# PRAM PROJECT

## Aqueous Parts Washer (APW) Field Demonstration of New and Improved Parts Cleaning Systems

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**Prepared For:**
**David Ellicks**
**AFRL/MLS-OLR**
**325 Richard Ray Blvd., Bldg. 165**
**Robins AFB, GA 31098**

**Prepared By:**
**NCI Information Systems, Inc.**
**2850 Presidential Drive, Suite 250**
**Fairborn, OH 45324**

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# 1 Introduction

This Final Technical Report (FTR) summarizes the activities and results obtained from a Productivity, Reliability, Availability, and Maintainability (PRAM) funded initiative to evaluate new aqueous parts washer (APW) technology. The principal objective of the aqueous parts washer evaluation task was to identify and evaluate recent APW technology advancements to improve the overall USAF parts cleaning capability and reduce manpower requirements for cleaning while continuing to meet environmental metrics. To accomplish this objective, commercially available APW technology were evaluated and down-selected several systems for field-testing at Air Force bases in specific parts cleaning operations.

This project also had at its intentions to demonstrate that if the proper engineering analysis is performed upfront, the automatic aqueous cleaning process is a viable replacement for most solvent cleaning systems. The project involved placing new equipment in field trials that would provide at least a 20-year life cycle for the equipment. Another goal of the project was to eliminate the need for supplemental cleaning operations and all corrosion problems associated with the aqueous cleaning process. The final goal of this project was to address the problem of hazardous waste generation from aqueous cleaning processes. This was accomplished by employing two cleaning bath treatment systems in field tests. The results of this project have been further used to produce a selection guideline to provide guidance to maintenance personnel for selection of new APW equipment for maximum leverage of the technology in their specific cleaning applications. The selection guide is Appendix A to this report. Also, specific operational guidelines were developed for the equipment that was field-tested. These operational guidelines can be found in Appendix B to this report.

# 2 Background

In the late 1980s and early 1990s, the United States military, and the government as a whole, made pollution prevention (P2) a primary focus. Concerns over ozone depletion, personnel exposure to carcinogenic materials, and the ever-increasing cost of hazardous waste disposal led to a significant amount of the military budget being dedicated to pollution prevention and/or elimination. With the adoption of the Montreal Protocol of 1987 which established as its goal the elimination of ozone depleting substances (ODSs) and the establishment of new volatile organic compound (VOC) and hazardous air pollutant (HAP) levels, military base environmental managers were forced to search for more environmentally compliant materials and processes. One of the areas targeted was the reduction of solvent cleaning operations. Solvent cleaning operations were usually very labor-intensive, produced a large amount of hazardous waste, and exposure to most solvents was deemed harmful to personnel.

At most bases, in order to become more environmentally friendly, solvent parts cleaning and vapor degreasing processes were replaced with automatic aqueous parts washers (APW) by the environmental management organizations. At the time, aqueous part cleaning was seen to have numerous benefits over solvent cleaning. It was environmentally friendly, it was supposed to substantially reduce hazardous waste streams, and the parts washers were automatic, eliminating operator time that was currently being spent scrubbing parts in solvent dip tanks.

During several major command surveys, the Air Force Corrosion Prevention and Control Office (AFCPCO) encountered parts cleaning problems that raised immediate concerns. NCI Information Systems was contracted to investigate the problems and potential solutions. The investigation to date has revealed that many of the attributes envisioned for aqueous cleaning by environmental managers had not been achieved and both APWs and the aqueous cleaning process had introduced new sets of problems. Numerous parts being cleaned were now corroding or being subjected to hydrogen embrittlement, equipment maintenance problems were being encountered, and cleaning was ineffective requiring personnel to perform supplemental hand cleaning (many times with unapproved materials).

At the time of the APW survey, it was estimated that 1900 APWs were in use across the Air Force. The APW survey team found that the introduction of the aqueous cleaning process into field maintenance operations had resulted in several unexpected problems. The survey found that, at most bases, the aqueous parts washing capability had been added only after the removal of all solvent cleaning capability or other alternatives. It was determined that, after equipment installation, no guidance had been given to the operators as to how to properly operate the systems. Many of the shop-specific technical orders (T.O.s) did not even contain approval for the aqueous cleaning process to clean their parts and where there was T.O. approval, it did not provide adequate guidance on operational parameters. Also, guidance was lacking as to what parts could not or should not be cleaned using the aqueous cleaning process. As a result, several shops were using the aqueous cleaning process to clean bearings and cadmium-plated parts.

The majority of APWs at each base were batch-purchased by the environmental managers using pollution prevention funds; therefore, none of the machines were designed for specific cleaning applications or requirements. This resulted in poor cleaning performance by the aqueous systems for many applications. Also, when the APWs were purchased, mild carbon steel machines were usually chosen over stainless steel to save money and/or to allow for the purchase of extra equipment. The service life for these machines was expected to be twenty years if proper maintenance was performed; however, several of the APWs inspected on the survey had rusted so badly that they had been condemned after only five years of service. This led to another problem as no provisioning had been provided to replace equipment when it became unusable.

At about the same time, the Air Force Reserve Command (AFRC) began to notice a significant rise in its hazardous waste disposal costs. This increase was attributed to the large amounts of APW bath water that were becoming contaminated during the cleaning process. This problem was also encountered on the survey performed by NCI Information Systems. Approximately 40% of the APWs encountered on this survey were producing hazardous waste and the waste streams being produced by these machines were usually greater than the waste stream generated by the solvent systems that they had replaced.

In order to solve some of these problems, this project evaluated the latest APW technology and recommended specific APWs based on the particular cleaning operation of each shop. As with any process, in order to achieve the maximum benefit, the equipment must be configured for the specific application. The following report covers a discourse on what considerations were taken into account in the down selection to the systems that were field tested at Eglin AFB and Barksdale AFB over the course of the project.

# 3 APW Technology

This project involved the evaluation of the latest technology in aqueous cleaning to identify several different categories of aqueous cleaning equipment and demonstrate the application of the technology to significantly improve cleaning operations. One of the objectives of this project was to select a variety of aqueous parts washers, differing in size and functionality, to show how technology advances can be employed to significantly improve cleaning effectiveness capabilities while achieving equally important environmental advantages. The amount of equipment available for aqueous cleaning and the broad amount of cleaning requirements that exist throughout the Air Force are too large to completely address in a single project. In reviewing the previous work NCI has done in evaluating the Air Force aqueous cleaning problems, it was decided to address three categories of cleaning equipment and to apply them to challenging cleaning requirements in order to demonstrate their effectiveness. In this area, achieving success can only be accomplished by engineering the technology to the cleaning requirement. The viable application of aqueous cleaning technology is ultimately an effective alternative to solvent cleaning and will in many cases eliminate or reduce solvent cleaning requirements as a byproduct of its success.

## 3.1 Baseline Comparison

In order to evaluate what potential improvements are possible by introducing new APW technology to the field, it was necessary to first establish a baseline comparison with what APWs are currently in use at the various maintenance shops and their associated cleaning requirements. The vast majority of APWs currently fielded by the Air Force are Better Engineering carbon steel units. Twenty-five different models of Better Engineering units were seen on the APW survey previously performed by NCI. The next closest vendor was MART with 2 different models seen on the APW survey, both of which were predominant in the wheel and tire shops. A rough estimate is that Better Engineering units make up approximately 80% of all Air Force fielded systems.

## 3.2 Classes of Equipment

Size is the determining factor in classes of equipment. There are 3 main categories of aqueous cleaning equipment for general-purpose use that are produced by a variety of manufacturers. The 3 classes established for this project are based on the overall size of the machines and the cost of the equipment is commensurate. For the purpose of this report, the classes will be identified as small, intermediate, and large. The small class is made up predominantly of tabletop washers that cost under $5000. Not all manufacturers produce these small units in their line of aqueous cleaning equipment. This class of washer is ideal for cleaning numerous small parts when that is the only cleaning requirement or when there are many small parts in addition to other cleaning requirements and the small parts batch cleaning is an impediment to the other cleaning requirements in a larger machine. In this size of equipment, the most widely used throughout the Air Force are the Impulse models produced by Better Engineering.

The intermediate class of washer is what the majority of base maintenance shops are currently using. These aqueous cleaners are typically cabinet size and capable of holding parts of up to 2 feet by 3 feet in dimension. They are available in both front-loading and top-loading designs and cost between $3,000 to $15,000. The most widely used throughout the Air Force are the various front-loading models produced by Better Engineering. The front-loading model has an octagonal door which when opened, exposes 55% of the parts basket. These units typically have multiple manifolds for spray nozzles and a rotating basket for the parts. They are almost always equipped

**Figure 1 Better Engineering Front-Loading Aqueous Parts Washer**

with an external disc oil-skimming system as standard. The size of this class of equipment will accommodate most parts requiring cleaning in back shop maintenance throughout the Air Force.

The large class of washer is mainly employed in Air Force wheel and tire shops. These washers have a large capacity and can cost up to $60,000. The large washers are mostly the top loading type (clam shell) and can hold 2 to 8 aircraft main wheel halves at a time, dependant on size of the washer and the wheels. Top-loading models are usually chosen when floor space is a premium. The lid of a top loader is powered up and down with a rear-mounted motor and eliminates the floor space needed for a front-loading door to be opened.

**Figure 2 Better Engineering Top-Loading Aqueous Parts Washer**

### 3.3 Equipment Evaluation

It was decided for the purpose of this project that one piece of the latest technology aqueous cleaning equipment would be selected from each of the equipment size categories and utilized for improving a specific cleaning application for validation in their ability to improve aqueous cleaning. There are numerous vendors that make products for aqueous cleaning in each of the previously mentioned classes of equipment, so in order to narrow down the number of choices a certain standard was set from which to start. From our observations on the USAF APW Survey it was obvious that a critical problem arose in the initial procurement of the machines. In order to save on initial procurement costs, mild carbon steel machines were purchased instead of stainless steel. While mild carbon steel machines may be ideal for most commercial enterprises, they are not the proper choice for military operations. Mild carbon steel machines require a "burn-in" phase in which the machine is washed with rust inhibitor to protect the steel from oxidizing. This must be the first process performed on a carbon steel machine after it has been purchased. Unfortunately, it can sometimes take up to a year for a machine to be hooked up. During this period the mild carbon steel the machine is constructed from will rust. Therefore, when the machine is finally hooked up and run, the operator has to contend from the beginning with washing with "rusty" cleaning solution. For this reason, one requirement established on the purchase of this project's aqueous parts washer systems is that the machines be constructed out of stainless steel. Stainless steel machines are known to typically have approximately a 20-year life cycle. The mild carbon steel APWs purchased for the Air Force are seeing approximately a 5-year lifetime. Stainless steel APWs on average cost approximately double of what their mild carbon steel counterparts do; therefore, the life cycle costs of the mild carbon steel machines are approximately double that of the stainless steel machines.

Another requirement for down selection was that the machines chosen exhibit unique qualities that provide exceptional capability for the intended cleaning applications selected for this project. Companies that produce clones of currently fielded parts washers were not considered for selection regardless of price.

Finally, the aqueous parts washers chosen had to completely satisfy the shop's unique cleaning requirements, had to be user friendly, provide easy access for clean out, and require less maintenance than their current equipment. Meeting these standards ensures the equipment provides more time online in operation while improving productivity and efficiency.

## 3.4 Equipment Versus Cleaning Requirement

There are a variety of cleaning requirements throughout the various Air Force maintenance shops. Even within a particular maintenance shop, cleaning requirements can differ due to varying weapon systems and locales.

Unlike when the aqueous parts washers were first introduced, the objective was to choose machines that would meet the specific requirements of a particular shop. Also, it was necessary to make sure that the parts washers chosen would meet all the requirements in each shop's specific technical order requirements and that aqueous cleaning was authorized.

## 3.5 Shops and Cleaning Requirements Selected

Due to its proximity to Robins AFB, Georgia and the number of wings located at the base, NCI Information Systems, Inc. initially coordinated with Eglin AFB environmental personnel to perform an initial site survey of the base. From this survey, it was determined that the 33rd Fighter Wing would be suitable for the aqueous parts washer field test as it had shops that could utilize each of the 3 different classes of APW equipment and were experiencing cleaning difficulties with their current APW or lack of one. However, due to state environmental regulations it was determined that another base would be needed to field test the bath treatment systems for managing hazardous waste water generated by the APW's. Barksdale AFB in

Shreveport, Louisiana was determined to be a site that had APW hazardous waste problems and would be an ideal candidate. The APW's at Barksdale AFB were their largest generator and source of hazardous waste. An initial site survey at Barksdale AFB resulted in the identification of shops that would be suitable for the 2 different types of bath treatment systems identified.

After discussions with 33rd FW personnel and reviewing cleaning requirements of the various shops it was determined that there were 3 shops with cleaning requirements that could be significantly improved with proper application of the latest technology APWs. A pre-field trial questionnaire was given to shop personnel to assess the existing cleaning process and procedures prior to the selection of the new technology APW to improve their cleaning process. These results are discussed below for each of the shops.

#### 3.5.1 33rd FW Propulsion Shop (Eglin AFB, Florida)

The cleaning requirement for the 33rd FW propulsion shop was several small augmentor parts from the F100 engines. However, the shop did not possess any of the 3 cleaning processes authorized for cleaning these parts. Aqueous cleaning was identified in the shop specific technical orders (T.O. 2-1-111 and 2J-F100-36-10) as one of the approved processes that could be substituted for solvent cleaning. The shop had a large Better Engineering top-loading model to clean their various parts; however, the shop was unaware of an approved aqueous cleaner to clean their parts with even though aqueous cleaning was identified as a process that could be substituted for solvent cleaning. There was little overall operational guidance and the technical order called out an aqueous cleaner (Daraclean 235 XL) that did not exist. As a result, the shop was only using water heated to around 180 degrees Fahrenheit to clean their parts within the large parts washer. However, the large pressures emitted by the parts washer pushed around the smaller parts within the washer, even when placed within a parts basket specifically built for the washer. Concerns were raised that the forces exerted by the nozzle pressure might result in potential damage to the parts.

