have required levels of filtration for specific process stages.

If filtration of a higher level is required/desired, ultrafiltration can remove contaminates in the 0.001 to 0.1 micron size range[9]. These types of systems are designed to remove contaminates such as emulsified oils, rather than standard carbon dust and dirt. When considering this form of filtration, work very closely with the chemical supplier to ensure that their products are compatible.

Floating contaminates can be removed by incorporating a side stream coalescing system. On a continuous basis, solution on the top of the process tank is sparged to an overflow trough, which drains to the coalescing tank. This tank is designed in such a way as to create a "quiet zone" which provides ample time for the floating contaminates (some oils, carbon, dust, etc.) to pop from the solution, then be efficiently removed. The cleaned solution is then pumped back to the process tank. Its return flow is what creates the sparging effect across the top of the solution. When considering coalescing as an option, it is imperative that the cleaning chemical formula promotes the splitting/floating of oils and is not an emulsifying type of cleaner.

Many OEM standard procedures will specify that the rinse water is treated for dissolved solids such as minerals and salts. Methods such as reverse osmosis and deionizing resin bed systems are quite common. However, deionized water is the most common form used in final rinse stages where high levels of rinse water purity are required[10]. These systems are usually leased from a local water treatment provider, who will maintain them as part of their service. Some local water supplies are so high in dissolved solids that treated water may not be optional, as their mineral content can have adverse effects on the final product.

Vender/Supplier Selection

After determining the basic requirements for the cleaning system, such as the number of process tanks, volume requirements and the preferred method of material handling, it is time to solicit potential suppliers for bids. Selecting the preferred company or companies to build the new cleaning line is a critical step in the process of designing and installing a new overhaul line.

Thorough Understanding of the Engine Overhauling Industry

Engine overhauling is an industry with very unique requirements for reasons detailed in this paper. The chosen vendor should have a thorough understanding of all of these aspects. Part size, part cost and unique cleaning chemicals require special attention and have specific requirements that the prospective equipment manufacturer should fully understand. Engine manufacturers will have minimum requirements and design requirements which some vendors may have never had exposure to, or experience in designing. What they may have previously built and is their standard design may not be appropriate in an engine overhaul line.

Industrial Cleaning Experience

There are many issues that separate the cleaning industry from other chemical processing applications such as plating or coating lines. Effective cleaning systems require industrial designed process tanks with dependable industrial mechanical agitation in the form of liquid agitation, part agitation or ultrasonics. Engine cleaning lines are no longer just large soak tanks. The supplier should have proven experience with one or more of these methods.

Customer References

References are a good way to not only find out about the company's product, but they also enable you to find out what type of after-sales support can be expected. As the engine overhaul business changes, it is critical that the supplier be positioned to address these changes. Contacting references can be one way to measure a vendor's after-sale support.

Obviously, a potential vendor will provide satisfied customers as references. So, it is probably a given that the references will speak highly of the supplier and the product. For this reason, it is important to inquire on other issues such as why this vendor was initially chosen over others, what is the percentage of operating uptime/downtime, what are the typical maintenance requirements and how user friendly is the system. It is also helpful to visit some of these references in person for obvious reasons.

Pricing

Traditionally, price has been a driving factor for cleaning acquisition projects. When considering costs, factor in more than the purchase price. Consider the cost of ownership, which will include, process efficiencies, usage costs (power requirements, chemical usage estimates, etc.) and cleaning yields. 100% first time cleaning versus the need to re-clean, represents a significant usage cost savings. In addition, factor in costs associated with warranties, extended warranties and guarantees.

When comparing pricing between two or more vendors, whenever possible, ensure that "apples are being compared to apples." Ask for as much detail as possible in the proposal so that an educated, objective comparison can be made. For example, one vendor may consider a sufficient liquid agitation rate to be 190 LPM (≈50 GPM), while another may have quoted 1150 LPM (≈300 GPM). If the process tank sizes are comparable, the differences between these rates in this example are significant and so are the costs associated with building them.

Summary and Conclusion

The aerospace engine overhaul industry is a dynamic industry which is constantly changing as aircraft and components change. Current trends include: 1) Increased process tank sizes due to larger engines and components. 2) The updating of soak tanks with the implementation of mechanical agitation to improve cleaning and reduce cleaning cycle times. 3) The reduction and elimination of solvents due to new environmental regulations. 4) Increased process control and higher levels of traceability to meet today's higher standards. 5) A move towards cellular cleaning to minimize in-process material handling costs and to bring total control of the part back to the work cell.

The engine overhaul industry is unique in many ways. Part sizes and variances, exotic metals, high component costs and requirements for high levels of traceability are just a few. Even with these unique issues, the basic cleaning formula still holds true. When designing a new cleaning line or improving an existing line, it is important to understand this basic cleaning formula of time, temperature, chemicals/concentration and method of cleaning. Each variable has a direct effect on the others. By changing one factor of the formula, it may have an exponential effect on others.

When designing a new cleaning line, one must determine: 1) The optimal number of process tanks. 2) The proper tank size and dimensions to accommodate the parts in the best orientation for the most effective cleaning. 3) The method of agitation that is most effective in your specific application at removing the soils. 4) Determine which method of heating best fits the application/situation and how to properly size the heating capacities of the process tanks to ensure that the recommended operating temperatures throughout the processes are maintained. 5) Determine what level of automation and material handling is needed to meet the volume requirements and provide the desired level of operator interface. 6) Which ancillary equipment may be advantageous to minimize the system's waste stream generation.

One of the most critical decisions in designing a cleaning line is the selection of a vendor. When considering vendors one should include the following in the decision making process: 1) Do they have a thorough understanding of the engine overhaul industry and those requirements that make it unique? 2) Do they have industrial cleaning experience and have experience designing systems with mechanical agitation? 3) Do they have strong references and experience cleaning and handling similarly sized parts, if not direct experience with cleaning in the aerospace industry? 4) When comparing system costs, consider the usage cost, not just the initial purchase cost. 5) Request detailed proposals so an educated, objective decision can be made.

Projects of this size, complexity and magnitude require a great deal of research, time and effort. By thinking it through and using a step-by-step approach in the decision making process, it can simplify the complexity of the project and help to guarantee that the best system for your specific application is selected.

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