As a result, maintenance personnel had resorted to cleaning the small augmentor parts in a bucket of room temperature water. The main soils being removed were dirt, grease, oil, fuel, and carbon deposits on what are unpainted parts. Four out of seven of the shop personnel evaluated the soils as being moderate to heavy with the remaining three shop personnel feeling that the parts were very heavily soiled. The hand scrubbing method was very ineffective and laborious. The shop personnel usually spent a whole afternoon gathered around the bucket scrubbing parts.

For the pre-field trial questionnaire, the shop personnel were asked to provide input on the ability of their current APW to perform cleaning on their small augmentor parts. Shop personnel were also asked about the hand cleaning process, but input was desired on the aqueous parts washer process to find out what areas could be improved if a new APW was to be installed in the shop for cleaning the small parts. All but one of the shop personnel felt that the current APW did not meet the required cleaning standard. In fact, one member of the shop commented that it usually took two to three 45-minute cycles to clean anything effectively. All shop personnel however found the machine easy or very easy to operate. The machine so far had required very little maintenance. Drying of the parts was performed either by leaving the parts in the APW cabinet to have the parts dried by evaporation of the liquid or removed from the washer and dried with a shop rag. All but one of the shop personnel said they would not recommend their process to other maintenance personnel as a replacement for their systems. Those in the shop that had used vapor degreasers or other solvent systems felt that the solvent degreasing processes performed a lot better at removing the carbon deposits from the parts. As long as some supplemental hand cleaning would be required in the process, the feeling was that the shop would prefer to use solvent to an aqueous based system. The APW had only been in the shop for a few months and a cleanout of the bath had not been performed. The only hazardous waste they had to report was the small amount of sludge being removed by the external disc oil skimmer. When asked to provide potential ways to improve the current process, responses ranged from finding an approved aqueous cleaner, switching to solvent, or having a hand held pressure washer.

It was determined that the shop would get the best results from using a small aqueous parts washer in addition to the large parts washer they currently had. This parts washer would need to be relatively small, but have the capability to hold several small parts within its wash cabinet at a time. Also the nozzles needed to be close to the parts and be able to access the parts through whatever was used to hold the parts within the cabinet. In addition, the parts washer needed to be portable so that the washing of the parts could occur in one area of the shop and the parts washer could be drained in another. In addition, the parts washer needed to require minimum upkeep and be fairly easy to operate.

### 3.5.2 33rd FW Armament Shop (Eglin AFB, Florida)

The armament shop's existing cleaning process consisted of 2 different-sized Better Engineering front-loading models to clean their various parts. Out of 10 shop personnel, 4 felt the cleaning effectiveness of the APWs was fair, 5 felt it was good, and 1 thought it did an excellent job. There was a similar breakdown in the personnel's opinion of whether or not the process met the required cleaning standard. Forty percent felt it did not meet the standard, fifty percent felt it met the standard, and ten percent felt it exceeded the standard. The primary soils being removed from parts were aircraft grease, grime, sand, dirt, rust, and lubricants. Six of the maintenance personnel thought the soils were medium to heavy and four were of the opinion that the soils were extremely heavy. Parts were dried either by leaving them in the machine for a couple of minutes after the wash cycle had completed or removing the parts, shooting them with compressed air, and wiping down with a shop rag. All shop personnel found the equipment easy to use with the main complaint being the difficulty of cleaning out the bath reservoir. Complaints were that the bath reservoir area was not very accessible, allowing only one person to be involved with the cleaning operation. This operation usually took 2 to 3 hours to complete.

Seven of the shop personnel said they would recommend the current cleaning process to other maintenance personnel; however, half the shop personnel felt it did not do as good a job cleaning the parts as solvent degreasing had. The machines were currently producing about 5 gallons of sludge a month as hazardous waste. The bath water itself tested non-hazardous and was flushed down the industrial drain at every cleanout. The shop currently had three problems with the APWs. One was that the parts washers did not possess a fresh water rinse capability as was required by technical order guidance in T.O. 11W1-7-14-2. The second was that they were currently going through approximately one sock filter every two weeks. The sock filters were being used up not by removing a large amount of contaminants from the bath, but because they were collecting powder residue from the powdered soap being used. While they had followed manufacturer's directions in mixing the soap into solution, always a large portion would settle to the bottom of the washer and be pumped through the system and settle on the sock filters. The third problem was also soap-related as the powder residue covered parts at the end of a wash cycle resulting in the need to perform multiple wash cycles frequently. At the end of these wash cycles parts would be removed and wiped off with a cloth. The majority of the time, powder residue would still remain on the part so the parts were lubricated and wiped down again to remove any remaining powder residue. The soap being used was Better Engineering's Natural Orange without d-limonene, which is a Mil-C-29602 Type II (powder) approved cleaner.

Maintenance personnel suggestions of ways to improve the cleaning process were to provide better jet spray nozzles and filters, an improved method of cleaning out the bath reservoir, adding fresh water rinse capability, a self-monitored solvent/soap system, and better maintenance support from the vendor. Maintenance procedures were attached in a pouch on the side of the APW and monitored for upkeep. Maintenance was divided into weekly and monthly requirements.

Analysis of the APWs and this cleaning process revealed the APWs to be of a design inappropriate for this particular shop cleaning application. The filtration system was overly complex for the soils that the shop had to remove. While the APWs might perform extremely well in another cleaning application, they were not suited for the cleaning requirement they were purchased for. The equipment size for the shop's cleaning requirements matched well with what an intermediate size parts washer could provide.

#### 3.5.3 33rd FW Wheel and Tire Shop (Eglin AFB, Florida)

The wheel and tire shop had a large Better Engineering top-loading APW to clean their wheel rims. Their cleaning operation using it had been viewed on the APW survey and at the beginning of this project the environmental personnel in the 33rd FW were concerned over the hazardous waste it was generating. The washer was in use at the start of this project and was later taken offline as a result of the hazardous waste generation and anticipation of the APW to be installed during this project. With the APW having been taken offline several months prior to the beginning of this project, all of the shop personnel were newly assigned during this period prior to installation of the new technology APW. This resulted in their having no experience in using an APW for cleaning wheels. This would prove later to be a problem when the new APW was introduced. The personnel being unfamiliar with the APW cleaning process had expectations that were not realistic. Cleaning of aircraft wheels is one of the most difficult cleaning tasks in aircraft maintenance operations and especially difficult for an APW. The APW cleaning process utilizing high pressure water jets creates what is know as a boundary layer at the surface where water movement does not occur and extremely fine soils, such as brake dust, will not be removed. When the cleaning task involves these kinds of soils, as with aircraft wheels, the problem can be overcome with more aggressive detergents. However, the Air Force prohibits this and has strict requirements on the cleaning materials that may be used in the APW bath for wheels and landing gear components. The shop's cleaning process in the few intervening months prior to the new technology APW installation consisted of hand cleaning the wheels. This was being done using a general aircraft cleaning soap and solvent cleaning was being used for bearings and wheel tie bolts. The process was difficult and labor intensive, but produced relatively clean wheels.

In order to develop data on the new technology APW implemented in the Wheel and Tire shop during this project and a similar cleaning process using an APW, it was necessary to travel to Seymour Johnson AFB in Goldsboro, North Carolina to establish a baseline. The conditions were slightly different than those in the 33rd FW shop prior to taking the Better Engineering parts washer offline. The comparison between the APW process implemented at the 33rd FW and at Seymour Johnson AFB will be shown later in this report.


**Figure 3 Setup of 33rd Wheel & Tire Shop Prior to Field Trial (BE APW is Inactive)**

## 3.6 Selection of APW Technology

A thorough review of all available technology was performed to determine the most capable equipment to accomplish the selected cleaning requirements. Given all the parameters of the cleaning requirements for each shop, aqueous parts washers were down-selected to install in the various shops. It was determined that the JR Industries JR-1 would be field tested by the propulsion shop, the EMC 100E-SS APW would be placed in the armament shop, and the Harry Major SWASH 500 would be utilized in the wheel and tire shop. In the process of selecting this equipment, a selection guide was developed for use in most cleaning applications by shop personnel when choosing to replace their existing equipment or introduce the use of an APW in a cleaning application. This selection guide is appendix A and provides the background used in selecting the following equipment.

### 3.6.1 JRI Industries JR-1 Countertop Model

This model provides a compact design that can be utilized on a standard workbench, thus providing the portability the propulsion shop required. The unit contains a motor driven rotating basket and top, bottom, and side spray bars arranged in a fan spray jet arrangement. The inside working height is 15 inches with a turntable diameter of 15 inches. It contains a ¾ horsepower horizontal pump capable of producing a flow of 13 gallons per minute at 28-psi pressure. The solution capacity is 12 gallons and the weight capacity is 50 pounds. The door seal is mechanical. The machine possesses a 2-kilowatt electric heat source that draws less than 20 amps. The stainless steel model was chosen in accordance with the selection parameters, which added $1,300 to the cost of the APW. The various available options on this model are an oil removal system, low water shut-off, oil absorbent pads, portable cart, small parts basket, and programmable timer. The only option chosen was the low water shut-off. This option was chosen to avoid the heater being burnt out due to an insufficient water level. The 110-volt power source model was chosen to permit its ease of use throughout the shop, this unit is also available in a 220-volt model.

#### 3.6.2 Equipment Manufacturing Corporation (EMC) 100E-SS

This unit was selected for the numerous features that are well suited to the requirements of the armament shop. This EMC model does not use fan type spray nozzles. They use a straight stream jet configuration provided by holes spaced ¾” apart from one another in a rectangular spray manifold that runs along the sides of the wash cabinet. The machines are insulated and possess an internal variable overflow weir oil skimmer. The pump produces a flow of 120 gallons per minute. The models have a 30-minute countdown wash timer. Power requirements are 240 volt, 3-phase, 40 amps (convertible to 240 volts, 1 phase, 50 amps) or 440 volt, 3-phase, 20 amps. The 240-volt, 3-phase model was chosen for the armament shop as it was the available power source. The machines possess deep funnel floors with 2-inch ball valves to drain the cleaning bath. EMC models do not possess a fresh water rinse cycle; subsequently, the unit procured was modified by EMC to add this capability to support the armament shop technical order requirements.

#### 3.6.3 Harry Major Machine SWASH S500

Harry Major systems can best be described as industrial dishwashers. The first thing one notices about the Harry Major system is that it is significantly more aesthetically pleasing than the standard parts washer. They contain a viewing window similar to a clothes washer that allows the user to see the cleaning process in progress. The machines contain a programmable keypad that can access any number of preset programs. This allows for simplicity of operation allowing the maintenance user to request a cleaning program for the specific part he/she is cleaning. The machine contains a hot wash to 180 degrees Fahrenheit, a drying cycle up to 212 degrees Fahrenheit, a 60 pound capacity rollout tray for loading parts, and an automatic fill feature that adds water as needed from the reservoir. All of the plumbing required for the machine is self-contained allowing the machine to be used immediately any place that can provide the power hookup needed to operate the machine. A belt oil skimmer and 44-micron filter are used for removing wastes from the bath solution. The machine is amazingly quiet producing only 70 dB of noise while in operation. For comparison, 50 dB is the noise level for everyday conversation. This is state of the art equipment and as a result, has a high cost. Options include vertical rotate, horizontal rotate, load/unload tray, and a stainless steel basket.

The smallest model (S500) was purchased for the wheel and tire shop. This would allow the parts washer to accommodate two F-15 main wheel halves at a time. In additional the load/unload tray was purchased and two parts racks were designed. One parts rack for the F-15 main wheels and one for F-15 nose wheels. The nose wheel rack was designed to accommodate 4 nose wheel halves at a time.

# 4 APW Bath Treatment Technology

## 4.1 Classes of Equipment

One of the main reasons aqueous parts washers were believed to be more environmentally compliant than the standard solvent operations they replaced was the reduction in hazardous waste. However due to misunderstanding and miscalculation, in many cleaning applications the aqueous cleaning process became larger hazardous waste generators than the solvent operation. The replacement of solvent tanks with APWs resulted in large aqueous cleaning baths now becoming contaminated from the cleaning process and the entire bath having to be treated as hazardous waste. Therefore, an integral part of this project for advancing APW technology had to deal with hazardous waste reduction. When dealing with reducing the waste produced by aqueous parts washer baths, there are two basic schools of thought. One is to use a bath filtration technology in which the bath is run through a specific media that has an affinity for the waste in the bath solution and clings to it removing the waste from the bath. This results in clarified bath solution that can be returned to the bath reservoir for reuse. The other school of thought is to evaporate the water from the bath solution leaving only the solid waste reducing the overall volume of the waste to be disposed. One of each of these types of systems was selected for field testing at Barksdale AFB to compare the trade-offs of the two different systems.

## 4.2 Shops and Hazardous Waste Reduction Requirements

The main criteria for down selecting the bath treatment systems was to determine the technology or system that would provide the greatest amount of waste reduction, be compatible with shop requirements, and provide the best cost benefit for each of the individual shops. There are complex and not always consistent regulations, or variations of interpretations to regulations on managing some hazardous waste from base to base. This has resulted in environmental managers and a majority of shop chiefs becoming very well versed over the last decade in methods for hazardous waste disposal and the reduction of hazardous waste generation.

### 4.2.1 Regulations Governing the Use of Bath Treatment Systems

Military and other government agencies must always fully comply with the regulatory limits set by the Environmental Protection Agency as the standard bearers for the policies set by the government. Standards for compliance are always an issue as permitting requirements and their costs can vary greatly from state to state, resulting in a process being viable in one state but not another. Therefore, environmental managers and sometimes maintenance shop chiefs are tasked with ensuring that the particular process they want to implement is in compliance with regulations. Generally, they must also do a cost-benefit analysis to show that the process would be less than what would be required to dispose of all the waste as hazardous. For each state, the definitions of some of the key environmental terminology can differ quite significantly resulting in a large discrepancy as to what is allowable. The evaporator systems are viewed as treatment systems in several states because it reduces the amount of hazardous waste that needs to be disposed of by evaporating all of the water from the system. However, a key difference among state environmental regulatory agencies is what is considered a "closed loop system" versus an "open loop system". To demonstrate this the example of the evaporator systems will be used.

For most states a permit is not required for a treatment system if it is considered to be a "closed loop system". For some states, this means that the evaporator system is considered an "open loop system" unless the water evaporated from the bath is recaptured. For other states, the evaporator is considered "open loop" even if the evaporated water is recaptured, if it services more than one machine and requires being disconnected from one machine and hooked up to the other for processing. As a result, it is recommended that all environmental managers and shop maintenance chiefs examine their state regulations before acting on any of the information presented on bath treatment systems later in this report.

#### 4.2.2 2nd MXS Wheel and Tire Shop (Barksdale AFB, Louisiana)

The 2nd Wheel and Tire Shop cleans a large volume of B-52 wheel rims and the bath was consistently testing hazardous with significant amounts of cadmium. The annual volume of hazardous waste generated from the cleaning process in this shop was 1732 pounds. The hazardous waste generated from the cleaning was the cleaning bath and sludge from the oil skimmer. The shop was using a MART Tornado 40 parts washer to clean their wheels and was quite pleased with its performance. They were currently using Daraclean 235 as their aqueous cleaner. In August 2001, the landing gear directorate had sent out a letter to all wheel and tire shops requiring them to switch to Calla 296. This requirement allowed the shops to use the Daraclean 235 solution until they consumed their existing stocks. The MART EQ-1 system was selected as a bath filtration recycling system to be installed in the shop because it would best support a single wash system. It was determined that using a filtration system to clarify the bath solution for reuse would be the most feasible solution for reducing the hazardous waste generation.

#### 4.2.3 917th Jet Propulsion Shop (Barksdale AFB, Louisiana)

The 917th Jet Propulsion Shop had recently become the Engine Depot for all A-10 aircraft engines and as a result there production of hazardous waste from the aqueous cleaning process had increased substantially. During the year prior to this project, the shop had produced six 55-gallon drums of hazardous waste (2412 pounds). The shop had 3 different APWs with different cleaning solutions. For such an operation a filtration system such as the MART EQ-1 could not be used as the technology depends on a similar chemistry being used and similar soils being removed in all the parts washers whose solution is to be clarified. Therefore, a water evaporator system (EMC Water Eater) was chosen for installation to evaporate the solutions, leaving only the solid sludge to be drummed up.

### 4.3 Overview of Bath Treatment Systems Selected for Field Testing

From the initial site survey to Barksdale AFB, it was determined that the most benefit would occur from placing the EMC Water Eater waste water evaporator in the 917th Jet Propulsion Shop and the MART EQ-1 System in the 2nd Wheel and Tire Shop.

#### 4.3.1 EMC Water Eater 85E-SS

Wastewater evaporators have the potential to dramatically reduce the waste stream produced by aqueous parts washer baths. Approximately 90% of the bath is composed of water. Evaporation will turn this water into vapor leaving only the contaminants behind reducing the waste volume significantly.

A United States Air Force MEEP Project evaluated the Water Eater Model 255G from April 1997 to January 1999. The Water Eater evaporated a total of 78.03 drums (36,937 pounds) of wastewater during the life of this project. This resulted in a 97 percent reduction in the hazardous waste disposal requirements for the participating shop. The Water Eater is powered by electricity or natural gas and possesses an exhaust system that draws vapors from the top of the tank to the outside of the building. After an initial warm up cycle of one hour, the Water Eater will evaporate up to 4 (with the automatic fill feature) to 6 gallons (with the batch fill feature) per hour of water. Liquid waste material can be drained via a 2-inch step down drain or pumped out. The Water Eater has a 70-gallon per minute self-priming pump option.

It is recommended that the Auto Fill system should be used when a large volume system is to be processed. It includes a 70-gallon per minute combination fill and cleanout pump, high-level backup shutdown sensor, manual pump switch, and a diverter valve. For smaller systems (100 gallons or less) it is recommended that only the pump should be purchased. For all systems it is recommended that the hose assembly should be purchased to connect the Water Eater with the aqueous parts washer.

#### 4.3.2 MART EQ-1 250

The MART EQ-1 system works by using adsorption and electrostatic forces to encapsulate the waste and thereby clarifying the bath for reuse.

A United States Air Force MEEP Project evaluated the MART EQ-1 from July 1998 to March 1999 at Whiteman Air Force Base. Based on the test results, the system was recommended for use by the test unit.

The EQ-1 is available in three different capacities: 250, 375, and 500 gallons. It should be noted that the EQ-1 can only process a bath quantity half the size of the EQ-1's capacity. Included in the price for these three models is 1 roll (250 yards) of filter media and 50 pounds of "Magic Dust". A forklift sleeve is located at the base of all models. For those applications where more portability of the system is required an option of locking casters is available. In order to hook up an EQ-1 to an aqueous parts washer it is necessary to have a pump and hoses to transfer the aqueous solution from the parts washer to the EQ-1 and back again. MART offers a transfer cart and assembly that meets these needs. This assembly consists of a 2" air operated diaphragm pump mounted on a cart with swivel casters and brakes and 15 foot long inlet and outlet hoses with 1 ½" quick disconnects at each end. The pump has an adjustable flow rate up to 140 gallons per minute. Additional 250-yard rolls of filter media can be purchased along with additional "Magic Dust" by the fifty-pound drum.

About 3 to 8 pounds of "Magic Dust" are required for every 100 gallons of aqueous solution to be processed. The bath should undergo treatment whenever the aqueous solution appears to have lost any cleaning effectiveness. While this will vary with the type of parts being washed a good rule of thumb is after every 40 loads or 10 machine hours of cleaning. The water processing takes approximately 1 hour for every 100 gallons being processed and uses approximately 5 yards of filter paper. From this process approximately 85% of the aqueous solution is returned to the parts washer as good as new.

The system returns clarified solution with chemical to the aqueous parts washer for reuse. The process utilizes flocculation technology to adsorb oil and grease and other contaminants and encapsulate them into a solid waste that does not leach in a TCLP test.

# 5 Implementation of Technology

Implementation consisted of installing the latest technology APWs in shops for specific cleaning applications to demonstrate the advantages and improvements to be gained and to justify the associated costs in the return on investment. Field test plans were designed to evaluate the effectiveness of the APWs and APW bath treatment systems in actual Air Force maintenance operations. Each individual field test was designed to evaluate a down-selected APW for cleaning process improvements or an APW bath treatment system for reducing the waste produced from a particular shop's aqueous cleaning process. Each APW was chosen based on the individual shop's cleaning requirements and each APW bath treatment system was chosen based on each individual shop's particular waste reduction requirements. Maintenance personnel provided information during the field trial through input into a spreadsheet that tracked the cleaning process or how much waste was eliminated depending on the particular system being used by the shop. A second page of the spreadsheet provided additional feedback as to when the APW or APW bath treatment system was cleaned out and when maintenance was performed on the equipment. This field trial lasted for a period of nine months in all shops but the 33$^{rd}$ FW wheel and tire shop where the field trial lasted for a period of six months. If at the end of the field trial, the shop was satisfied with the performance of the APW or APW bath treatment system, the system would be turned over to them and become the property of the shop. If at any time the shop became dissatisfied with the APW or APW bath treatment system, the system would have been removed from the shop and replaced with their previous system. All shops chose to keep their equipment at the end of this project.

It was important for maintenance personnel to realize that data collected from the individual field tests would comprise a significant portion of a report to be provided to the Air Force on the applicability of aqueous cleaning processes in field maintenance level operations throughout the Air Force. Maintenance personnel were asked to provide both honest and open input/observations (both quantitative and qualitative, positive and negative) about the aqueous cleaning process and waste reduction processes so that an accurate assessment of the system performance and the suitability for the assigned task could be determined. It was also essential not to deviate from the specific procedures outlined in the test plan unless discussed and approved by both NCI and Air Force supervision. Appendix B contains the operational guidance provided to each shop in their individual test plans. These operational guidelines should be suitable for all shops that choose to purchase this equipment with exceptions where they are in conflict with shop specific technical orders.

Maintenance personnel filled out the spreadsheet and e-mailed a copy back to NCI personnel at either the beginning or end of every week depending on shop preference. The spreadsheet information was then entered into a database for analysis. The spreadsheet was designed in Excel and made liberal use of look-up tables to minimize the amount of time shop personnel would have to take in order to enter information each week.

# 6 Field Testing Results

Any field testing for an appreciable period of time in operational units will always involve a turnover of personnel and the associated problems of maintaining continuity of data collection and consistency of the testing. During this project another terrible tragedy also had an effect on conducting the evaluation and that was the events of September 11, 2001. Even with these issues the data collected and support provided by everyone in all of the shops participating was outstanding and our thanks go out to them in making this a successful program for the Air Force.

### 6.1 33rd FW Propulsion Shop

The JR-1 APW was chosen for the propulsion shop due to its compact size and suitability for cleaning small parts that could not be cleaned in the large APW. This compact size ensures that the nozzles are only a few inches from the parts allowing maximum impact and efficient soil removal. The size also keeps the parts washer from taking up a large footprint within a shop. A small table with casters can be constructed to allow quick transport between different areas of the shop, so all small parts can be cleaned without having to transport the parts to the parts washer. Also the small table would allow the parts washer to be at a height so that personnel do not have to bend over to place parts in the washer or to operate it. The parts washer contains a cylindrical parts basket made out of expanded metal. The holes in the parts basket mesh are small enough to prevent parts from falling through the basket. The size of the holes in the basket however are a double-edged sword in that the smaller the holes are the more difficult it is for the full impact of the spray to get to the parts. The only nozzles unimpeded by the mesh are those in the top of the parts washer. The bath temperature of the APW can be controlled through settings on a small thermostat on the side of the parts washer.

**Figure 4 JR-1 Parts Washer (Front View)**

The JR-1 APW was procured and shipped directly to the propulsion shop and their personnel then welded casters to the bottom of the machine and tried it out before NCI personnel had established the field trial procedures. It was indicated that the desire was to fabricate a table for rolling the machine around on, however the shop chose to use the casters placed on the underbody of the APW to move it around the shop. It was also found that the on/off switch on the machine was broken but it could not be determined when or where it had happened. One deficiency in the machine was noted in the first week of use. There was no way to tell when the solution within the parts washer reached the desired cleaning temperature. This is a deficiency that needs to be addressed since usually if aqueous cleaners are operated below 130 degrees Fahrenheit significant foaming of the cleaning solution may occur. A small green indicator light should be added that will turn on when the bath has reached the desired temperature. Prior to the introduction of the small JR-1 APW into the propulsion shop, maintenance personnel were having to clean small parts by hand in a bucket of room temperature soapy water. This took a significant amount of time and was not productive use of their personnel. The addition of the JR-1 APW significantly improved this operation. Table 1 shows a comparison of the aqueous cleaning process using the JR-1 APW compared with both the large Better Engineering APW and the laborious hand wash. Since washing parts in the Better Engineering parts washer could result in damage to small parts this process was essentially not an option for the shop to use when

**Figure 5 JR-1 Parts Washer (Side View)**

cleaning small parts. Therefore, the meaningful results are derived from the comparison with the manual hand wash process that the shop was performing before the introduction of the JR-1 APW. The introduction of the JR-1 into the shop resulted in a significant savings in the productivity of the cleaning process. A drawback of the JR-1 is the time required to heat the bath each day for use, but this does not impact the productivity of shop personnel. Because the APW is so small, the shop did not feel it made much sense to keep the solution in the APW heated at all times of the day like the larger Better Engineering unit. This heat up period accounts for 54.5 to 57.1% of the overall process time but has no impact on productivity and the actual time required for cleaning. Consequently, the real savings can be seen in man-hour reduction. Once the APW has been heated up the wash cycle can start and does not need to be monitored. The cycle however only ends when maintenance personnel turn the cycle off (there is no automatic timer) so personnel must be careful not to leave the parts washer on for long periods of time. Wash cycles were set at 10 minutes in the operational guidance. However, the cycle had to be extended to 20 minutes to get the parts to the desired level of cleanliness when large numbers of parts were cleaned at one time or heavier soils needed to be removed.

At the beginning of the field trial the shop still had to use only heated water in the JR-1 APW because there was no approved aqueous cleaner for the augmentor parts. Cleaning with only hot water proved to be ineffective, as an oil film remained on the part at the end of the cleaning cycle. The parts required either an additional wash cycle or a scrubbing of the part to remove the film. After some extensive investigation by both propulsion shop and NCI personnel with cognizant

| | | | | Improvements achieved with the JR-1 | | | |
|---|---|---|---|---|---|---|---|
| Cleaning Process | BE APW | Hand Wash | JR-1 APW | Process Time Savings | Percent Reduction | Man-Hour Savings | Percent Reduction |
| Heat Up Washer | Kept At Elevated Temp | None | 20-30 minutes | (20-30 minutes) | N/A | None | None |
| Initial Cleaning | 90-135 minutes | 60 minutes | 10-20 minutes | N/A<br>40-50 minutes | N/A<br>66-83% | N/A<br>60 minutes | N/A<br>100% |
| Post Cleaning Wipe | 5 minutes | 5 minutes | 5 minutes | None | None | None | None |
| Total Process Time | 95-140 minutes | 65 minutes | 35-55 minutes | 10-30 minutes | 15.4-46.2% | 60 minutes | 100% |

**Table 1 Propulsion Shop Aqueous Parts Washer Cleaning Process Comparison**

engineering at OC-ALC, Blue Gold Spray Wash was identified as an approved aqueous cleaner. While the cleaning effectiveness improved with the addition of the aqueous cleaner, the shop was experiencing significant foaming of the cleaning bath. This resulted in having to wipe up the floor after each use of the APW. The manufacturer of the Blue Gold Spray Wash, Modern Chemical, was contacted to track down how to solve the problem. Further investigation found that a distributor of the Blue Gold product line had sold several 55-gallon drums of Blue Gold Industrial Cleaner mislabeled as Blue Gold Spray Wash to the Defense Logistics Agency (DLA). While the two cleaners are very similar, the Blue Gold Spray Wash contains an anti-foaming agent so that it can be used in high-pressure spray washers. Two 5-gallon containers of the Blue Gold Spray Wash were purchased directly from Modern Chemical and supplied to the shop, thus allowing the shop to use the proper cleaner. The shop returned their 55-gallon drum to DLA and replaced with the proper cleaner.

After switching to the proper cleaning solution, the shop performed 30 wash cycles over a period of 20 weeks. Assuming this is representative of the shop's typical load, the shop will reduce the man-hours spent cleaning small parts from 85 hours annually to 7 hours, for an overall reduction of 78 hours a year.

Shop personnel were very pleased overall with the performance of the small JR-1 APW, but several indicated that a slightly larger washer would have been more ideal so they could wash more parts in a single batch. This is a common request in discussions with most maintenance shops and probably one of the bigger hurdles in purchasing the proper machine for a shop. If the current machine works well, it is assumed a bigger machine would work just as well but would allow more parts to be washed at a time. However, as larger parts washers are bought to allow for more parts to be washed in a single batch, this results in a greater distance the nozzles are from the parts being cleaned and therefore cleaning effectiveness decreases. Shop personnel were asked to compare their previous processes with their current process on a scale of 1 to 5 in terms of cleaning efficiency with cleaning efficiency defined to them as how effective the process was at providing them with the desired level of cleanliness. Only 3 maintenance personnel were present for the entire field trial. The shop personnel on average rated the previous process as a 1.67 and the new process as a 5 for an overall increase of 66.7% in cleaning efficiency. It must be noted that this is a qualitative assessment depending on the opinions of maintenance personnel and may vary from shop to shop.

The application of the latest technology APW, the JR-1, for the identified cleaning process in the 33rd FW Propulsion shop was a complete success. The effectiveness of the cleaning process was improved dramatically with the use of the JR-1 and it essentially reduced the manpower requirements to nothing. Maintenance and upkeep of the JR-1 are minimal and the unit will have a significant operational life cycle without replacement. All of the metrics for productivity, reliability, availability, and maintainability were met in great measure and the return on investment was well established.

## 6.2 33rd FW Armament Shop

The EMC 100E-SS APW was chosen for the armament shop to improve the aqueous cleaning process in all respects. This is a case where advancement in technology for the APW best suited for the armament shop's cleaning requirements does not have to equate to sophistication. The guns and their components being cleaned and the soils being removed are basic and what was needed was an APW well designed to be highly effective and simple. The KISS ("Keep It Simple, Stupid") principle was employed when selecting an APW for this shop's application to be sure the equipment didn't become an issue in accomplishing the basic cleaning requirement. The EMC is a well-designed machine that is user friendly, easily maintained, and very effective for certain cleaning requirements. Because of the waste generation from this cleaning process, the EMC was ideal in that it only utilizes simple perforated screens to filter out large particulates and is not equipped with fine micro filters that require periodic replacement. Instead of spray nozzles, hollow rectangular bars with holes drilled every ¾" are used to supply the pressurized spray to the part surfaces. The basket is rotated from the top of the machine, eliminating the drive wheels used by other manufacturers that wear out routinely. This APW also has a tank bottom slanted towards the drain port on the machine to facilitate easy clean out. Instead of the external disc skimmer used on the Better Engineering APW, the EMC machine contains an internal weir skimmer where the top layer of oil film is removed by opening up a ball valve and watching the liquid as it leaves the machine. When the fluid exiting the machine changes from oil to water the ball valve must be closed. By being internal to the machine, this skimmer system eliminates a large amount of heat that is exhausted from an aqueous parts washer each month. The parts washer is also insulated, allowing the machine to maintain a constant temperature with minimal energy consumption and preventing possible harm to personnel from accidentally touching the cabinet.


**Figure 6 EMC APW (Front View)**

When the EMC machine was first installed, the shop was using Better Engineering's Natural Orange without d-Limonene, which is a Mil-C-29602 Type II (powder) qualified soap. As a result, the shop was having problems with soap residue remaining on the part after the wash cycle. In order to eliminate the problem of soap residue it was necessary to identify and obtain one of the Mil-C-29602 Type I (Liquid) qualified cleaners for the shop. Our recommendation for a cleaner was Ardrox 6333a. The shop then contacted the Hazardous Materials Pharmacy (HazMat) to obtain this cleaner. This introduced another problem that has been seen routinely with many cleaning operations. HazMat responded to the shop by saying that they could not order the cleaner and must choose from a list of cleaners provided by HazMat. None of the cleaners suggested by HazMat were qualified to Mil-C-29602, but to another specification, Mil-C-87937, a cleaner specification for exterior aircraft cleaning. Assistance was provided to the shop in the form of proper technical order references and authorizations for the Mil-C-29602, the only approved cleaner for use in the APW jet washers, and the shop was able to obtain the Ardrox 6333a and began using it three months prior to the end of the testing.

Table 2 summarizes the cleaning improvements achieved through installation of the EMC APW in the armament shop. It was necessary to introduce a liquid soap for replacement of the powdered soap to improve the whole process and that resulted in additional process time improvements. Initially, the shop noticed a slight decrease in cleaning effectiveness after the new liquid soap was introduced, but this was corrected by slightly increasing the cleaner concentration. The shop's cleaning process using the Better Engineering APW consisted of a 10 to 15 minute hand cleaning pre-wash with a general purpose cleaner, two or three 15-minute wash cycles in the APW, a 10-minute post wipe to get the parts to a suitable level of cleanliness and remove soap residue, and a 5 to 6 minute blow dry using compressed air. The 10-minute post-wipe involved wiping the parts down with a cloth and then adding lubricant to the surface of the part. This lubricant helped to remove any remaining powder residue from the part. The part was then given a final lubrication in accordance with shop specific technical orders. After installation of the EMC APW, the shop performed only one 15-minute wash cycle in the APW, a 5 to 6 minute fresh water rinse to remove soap residue, and a 1 to 2 minute blow dry using compressed air. Introduction of the liquid soap further improved the process by shortening the fresh water rinse to 1 to 2 minutes from 5 to 6 minutes. By the end of the field trial, the shop had reduced its overall cleaning cycle process time by 33 to 54 minutes. Man-hours spent for each cleaning cycle were reduced by 18 to 24 minutes. Shop personnel were asked to compare their previous process with their current process on a scale of 1 to 5 in terms of cleaning efficiency with cleaning

| Cleaning Process | BE APW | EMC APW w/ powdered Soap | EMC w/ Liquid Soap | Improvements achieved with EMC | | | |
|---|---|---|---|---|---|---|---|
| | | | | Process Time Savings | Percent Reduction | Man-Hour Savings | Percent Reduction |
| Pre-wash | 10-15 minutes | None | None | 10-15 minutes | 100% | 10-15 minutes | 100% |
| APW Cleaning Cycle | 2-3 15-min cycles | 1 15-min cycle | 1 15-min cycle | 15-30 minutes | 50-67% | N/A | 0% |
| Wipe off w/cloth, Lubricate, Wipe off w/ cloth | 10 minutes | N/A | N/A | 10 minutes | 100% | 10 minutes | 100% |
| Fresh water rinse | Not available | 5-6 minutes | 1-2 minutes | (1-2 minutes) | N/A | (1-2 minutes) | N/A |
| Compressed Air Dry | 1-2 minutes | 1-2 minutes | 1-2 minutes | N/A | N/A | N/A | N/A |
| Total Process Time | 51-72 minutes | 21-23 minutes | 17-19 minutes | 33-54 minutes | 64.7-75% | 18-24 minutes | 33.3-35.3% |

**Table 2 Armament Shop Aqueous Parts Washer Cleaning Process Comparison**

efficiency defined to them as how effective the process was at providing them with the desired level of cleanliness. Seven shop personnel participated throughout the entire field trial. The shop personnel on average rated the previous process as a 2.14 and the new process as a 5 for an overall increase of 57.2% in cleaning efficiency. It must be noted that this is a qualitative assessment depending on the opinions of maintenance personnel and may vary from shop to shop.

**Figure 7 Inside of EMC APW**

After all enhancements were incorporated into the cleaning processes, the shop performed 48 wash cycles over a period of 7 weeks. Assuming this is representative of the shop's typical load, the shop will perform 357 wash cycles a year and reduce the hours dedicated to cleaning time from between 303 to 428 hours to between 101 to 113 hours annually, for an overall reduction of between 196 to 321 hours a year. The annual savings in man-hours for accomplishing cleaning will be reduced between 107 to 143 man-hours.

Implementing the latest in improved technology equipment not only improves the cleaning process, but it improves all the factors associated with the process including the maintenance and upkeep of the equipment. In the case of the EMC APW, this proved to have very measurable dramatic results in time saved performing routine maintenance. Table 3 summarizes these savings. The armament shop chose a maintenance practice of replacing the cleaning bath on a monthly cycle. This was done to prevent their bath solution reaching hazardous levels. This is not an excessive expense as the cleaners are relatively low cost. The limited access to the bath reservoir of the Better Engineering machine required approximately 2 to 3 hours for one man to clean out the reservoir. With the EMC machine's slanted tank bottom the process takes approximately 12 minutes - 10 minutes to drain the bath solution from the tank into the floor drain and another two minutes using the fresh water rinse to remove any sludge that might be clinging to the sides of the bath reservoir. In addition, filtration

**Figure 8 EMC APW with door open.**

change out was eliminated by not having the fine micron filters on the EMC and only using the perforated metal screens to capture the large particulate. This is not recommended for all cleaning processes, but is appropriate for this cleaning process in the armament shop. The spray nozzles of the Better Engineering APW clogged routinely requiring regular maintenance to unclog them. Mostly cleaning operations require the agitation and force of spray nozzles in order to accomplish effective cleaning. The requirements of the armament shop permitted the use of the EMC hollow rectangular bars with only the drilled holes providing water jets. These did not clog with the powdered soap and eliminated the weekly need of the armament shop having to unclog the nozzles due to the buildup of powder residue. Even before the switch to the liquid soap, there was no need to perform maintenance to remove any blockages from the horizontal spray bars. The operational guidance included checking the holes each week and cleaning them out if necessary, but shop personnel stated that it was never necessary to perform this process.

The EMC APW when used with the liquid cleaner required two additional maintenance procedures that were not necessary with the powder cleaner and Better Engineering APW. The first new requirement resulted from the introduction of the fresh water rinse, which provided the capability to comply with technical order guidance. However, it also resulted in the need to add a

| | Frequency | BE Parts Washer | EMC Parts Washer | Time Saved | Percent Reduction | Man-Hour Savings | Percent Reduction |
|---|---|---|---|---|---|---|---|
| Bath Replacement | Monthly | 2-3 hours | 12 minutes | 108-168 minutes | 90-93.3% | 118-178 minutes | 98.3-98.9% |
| Filter Change Out | Bi-Weekly | 5 minutes | None | 5 minutes | 100% | 5 minutes | 100% |
| Adding Soap | Weekly | None | 5 minutes | (5 minutes) | N/A | (2 minutes) | N/A |
| Skimmer | Weekly | Automatic During Operation | 1-2 minutes | (1-2 minutes) | N/A | (1-2 minutes) | N/A |
| Unclogging Nozzles | Weekly | 10-15 minutes | None | 10-15 minutes | 100% | 10-15 minutes | 100% |
| Total Regular Monthly Maintenance | | 176.7-258.3 minutes | 38-42.3 minutes | 138.7-216 minutes | 78.5-83.6% | 157.3-243.3 minutes | 89.0-94.2% |
| Other Repairs | Random | Usually Results in Significant Downtime | None So Far | N/A | 100% | N/A | 100% |

**Table 3 Armament Shop Aqueous Parts Washer Monthly Maintenance Comparison**

cup of cleaner to the bath at the beginning of each week to maintain the desired cleaner concentration. To ensure a thorough mixing of the soap, the machine is run for five minutes without any parts in the machine. The second requirement was the servicing of the oil skimmer. Since the oil skimmer in the EMC APW is manual, it was necessary to add a maintenance procedure where the skimmer is run for 1 to 2 minutes at the beginning of each week while the machine is warming up. The machine is off for the 48-hour weekend period, allowing the oils to separate from the cleaning solution and the weir oil skimmer to remove the majority of the oil from the bath solution. Most APWs commercially available use an external disc or belt skimmer that runs during the wash cycle. The concept is to remove oils that rise to the top of the bath. Non-emulsifying cleaners permit this as they do not dissolve or break down the oils and greases into the cleaning bath solution. However, this is not a very successful effort when using emulsifying cleaners that do break down the oils and greases into the bath solution. Unfortunately, the only cleaners approved for use in Air Force APWs are emulsifying cleaners. The oils will only partially separate from the bath solution when it is at room temperature and the skimmer is not in operation. Once the bath is reheated much of the oil will go back into the bath solution. Consequently, this is an extremely ineffective process.

Even with the addition of the two maintenance procedures, the man-hours and process time required for routine monthly maintenance were significantly decreased. Also the shop did not experience any downtime during the field trial to perform repairs on the parts washer. With the Better Engineering APW, maintenance repairs were usually required once every two months including significant downtime to replace the rotating rubber tire when it wore out every six months. The machine was down for these major repairs approximately 18 days out of the year. Therefore, the annual maintenance was reduced from 323.3 to 339.7 hours to between 3 to 3.9 hours, a savings of 98.9%.

As the results show, the armament shop has been extremely pleased with the performance of the EMC APW to improve their cleaning process. In fact, the shop is now looking into obtaining funds to procure a larger EMC model to replace the other large APW the shop has. While the larger APW is not used very often, there are some parts that will not fit into the smaller APW. The shop also plans to split the current load of the EMC APW with the new one once it is obtained to continue to decrease shop hours dedicated to cleaning equipment. One of the shop supervisors indicated the only change he would make to the EMC machine is to add auto-fill capability. This would allow the machine to be fool proof. The only problem the supervisor had experienced with the APW was shop personnel coming to him and reporting that the APW was broken. Every time this occurred, he would check the water level and notice that the low water shut-off had engaged. He would discuss the need to maintain the water level in the APW with the shop personnel, add water to the APW, and begin operations again.

### 6.3 33rd FW Wheel and Tire Shop

The most difficult cleaning requirement addressed in this project is that of the Wheel and Tire shop. Aircraft wheels are subject to grease, oil, hydraulic fluid, brake dust, and heat. To clean these wheels effectively and with the least amount of effort is a daunting task. The Harry Major Machine APW was chosen for the wheel and tire shop as the parts washer with the most potential to effectively accomplish this task. The soils that accumulate on the wheel rims are by far among the most difficult cleaning tasks required by the aqueous cleaning process in Air Force operations.


**Figure 9 Harry Major Swash 500 (Front View) [Left Side Door is Open Allowing Access]**

The Harry Major Swash 500 APW was chosen for the wheel and tire shop for its numerous advantages over the Better Engineering top loader that the shop was previously using. One of the shop's concerns was making the most of its limited floor space and the Harry Major APW provided several features that enabled it to reduce the footprint in the shop. First, the machine is equipped with a guillotine door that rolls straight up allowing access to the wash cabinet without taking up any additional horizontal space. On each side and the rear of the machine are two hinged doors that lock together in the center. This allowed easy access to the internal workings of the machine for maintenance without having to view unsightly machinery. These doors also can be removed by simply lifting the door straight up off the hinges. The only plumbing required was a water hose hookup allowing the shop the capability of moving the machine to different locations within the shop by eliminating the need for any hard plumbing. The machine is equipped with adjustable levelers that when placed in the desired position ensures the machine does not move.

This aqueous parts washer has a number of very advantageous features to it not found on most other equipment. A simple touch screen control panel on the front of the machine allows the operator to choose one of four wash cycles held in memory or to modify one of the cycles to a desired setting. A wash cycle consists of both a wash period and a drying period. In addition, the control panel allows the operator to turn on each of the parts washer functions separately such as

**Figure 10 Internal Configuration of the Harry Major SWASH 500 Wash Cabinet**

the oil skimmer, the steam extractor, and the heating element. The machine is also equipped with metering valves for control of the water level that prevents operation in the advent the water level rises above or drops below a preset value. Due to foaming issues with the cleaning solution being used, the controls were modified so that the machine also shuts off if the water level gets too high. This prevents the cleaning solution from foaming out of the bath reservoir and onto the floor or burning up heating elements if the water level drops. The wash cabinet contains a window so one can view the cleaning process as it occurs allowing maintenance personnel to observe if something is working improperly.

An axial drying fan is mounted above the cleaning chamber of the machine and air is fed into the wash cabinet through a grill. The hot air quickly dries the parts inside the cabinet while a steam extractor fitted above the wash cabinet draws the air from the chamber and condenses the steam and returns it back to the bath.

The bath reservoir is insulated allowing the reservoir to maintain temperature and fluid levels more easily. This also prevents the machine from significantly heating up the shop and providing discomfort to personnel. In addition, personnel can touch the outside of the machine without fear of burning themselves. The machine also came equipped with an auto-fill feature to maintain the bath level within a certain desirable range.

**Figure 11 Easy Access Bath Cleanout Door**

A panel door on the left side of the bath reservoir can be opened after the bath has been drained providing easy access to the interior of the bath reservoir to perform quick removal of any remaining sludge in the cabinet.

**Figure 12 Opened Access Door During Cleanout**

A belt-type oil skimmer is used to remove oil and sludge from the bath reservoir.  This belt skimmer was tremendously more effective than the disc skimmer used on most APW's.  The belt skimmer removed five gallons of waste from the machine over a six-month period.  The Better Engineering machine skimmer had never removed more than a gallon of waste per year.  This results in a cleaner bath and allows for an extended period of cleaning before it is necessary to clean out the bath reservoir.  The skimmer is the only opening in the bath reservoir where heat may escape.  While this may result in some evaporation of the cleaning solution, the opening is necessary in order to also provide access for pumping out the bath reservoir if there is a chance the bath might be hazardous.

**Figure 13 Harry Major SWASH 500 (Rear View with Access Doors Open)**

This machine is designed with a guillotine door and a tray with basket for the parts to be cleaned in the washer. When the door is opened the tray pulls out placing the basket at about waist high. This provides for unencumbered ability to load parts into the work basket or fixtures for holding the parts rather than having to reach into the parts washer itself as with most other equipment. This makes it easy to both examine the parts or perform supplemental cleaning which can be done with the tray outside the cleaning cabinet using the flow through brush that pumps cleaning solution from the machine's tank and is returned into the tank.  The brush was specially designed by NCI and Harry Major Machine modified their equipment to incorporate the brush.  This feature allows additional cleaning if required.

Harry Major Machine modified their standard model Swash to achieve the best success in cleaning an F-15 wheel. To support this they were provided a condemned F-15 wheel to use as a test bed while they developed the spray bar manifolds and nozzles. A combination of carbon black and molybdenum disulfide grease were mixed together and applied to the wheel halves and baked in an oven for an hour at 180 degrees F to simulate the cleaning requirement. The problem of the boundary layer on water movement at a microscopic layer on the surface coupled with a specified cleaning solution that could not be modified presented an overwhelming problem. Harry Major along with assistance from NCI attempted several different nozzle configurations, but none could remove the soils completely due to the fineness of the carbon black being used to represent brake dust. The nozzle pressure coupled with flow of the cleaning solution and the detergency effect of the cleaner were not enough to overcome the thin boundary layer that prevented removal of the ultra fine carbon black. This resulted in the recognition of the need for the APW to possess a secondary cleaning process and led to NCI developing the hand held flow through brush. Harry Major Machine then modified their APW to add a pump and controls to flow the cleaning solution directly out of the bath into the flow through brush to provide a process that could be used as a final supplemental cleaning process. This process permits the wheel to be cleaned with the proper cleaner inside the APW and a final wash can be accomplished afterward without removing the wheel from the APW.

**Figure 14 Custom Designed Flow-Through Brush (Nipple Attached to Hose)**

Making this part of the APW cleaning process eliminates the need for personnel to possibly use unapproved cleaners to complete the cleaning after the wheels have been removed from the APW. Initially, a brush similar to that used on solvent tank cleaners was used (see Figure 9). This sort of brush possessed several problems. First, the brush did not stand up to the heated aqueous solution. Over time the bristles of the brush relaxed and became very soft to the point of being ineffective for cleaning. Second, the brush did not allow the user to get inside and clean out the surfaces of bolt holes in the wheel. To resolve this the flow through brush was developed by having shop personnel evaluate numerous types of brushes with different shapes, sizes and bristles to determine the best materials and style of brush for this requirement. A brush was then designed to specifications developed by NCI and procured from Gordon Brush (Figure 14). The brush manufacturer custom made the flow through brush with bristles that could withstand the 160 degree Fahrenheit bath that would be flowing through it.

**Figure 15 F-15 Main Wheel Half Prior to Cleaning**

**Figure 16 F-15 Main Wheel Half Prior to Cleaning**

**Figure 17 Harry Major APW After Wash Cycle Using Original Parts Racks**

In order to clean the F-15 wheels in the Harry Major Machine APW, racks were designed to support the wheel halves vertically within the parts washer. The initial parts racks designed for use with the APW were cumbersome and did not allow maintenance personnel easy access to the wheels for the secondary cleaning process. Initially a rack was not provided for the nose wheel rims as it was possible to lay them down within the existing basket of the APW. However, the nose wheel halves were light enough to be tossed around by the water pressure and needed to be secured. After eliciting the input of shop personnel, two new parts racks were designed. One rack for the main wheel halves and one rack for the nose wheel halves were fabricated. These racks were designed to provide the necessary support while maximizing the access area for accomplishing the supplemental cleaning with the flow through brush while the wheels remained in the racks. The racks were designed with plastic bushings and rollers so that the wheel halves could be easily turned during the use of the flow through brush. This proved to be extremely successful in providing for easy access to the wheels for the supplemental cleaning, if required, without the wheel rims having to be removed from the APW and control/containment of the cleaning solution.

In the interim between the start of the project and delivery of the Harry Major Machine, the shop chose to stop using the Better Engineering APW because of high cadmium levels in the cleaning bath. The APW was then removed from the shop and full documentation of that cleaning process

**Figure 18 Harry Major APW With Modified Parts Racks Providing Easier Access**

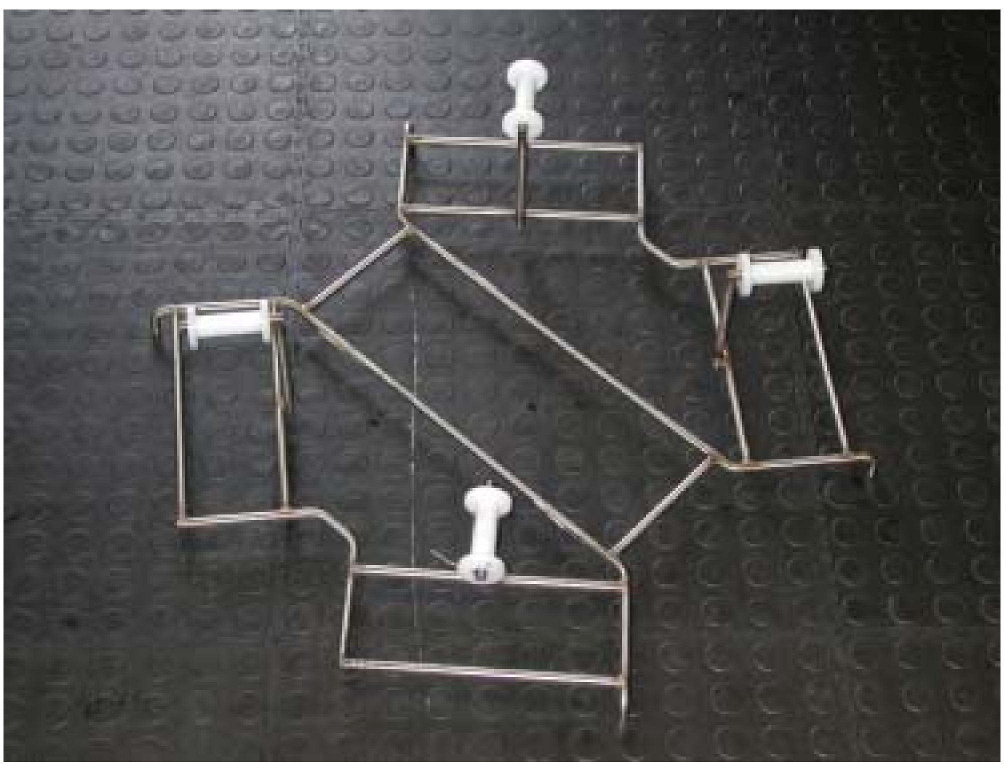

**Figure 19 Modified Nose Wheel Rack**

was not possible. However, there are known differences between the two machines that were significant improvements to the cleaning process as a result of the design of the Harry Major Machine APW. All of the cleaning cabinet and plumbing were made from stainless steel and eliminated all corrosion problems. The pull out tray at waist height eliminated the wheel halves having to be picked up and lifted over the edge and down into the basket of the clam shell APW. The auto fill and low water shut off made control of the APW much easier and when problems arose from the foaming of the new Calla 296 cleaner, it was easily made manageable.

Since no data was available on the aqueous process that was present in the shop prior to the field trial due to a complete turnover of personnel in the shop, data gathered at Seymour Johnson AFB was used for comparison. Table 4 shows the comparison between the cleaning process using the Harry Major Machine APW and the cleaning process using the MART APW. The Harry Major Machine can only process one F-15C wheel rim (two wheel halves) at a time; whereas, the MART APW can wash 5 F-15E wheel rims (the rim is cleaned as one piece and not split in two) at one time. Even though the Harry Major Machine only processes one F-15C wheel (two wheel halves) at a time the total process time for cleaning was only approximately 1 minute longer per wheel than the cleaning process using the MART APW. However, while the process time was slightly longer, the man-hours required in the cleaning process were significantly reduced.

| | MART APW | Harry Major APW | Process Time Savings | Percent Time Reduction | Man-Hour Savings | Percent Man-Hour Reduction |
|---|---|---|---|---|---|---|
| Pre-wash | 5.5 minutes | None | 5.5 minutes | 100% | 5.5 minutes | 100% |
| 1st Auto Cycle | 3.6 minutes | 4-minute wash, 1-minute dry | (1.4 minutes) | (38.8%) | None | None |
| Agitation with Green Pad or Flow Through Brush | None | 3 minutes | (3 minutes) | N/A | (3 minutes) | N/A |
| 2nd Auto Cycle | None | 4-minute wash, 1-minute dry | (5 minutes) | N/A | None | N/A |
| Post Wipe | 3 minutes | None | 3 minutes | 100% | 3 minutes | 100% |
| Total Process Time Per Main Wheel | 12.1 minutes | 13 minutes | (0.9 minutes) | (7.4%) | 5.5 minutes | 45.4% |

**Table 4 Wheel & Tire Shop APW Cleaning Process Comparison for Main Wheels**

Based on data gathered during the field trial, the 33rd wheel and tire shop will clean approximately 895 main wheels on average annually. Using the Seymour Johnson data as a baseline, man-hours can be reduced from 127 hours to 45 hours per year using the Harry Major APW.

The cleaning process using the Harry Major APW involves two automatic wash cycles with a secondary agitation using the flow through or green scrub pad in between these cycles. The green scrub pads are used when the soils are light and the flow through brush is used if there are heavier soils. We have noted that when a wheel is not cleaned completely by an aqueous parts washer, the shop will then usually resort to some amount of supplemental cleaning. Having the flow through brush ensures that supplemental cleaning operations are performed using an approved aqueous cleaner and the wheels do not have to be removed from the APW. Additionally, the residual soils are easily removed since the parts are warm and the bulk of the soils have already been removed. This also makes the cleaning solutions more effective.

Seymour Johnson AFB did not clean their nose wheels in the MART APW because they were unsecured and were blown around in the APW by the water pressure. Consequently, comparison of the nose wheel cleaning in the Harry Major APW was made against a solvent cleaning process being used by Seymour Johnson Wheel and Tire shop.

| | Graymills Liftkleen Solvent Cleaner | Harry Major APW | Process Time Savings | Percent Time Reduction | Man-Hour Savings | Percent Man-Hour Reduction |
|---|---|---|---|---|---|---|
| Immerse in Solvent | 1 minute | None | 1 minute | 100% | 1 minute | 100% |
| 1st Auto Cycle | None | 2-minute wash, 0.5-minute dry | N/A | N/A | None | None |
| Agitation With Green Pad | 2 minutes | 1 minute | 1 minute | 50% | 1 minute | 50% |
| 2nd Auto Cycle | None | 2-minute wash, 0.5-minute dry | N/A | N/A | None | None |
| Wipe clean with red rag | 1 minute | 1 minute | None | None | None | None |
| Total Process Time Per Nose Wheel | 4 minutes | 7 minutes | (3 minutes) | (75%) | 2 minutes | 50% |

**Table 2 Wheel & Tire Shop Parts Washer Cleaning Process Comparison for Nose Wheels**

Table 5 shows a comparison of nose wheel rims being cleaned using the solvent cleaning process performed at Seymour Johnson with the aqueous cleaning using the Harry Major APW. Solvent cleaning was being done in a Graymills Liftkleen that could process 3 wheel rims at one time; whereas, the Harry Major APW can process two wheels (four wheel halves) at a time. Process time is increased by 3 minutes with each wheel rim using the Harry Major APW, but man-hours are reduced by 2 minutes per wheel rim.

Based on data gathered during the field trial, the 33rd wheel and tire shop will clean 312 nose wheels on average annually. Using the Seymour Johnson data as a baseline, man-hours can be reduced from 21 hours to 10 hours per year using the Harry Major APW.

**The 33rd Wheel and Tire s**hop personnel were asked to compare the solvent hand cleaning process on wheel rims with the new Harry Major Machine APW process on a scale of 1 to 5 in terms of cleaning efficiency, with cleaning efficiency defined to them as how effective the process was at providing them with the desired level of cleanliness. The shop personnel on average rated the previous process as a 2.3 and the new process as a 4.3 for an overall increase of 46.2% in cleaning efficiency. It must be noted that this is a qualitative assessment depending on the opinions of maintenance personnel and may vary from shop to shop. Also for this particular shop the comparison was with hand cleaning using solvent versus the current replacement process.

Figure 20 33rd Wheel and Tire Shop At Work (Cleaned Wheels Visible on Work Table)

During the field trial the cleaning bath was changed out once. Some minor problems occurred during bath cleanout. The machine is designed with a drain plug in the back of the tank reservoir as well as a cleanout door on the side of the machine to facilitate clean out of the solid waste once the liquid has been removed. Due to the nature of wheel and tire shop baths sometimes testing hazardous, it was necessary to transfer the fluid from the tank to a 55-gallon drum. The designers of the machine never anticipated this particular result and therefore there were no access points for a suction tube to be inserted into the bath. As a result, it was necessary to unbolt the oil skimmer in the back of the tank to provide access to the bath. After the liquid was removed, the side door was then opened to remove any remaining solid waste. The small amount of remaining liquid solution was slightly above the bottom of the clean out door opening. As a result, shop rags had to be laid underneath the door as cleanout was accomplished. It has been recommended to the manufacturer that a slight ¼" lip be added around the door to prevent this problem from occurring (see figure 12). Also a small covered opening should be added to facilitate the insertion of a suction pump for liquid waste removal. The overall clean out process took approximately an hour and thirty minutes with the majority of the clean out time being spent on unbolting and rebolting the oil skimmer to the machine. Should the small corrections be made to the machine it is estimated a clean out time of approximately an hour is possible. This is a significant improvement from the machines seen on the APW surveys which took on average a full day to clean out due to the difficulty of accessing the inside of the tank reservoir. This is the largest maintenance procedure performed by the shop and should be performed approximately every 3 months to maintain bath cleaning performance.

**Figure 21 Emptying the Bath Solution by Pumping Into a Waste Drum**

The shop at Seymour Johnson AFB was employing a MART Tornado 60 with a 397-gallon bath reservoir. The APW was designed to meet the shops requirement to hold 5 wheels. They do not split the rim and wash the wheel as two wheel halves. The parts washer had been in the shop for a little under 4 years and still was in very good condition. The shop was using Armakleen MP-2 aqueous cleaner at room temperature. They had chosen to not use a heated bath and clean at room temperature instead, citing a March 2000 message issued by the landing gear directorate asking for a moratorium on using heated aqueous solutions in parts washer due to concerns over hydrogen embrittlement. Shop personnel said the message traffic changing what cleaners were authorized for heated aqueous cleaning had caused them to stay with the Armakleen product at room temperature, since they had noticed no significant difference in cleaning efficiency with the cleaning bath being heated or at room temperature. The shop was very pleased with the parts washer, especially its ability to clean 5 main wheels at a time.


**Figure 22 MART Tornado APW at Seymour Johnson AFB**

It should be noted that the cleaning standard that had to be met at the 33rd FW was higher than at Seymour Johnson AFB. Wheels were clean at both bases, but the 33rd FW had a higher appearance standard requiring removal of tightly adhering rubber and stains from the tire seat areas. Figures 20 and 23 show wheels after cleaning at both the 33rd FW and Seymour Johnson AFB with both wheels being functionally clean and the difference being appearance. This difference is primarily one of personnel preference.

**Figure 23 Removing F-15E Main Wheel Rims From MART Washer After a Wash Cycle**

Maintenance personnel at Seymour Johnson AFB performed a pre-wipe with the standard green scrub pad on all wheel rims to be cleaned with a spray bottle of the bath cleaner (ArmaKleen). This pre-wipe was to agitate the soils and make them easier to remove during the wash cycle. For one man, it took 5.5 minutes per wheel to perform the pre-wipe. Due to the large volume of the parts washer, maintenance personnel could insert 5 wheels per wash cycle into the turntable basket (because they washed the wheel halves assembled). A 15-minute wash cycle using room temperature water was used because the ArmaKleen cleaner couldn't be used if the water was heated. Personnel cited a March 2000 message issued by the landing gear directorate asking for a moratorium on using heated aqueous solutions in parts washer due to concerns over hydrogen embrittlement. One noticeable thing about the washer was that the spray jets above the wheel rims could have been closer which might have helped in removing soil. Upon completion of the wash cycle the wheels were removed and moved to the side of the shop for a final post wipe and heat shield inspection. The post wipe was to remove any residual soils trapped in the spaces of the wheel or remove any soils missed during the pre-wash, which seemed to clean more than the wash. This post wipe process with a plain red shop rag averaged 3 minutes per wheel rim. Assuming one person performs the cleaning process and loads the machine up to its maximum carrying capacity of 5 wheels, the total cleaning process takes 60 minutes, or 12 minutes per wheel rim.

Shop personnel were cleaning the nose wheels in a Graymills Liftkleen solvent immersion tank, because the pressures exerted for the parts washer tended to blow the nose wheels around. The shop was performing a pre-clean using a spray bottle containing the Armakleen cleaner. This pre-wash involved spraying each wheel with the spray cleaner and then scrubbing the surface using a green scrub pad to agitate the soils. The wheels were then washed using a 15-minute wash cycle. Upon completion of the wash cycle, the wheels would be wiped down using a shop rag to remove any remaining soils.


**Figure 24 Seymour Johnson AFB Graymills Liftkleen Solvent System Used to Clean Nose Wheel Rims**

## 6.4 2nd MXS Wheel and Tire Shop

The 2nd MXS Wheel and Tire Shop APW was producing a significant amount of hazardous waste of 1732 pounds annually. This waste consisted of the cleaning bath, from whenever it was replaced, and sludge collected by the skimmer. There are a number of systems for accomplishing cleaning bath filtration but, as noted earlier in the report, they must be an integral part of the APW. After evaluation, the MART EQ-1 system was chosen as the best candidate for this process. The MART EQ-1 system works by using adsorption and electrostatic forces to encapsulate the waste in a material called "Magic Dust" and thereby clarifying the bath for reuse. About 3 to 8 pounds of "Magic Dust" are required for every 100 gallons of aqueous solution to be processed.  The system then returns clarified solution with chemical to the aqueous parts washer for reuse.  The process utilizes flocculation technology to adsorb oil and grease and other contaminants and encapsulate them into a solid waste that does not leach in a Toxicity Characteristics Leaching Procedure (TCLP) test.  This process produces what is called a "burrito", because the Magic Dust is left in what looks like a burrito after the filtration process is complete.  This burrito is the only waste generated and it encapsulates all hazardous materials and passes the TCLP so it may be disposed of as a non-hazardous waste.

The bath should undergo treatment whenever the aqueous solution appears to have lost any cleaning effectiveness.  While this will vary with the type of parts being washed a good rule of thumb is after every 40 loads or 10 machine hours of cleaning.  The water processing takes approximately 1 hour for every 100 gallons being processed and uses approximately 5 yards of filter paper.  From this process approximately 85% of the aqueous solution is returned to the parts washer.  The system returns the clarified solution with the cleaning chemical to the aqueous parts washer for reuse.

**Figure 25 MART EQ-1 250 Installed in 2nd MXS Wheel & Tire Shop (Air Pump Is Located at Bottom Left)**

Since the MART EQ-1 claims to clarify the bath solution by encapsulating the waste and making it non-hazardous, the environmental manager at Barksdale AFB suggested NCI Information Systems, Inc. investigate whether or not the process could be used to change hazardous liquid waste to non-hazardous waste. As a result, two 55-gallon drums of the bath were stored and capped several months before the MART EQ-1 system was installed in the 2nd Wheel and Tire Shop. The sludge produced from the oil skimmer was collected at this time as well and tested. Ana-Lab Corporation of Shreveport, Louisiana performed TCLP tests on both the bath and the sludge material on November 14, 2000. Follow up tests were performed by Ana-Lab on August 15, 2001 on the burritos produced from filtering the bath water and sludge combination. The burritos tested non-hazardous but the bath solution actually increased in the amount of cadmium present. It was thus determined that the EQ-1 system should not be used as a method to purify bath solution for disposal; however, since the EQ-1 was successful in clarifying the solution and removing the oil from the emulsifying cleaner, the EQ-1 does meet the claim of the vendor. It should also be mentioned that the vendor does offer an option for a final polishing system that guarantees clarified solution that will meet regulatory criteria. This final polishing system costs $2673 and contains a carbon filter chamber and a resin chamber whose filter systems must be changed out over time.

A trip was made to Barksdale AFB in February 2002 to run the MART EQ-1 system on the APW bath solution. The intent was to allow maintenance personnel that were trained on the last trip to perform the process with supervision by our personnel; however, as seems to be the case with most Wheel and Tire shops the personnel had completely turned over yet again and it was necessary to train the new personnel on the process. This turnover in wheel and tire shop personnel is distressing since the MART EQ-1 system seems best suited and has been calculated to provide the most payback for this particular shop.

| Parameter | Regulatory Limit (mg/L) | Sludge before EQ-1 | Water/Soap before EQ-1 | Burrito after EQ-1 | Water/Soap after EQ-1 |
|---|---|---|---|---|---|
| Laboratory pH | | 7.0 @ 20 C | 10.2 @ 21 C | | |
| TCLP Selenium | 1.0 | None Detected (ND) | ND | ND | |
| TCLP Arsenic | 5.0 | ND | ND | ND | |
| TCLP Barium | 100.0 | 0.158 | 0.0545 | 0.0610 | |
| TCLP Cadmium | 1.0 | 3.11 | 0.790 | 0.665 | 5.25 |
| TCLP Chromium | 5.0 | 2.02 | 1.58 | ND | |
| TCLP Lead | 5.0 | ND | ND | ND | |
| TCLP Silver | 5.0 | ND | ND | ND | |
| TCLP Mercury | 0.2 | ND | ND | ND | |

**Table 6 TCLP Results for Aqueous Bath Waste**

By using the MART EQ-1 system to filter the cleaning bath, allowing dirt and pollutants to be removed, approximately 80% of the bath solution is returned back into the APW. A simple titration or hydrometer can then be taken to determine how much cleaner must be added to get the bath back up to the proper concentration. The overall filtration process took approximately 2 hours to perform. The bath being filtered from the MART machine was 180 gallons but the MART EQ-1 250 could only process 125 gallons at a time. Therefore, 125 gallons were processed and sent to the bottom holding tank of the EQ-1 system.

The final 55 gallons were then transferred to the top tank of the EQ-1. In addition, all the sludge that had built up on the bottom of the tank was cleaned out and transferred to the EQ-1 system. Following this transfer, the 125 gallons of clarified solution from the bottom of the EQ-1 were transferred to the empty APW tank. Since the 55 gallons were below the limit that could be processed, some of the bath from the APW that had already been clarified had to be transferred back to the top tank and added to the residual 55 gallons from the APW to provide the quantity necessary to allow bath processing. After the rest of the bath was filtered, it was returned to the APW. A titration test was performed to determine how much soap needed to be added to recharge the system. The titration test results indicated that there was a 10% concentration of the cleaning solution, which was above the recommended 7% concentration, so it was not necessary to add any cleaning solution to recharge the solution.

A summary of the waste reduction for the shop using the EQ-1 is shown in the following table. The hazardous waste savings are compared with 2001 totals since the EQ-1 was used to clean out hazardous waste drums in 2001 and not the APW bath itself. The non-hazardous burritos containing the encapsulated waste are the sole waste produced during the EQ-1 filtration process. The minor amount of hazardous waste still being recorded by the shop is due to the disposal of the sludge removed by the disc oil skimmer. The skimmer waste must be disposed of when the sludge container becomes full since the shop is not allowed to store hazardous waste. When an actual EQ-1 filtration is performed, any accumulated skimmer waste since the last cleaning of the sludge container is added to the bath solution being processed.

| | **Waste Volume (lbs)** | **Disposal Rate ($/lb)** | **Disposal Cost ($)** |
|---|---|---|---|
| **2nd Wheel & Tire Shop** | | | |
| 2001 | **1732** | **$0.40** | **$692.80** |
| 2002 (Projected) | **57.6** | **$0.68** | **$39.17** |
| Shop Savings | **1674.4** | **$0.68** | **$1138.59** |

**Table 7 Savings in Annual Hazardous Waste Disposal Cost for the 2nd Wheel & Tire Shop Before & After Installation of EQ-1**

The shop was using Daraclean 235 for cleaning their wheel rims. Barksdale AFB had an overabundance of the Daraclean 235 as they had made a large bath purchase to supply both the 2nd Wheel and Tire Shop and the 2nd Pneudraulics Shop. Shortly after purchase, it was recognized that the brake components contained magnesium and therefore could not be cleaned using the Daraclean 235. As a result, the 2nd Wheel and Tire Shop inherited the Pneudraulics Shop supply of Daraclean 235 also. In order to keep costs down the shop has chosen to exhaust their supply of

Daraclean 235 in accordance with guidance provided by the landing gear directorate before switching to the Calla 296 cleaner.

Calla 296 is significantly more expensive and requires a greater concentration than Daraclean 235. As a result, an additional benefit of the MART EQ-1's filtration process for this particular shop is to significantly reduce the cleaner cost incurred over the short term. Table 7 shows a comparison of the cleaner costs incurred by the Barksdale Wheel and Tire Shop that uses the EQ-1 as opposed to the same shop without the EQ-1. The table shows annual savings for both the current shop situation (Daraclean 235) and once the switch is made to Calla 296. It is assumed that 80% of the bath will be retained during filtration requiring a 20% recharge to maintain proper bath concentration. The total savings for the 2nd Wheel and Tire shop are the combined savings in cleaner costs and hazardous waste disposal. Until the supply of Daraclean 235 is exhausted the shop will save $6572 annually. Once they switch to the Calla 296 cleaner the shop should save $5600 annually.

| MART APW (Tank Capacity: 180 Gallons) | | | Without EQ-1 | With EQ-1 | |
|---|---|---|---|---|---|
| | | | Calla 296 (20% concentration) | Calla 296 (20% Concentration) Recharge | Daraclean 235 (7% Concentration) Recharge |
| Cleaner Quantity Required Each Bath Cleaning | | | 36 Gallons | 7.2 Gallons | 2.52 Gallons |
| # Cleanouts/Year | | | 4 | 4 | 4 |
| Annual Cleaner Consumption | | | 144 Gallons | 28.8 Gallons | 10.08 Gallons |
| Calla 296 | Price Per 55 Gallon Drum (DLA Price) | $2130 | $38.73/Gallon | $38.73/Gallon | |
| Daraclean 235 | | $782. | | | $14.22/Gallon |
| Annual Cleaner Cost | | | $5577.12 | $1115.42 | $143.34 |
| Annual Savings | | | | $4461.70 | $5433.78 |

**Table 8 Annual Cost Savings Achieved for the 2nd Wheel & Tire Shop for Reduced Cleaner Materials Consumption**

### 6.5 917th Jet Propulsion Shop

The 917th Jet Propulsion Shop has significantly increased its hazardous waste generation from aqueous cleaning operations using APWs as a result of becoming the Engine Depot for all A-10 aircraft engines. The shop had 3 different APWs with different cleaning solutions. For such an operation a filtration system such as the MART EQ-1 could not be used as the technology requires that the bath chemistry being used in each APW be similar along with the soils being removed in each of the APWs whose solution would be clarified. Therefore, the water evaporator system (EMC Water Eater) was implemented to evaporate only the water, leaving the solid sludge to be drummed up as hazardous waste. In the year prior to this project, the shop generated six 55-

gallon drums of hazardous waste (2412 pounds) from their APW baths that cost $965 to dispose of.

The propulsion shop generated and processed 265 gallons of APW cleaning bath during this project in the EMC Water Eater. This 265 gallons of liquid waste was reduced to 20 gallons of solid waste weighing 112 pounds. The Water Eater reduces the volume of waste generation significantly by 92% by evaporating all the water. However, since the waste disposal cost is by the pound, the sludge remaining to be disposed of as hazardous waste is a smaller reduction of approximately 62.4% in the weight of hazardous waste generated. Water evaporators by far appear to be the inexpensive way to quickly reduce the hazardous waste volume produced by aqueous parts washers. Several shops at various bases however have complained that they cannot use water evaporators unless a condensation catcher recaptures the evaporated water. For an initial investment of approximately $5000, a shop can reduce their annual hazardous waste volume by approximately 90%.

**Figure 26 EMC Water Eater**

Table 9 summarizes the hazardous waste savings for the 917th Jet Engine shop. Since the EMC Water Eater was not used for all of 2001 the comparison in savings are made with the projected values for 2002. It should be noted that bath cleanout was delayed on some of the APWs in the 917th Jet Engine Shop until installation of the Water Eater in 2001. This accounts for the huge difference in 2000 and 2001 totals; however, some cleanouts had already taken place. The total savings for the 917th Jet Engine Shop are solely in hazardous waste costs, unlike the 2nd Wheel and Tire shop that saved in cleaner materials as well.

| | Waste Volume (lbs) | Disposal Rate ($/lb) | Disposal Cost ($) |
|---|---|---|---|
| **917th Jet Engine Shop** | | | |
| 2000 | **2412** | **$0.40** | **$964.80** |
| 2001 | **201** | **$0.40** | **$80.40** |
| 2002 (Projected) | **100.8** | **$0.68** | **$68.54** |
| Shop Savings | **2311.2** | **$0.68** | **$1571.62** |

**Table 9 Annual Hazardous Waste Cost for the 917th Jet Engine Shop Before & After Installation of EMC Water Eater**

# 7 Conclusions

Though aqueous cleaning can be used as a direct replacement for solvent cleaning, it should be noted that aqueous cleaning is not appropriate for cleaning certain parts. This guidance is provided in the applicable shop technical orders as well as in T.O. 1-1-691 “Aircraft Weapons Systems Cleaning and Corrosion Control”. Maintenance shop chiefs should use this guidance to ensure that solvent cleaning is not completely removed from those shops that need it. Bearings and parts coated with sacrificial coatings such as cadmium should never be cleaned using the aqueous cleaning process.

This project has demonstrated that with the proper upfront engineering analysis the automatic aqueous cleaning process is a viable replacement for solvent cleaning systems. The new equipment purchased for the field trials should provide at least a 20-year life cycle resulting in a 400% increase in life cycle from the machinery the equipment replaced. In addition, maintenance required for upkeep of the equipment was reduced by 60% over previous equipment. Across the 3 shops, cleaning efficiency was improved by 57%, man-hours for cleaning were reduced by 66%, and process time was reduced by 36%. In addition, where possible supplemental cleaning operations and corrosion problems were eliminated. The two bath treatment systems installed at Barksdale AFB, Louisiana were a resounding success. The EMC Water Eater evaporator system reduced the waste stream by over 90%, saving the shop $1,571.62 annually. The MART EQ-1 system has allowed the wheel and tire shop to save $6,572.37 per year in cleaner and hazardous waste costs. It should be noted, however that the bath treatment systems may not be applicable at all bases due to different state regulatory permitting requirements. A selection guideline was produced to provide guidance to maintenance personnel during procurement of new APW equipment for maximum leverage of the technology for cleaning applications.

During the initial introduction of the aqueous cleaning process into the different Air Force maintenance shops, most APWs were purchased and given to a shop without any input from the shop’s maintenance personnel. As a result, a lot of personnel resented being forced to get rid of solvent cleaning and switch to aqueous. This contrasts sharply with instances where shop personnel were given significant input into the APW purchase decision. These personnel were invested in the decision and they took pride in the washer and its maintenance and use. It is suggested that opinions be gathered from shop personnel by whoever is procuring the equipment so that the equipment meets the needs of the shop and will find quick acceptance among personnel.

The future for aqueous cleaning in the military has the potential to be a bright one. By tailoring the aqueous cleaning process to the workload and requirements of each shop, the process should become a viable option to solvent cleaning not only from an environmental standpoint but from a performance one as well.

# 8 Acknowledgments

Numerous people made this effort work. We would like to thank all personnel from Eglin AFB, FL and Barksdale AFB, LA who participated in the field trials. We would especially like to thank Sgt Mike Darby of the 33rd FW armament shop, Sgt Dominic Calveresi of the 33rd Wheel and Tire Shop, Sgt Everett Ray of the 917th Engine Shop for their quick feedback in all aspects of the field trials. This project would have not been possible without the support, coordination, and oversight of the environmental personnel. Roy Penman and Sgt Greg Livingston of 33rd FW Environmental Group at Eglin AFB, FL were invaluable by providing us with constant feedback and help in resolving problems with the various shops. Shelia Amos of the 2nd Environmental Group at Barksdale AFB, LA helped organize and manage our field trials.

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# 10 Military Specifications

MIL-C-29602

# Appendix A -APW Selection Guide

This Aqueous Parts Washer (APW) Selection Guide was developed with the intent to provide maintenance personnel with some guidance during the procurement of new aqueous parts washers. Opinions presented are those of the authors and should not be taken as fact. There are numerous manufacturers of part washers and not all are included in this guide. The washers mentioned in this guide were the vendors evaluated or considered during the project period and any oversight is solely the responsibility of the authors and is not intentional. All maintenance shop chiefs and others who use this guide are advised to perform their own research on the equipment to ensure that new developments have not been made in the aqueous cleaning process since the release of this report. The facts and figures presented in the following guide are as of 2001. ***Prices are to be used only as a guide and are not intended to be taken as current***. Please contact the vendors of interest for the latest in military pricing.

Before selecting a parts washer, you should first determine your shop's cleaning requirements. You should then determine what type of cleaning system will best meet your cleaning requirements. Technical orders are a good place to look for any restrictions that might be placed on using a particular cleaning system. For example, bearings usually are not authorized to be cleaned using the aqueous cleaning process due to the fact that if they are not properly dewatered following the cleaning process they will most likely rust leading to binding during use. Cleaning parts with sacrificial coatings such as cadmium can be a source of contaminating the cleaning bath of APWs, making them a hazardous waste. These sacrificial coatings are designed to protect the steel substrate underneath and therefore give themselves up to protect it. As a result the coating is removed and becomes inherent in the bath. Once you have decided on what type of cleaning system (aqueous or solvent), you should contact your base's environmental manager to find out what your state regulatory requirements are. Your physical shop arrangement including workspace, installment location, energy rates, worker safety, required training needs, and the cost to maintain the equipment should also be considered.

Having this information in advance will make the selection process easier and cost effective. When you are ready to select a washer, you need to know what is being cleaned, the size, shape, weight, type of soil to be removed, and what is your shop's cleaning standard (just how clean is clean). Will the parts be cleaned in batches, and if so, how many to a batch, or will the parts be cleaned one at a time, and if so, how will they be secured during washing (basket, hook, rack, etc.)? These factors will help you in determining the size of the washer needed, the type of fixturing required to secure the parts, and the space required to install the unit.

The pressure of a spray washer may cause poorly painted areas to peel, so whenever painted components are cleaned in an aqueous parts washer it is recommended that two filtration systems be used. One, which will aid in the removal of large particles such as paint chips and one to capture the smaller particulates.

## Selection Criteria

The following sections summarize several of the subsystems that make up an aqueous cleaning system and what is recommended you consider before purchasing a machine so that you end up purchasing the best piece of equipment to perform the desired cleaning operation. When looking for an aqueous parts washer, many features are similar throughout the various product lines that are offered. However, there are some considerable differences between different products and it is important to understand how these differences will affect the performance of the machine you are looking to purchase.

## Washer Size and Type

The most important driver in determining what type (and therefore size) of APW to purchase should be the parts that one is attempting to clean. The wash cabinet should be large enough to hold the particular parts that are to be cleaned, but small enough so that the nozzles are not too far away from the part (See the section on nozzles for more information). An enormous wash cabinet can be purchased so that a number of parts can be washed at one time, but this usually results in very poor cleaning performance. When washing large parts it is usually more suitable to wash one or two at a time in a wash cycle so that the cabinet size is not that much larger than the parts being washed.

The weight of the part(s) and ease of accessibility to the washer will also help determine whether a front- or top-loading washer should be used. The location where the washer will be installed will also play a part in the selection. When determining the shop footprint available for the machine and then choosing an aqueous parts washer, one must keep in mind the space that will be taken up by the need to open the door of the parts washer. Personnel must be given enough room to move around the parts washer to load and unload the washer without being impeded. Clearance for electrical outlets, other attachments, noise levels and the ability to clean the machine without causing a hazard must also be considered.

## Jet Nozzles

Most of the aqueous parts washers contain some sort of spray nozzle arrangement to deliver water to the part requiring cleaning. The three most common types of nozzles are fan, cone, and straight stream. The fan and cone style spray jet nozzles are designed to flood the part being cleaned with large amounts of cleaning solution but with lower impact pressure much like the dishwasher in your kitchen. The user must not place the part being cleaned too close or too far from the nozzle head. If the part is too close to the nozzle stream, the spray may not impact some areas. If the part is too far away, nozzle streams will cross, resulting in a loss of impact pressure and cleaning ability. The straight stream spray jet provides a significantly greater impact pressure but covers a smaller area resulting in the need for more nozzles in order to provide the same coverage given by the fan style. For heavier soils, straight stream nozzles might be the nozzle design of choice but the need for additional nozzles to cover the part area will most likely result in a higher priced piece of equipment. For light soils, fan or cone style nozzles should prove to be the better choice.

| Included Spray Angle | W/D Ratio | Theoretical coverage (W) at various distances (D) from nozzle | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Distance (D) inches | | | | | | |
| | | 2 | 3 | 4 | 6 | 8 | 10 | 12 |
| | | Theoretical coverage width (W) inches | | | | | | |
| 5 | 0.087 | 0.2 | 0.3 | 0.3 | 0.5 | 0.7 | 0.9 | 1.0 |
| 10 | 0.175 | 0.4 | 0.5 | 0.7 | 1.1 | 1.4 | 1.8 | 2.1 |
| 15 | 0.263 | 0.5 | 0.8 | 1.1 | 1.6 | 2.1 | 2.6 | 3.2 |
| 20 | 0.353 | 0.7 | 1.1 | 1.4 | 2.1 | 2.8 | 3.5 | 4.2 |
| 25 | 0.443 | 0.9 | 1.3 | 1.8 | 2.7 | 3.5 | 4.4 | 5.3 |
| 30 | 0.536 | 1.1 | 1.6 | 2.1 | 3.2 | 4.3 | 5.4 | 6.4 |
| 35 | 0.63 | 1.3 | 1.9 | 2.5 | 3.8 | 5.0 | 6.3 | 7.6 |
| 40 | 0.728 | 1.5 | 2.2 | 2.9 | 4.4 | 5.8 | 7.3 | 8.7 |
| 45 | 0.828 | 1.7 | 2.5 | 3.3 | 5.0 | 6.6 | 8.3 | 9.9 |
| 50 | 0.932 | 1.9 | 2.8 | 3.7 | 5.6 | 7.5 | 9.3 | 11.2 |
| 55 | 1.04 | 2.1 | 3.1 | 4.2 | 6.2 | 8.3 | 10.4 | 12.5 |
| 60 | 1.15 | 2.3 | 3.5 | 4.6 | 6.9 | 9.2 | 11.5 | 13.8 |
| 65 | 1.27 | 2.5 | 3.8 | 5.1 | 7.6 | 10.2 | 12.7 | 15.2 |
| 70 | 1.4 | 2.8 | 4.2 | 5.6 | 8.4 | 11.2 | 14.0 | 16.8 |
| 75 | 1.53 | 3.1 | 4.6 | 6.1 | 9.2 | 12.2 | 15.3 | 18.4 |
| 80 | 1.68 | 3.4 | 5.0 | 6.7 | 10.1 | 13.4 | 16.8 | 20.2 |
| 85 | 1.83 | 3.7 | 5.5 | 7.3 | 11.0 | 14.6 | 18.3 | 22.0 |
| 90 | 2 | 4.0 | 6.0 | 8.0 | 12.0 | 16.0 | 20.0 | 24.0 |

**Table A1 Theoretical Coverage of a Fan Nozzle Stream For Various Nozzle Angles and Distances From the Nozzle Orifice**

Table A1 shows the theoretical coverage of a fan nozzle stream for various distances from the nozzle opening. Figure A1 provides a cartoon of an individual nozzle. For example, if nozzles are 3” apart from one another and the part is located approximately 6” from the nozzle orifice the W/D ratio for this particular case is 3”/6”=0.5. There are three nozzle angles that are candidates for this application (25, 30, and 35 degrees). The closest W/D ratio in the table is for the 30-degree angle (0.536).

For 25 degrees, the theoretical coverage is $W = \left(\frac{W}{D}\right)(D) = (0.443)(6) = 2.658$

For 30 degrees, the theoretical coverage is $W = \left(\frac{W}{D}\right)(D) = (0.536)(6) = 3.216$

For 35 degrees, the theoretical coverage is $W = \left(\frac{W}{D}\right)(D) = (0.630)(6) = 3.78$

Figures A2-A4 shows representative schematics of the spray pattern expected for each case. Figure A3 is representative of the 25 degree angle fan nozzle configuration where the spray is too close to the part to be cleaned resulting in areas that are not impacted by the cleaning solution and remain soiled. Figure A2 is representative of the 30-degree angle fan nozzle configuration where the theoretical coverage is greater than the spacing of the nozzles. However, the actual coverage is slightly less than the theoretical resulting in a fairly uniform spray coverage by the 30-degree fan nozzle configuration. This is the desired solution. Figure A4 is representative of the 35-degree angle fan nozzle configuration where the spray is too far from the part to be cleaned resulting in the nozzle streams impacting one another before hitting the part reducing the overall effectiveness of the spray. Table A1 only shows theoretical spray coverage for fan nozzles up to 12 inches. This is because as the distance between the part and the nozzle orifice increases there is a significant decrease in overall impact force and effectiveness of the nozzle spray. It is recommended that parts never be located greater than 12 inches from an APW cabinet's spray nozzles.

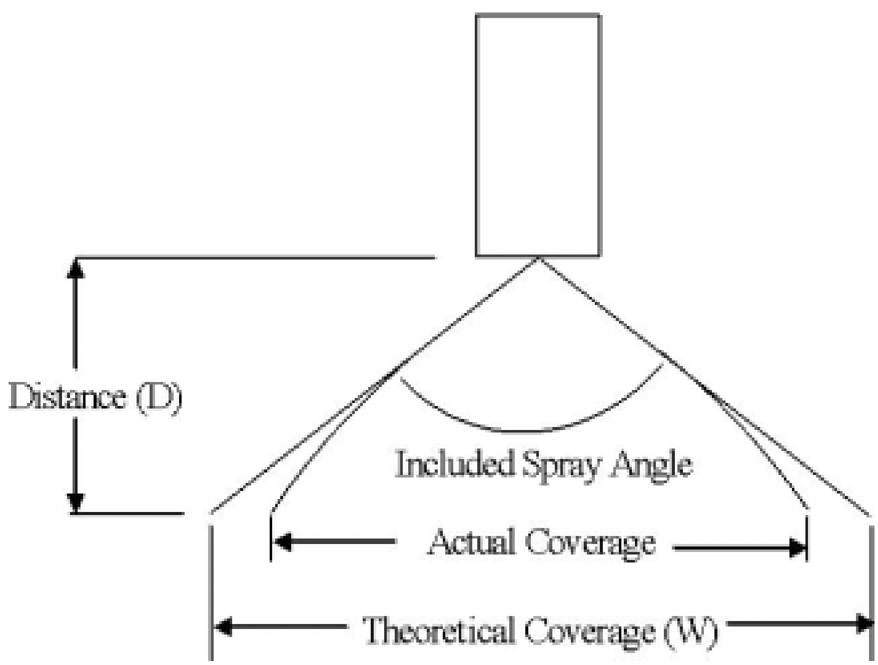


**Figure A1 Depiction of Fan Nozzle Spray Coverage**

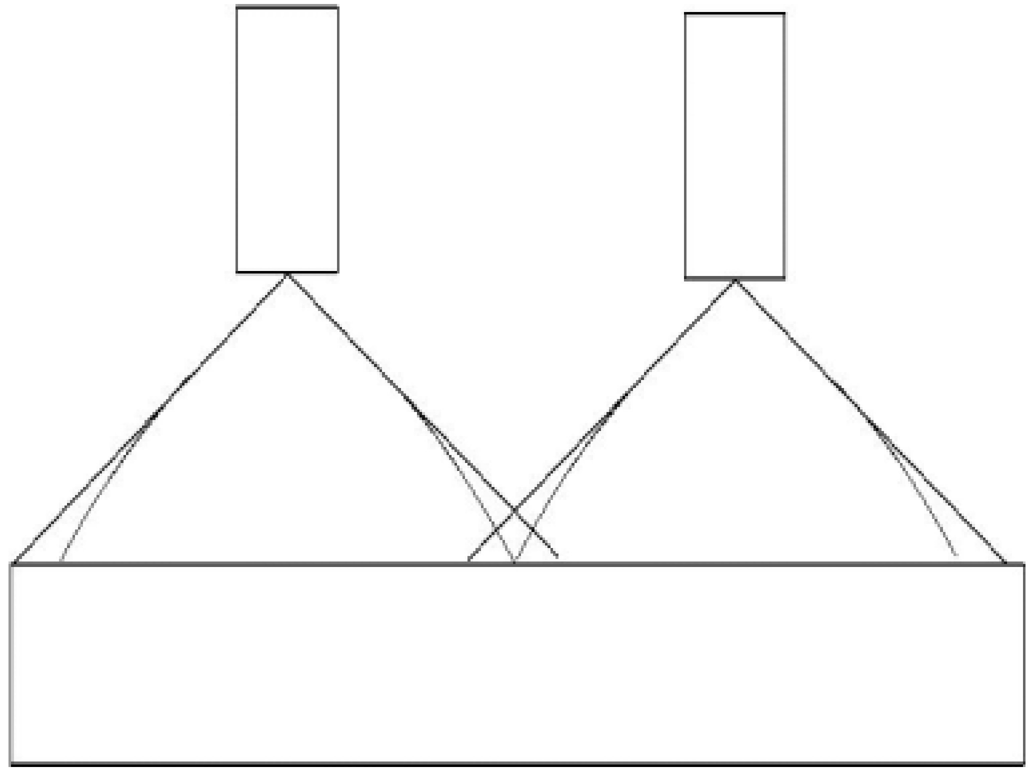

**Figure A2 Ideal Case: Spray Nozzles Provide Continuous Coverage**

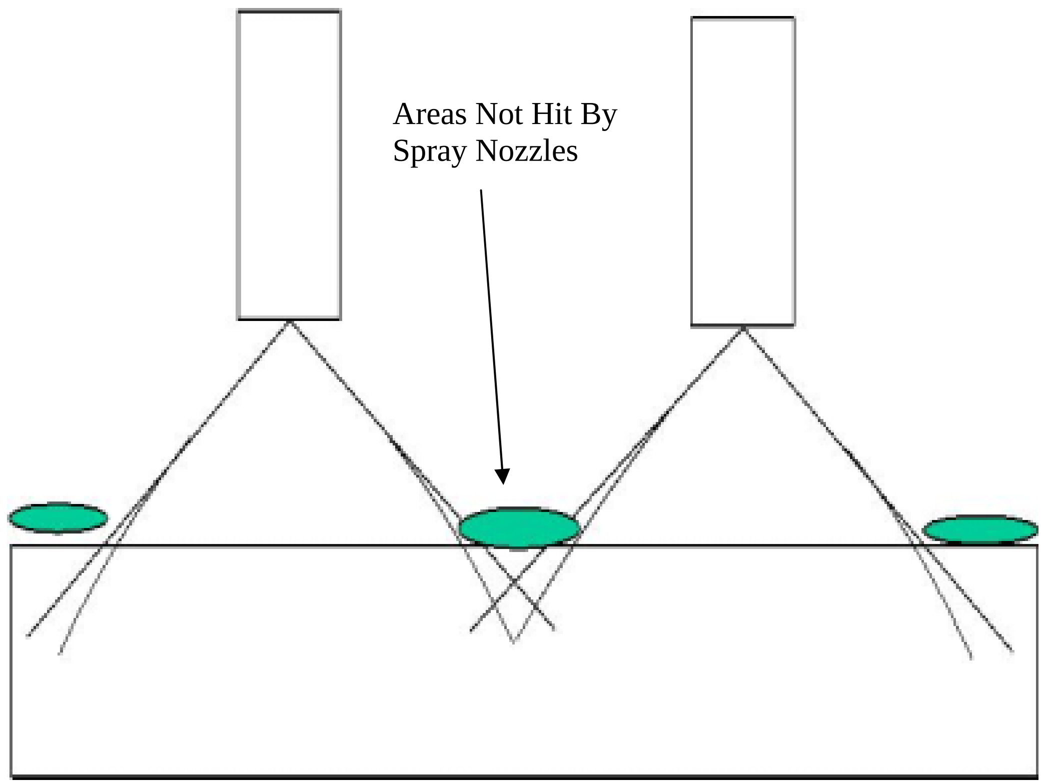


**Figure A3 Part is Too Close to the Nozzles Resulting in Incomplete Coverage**

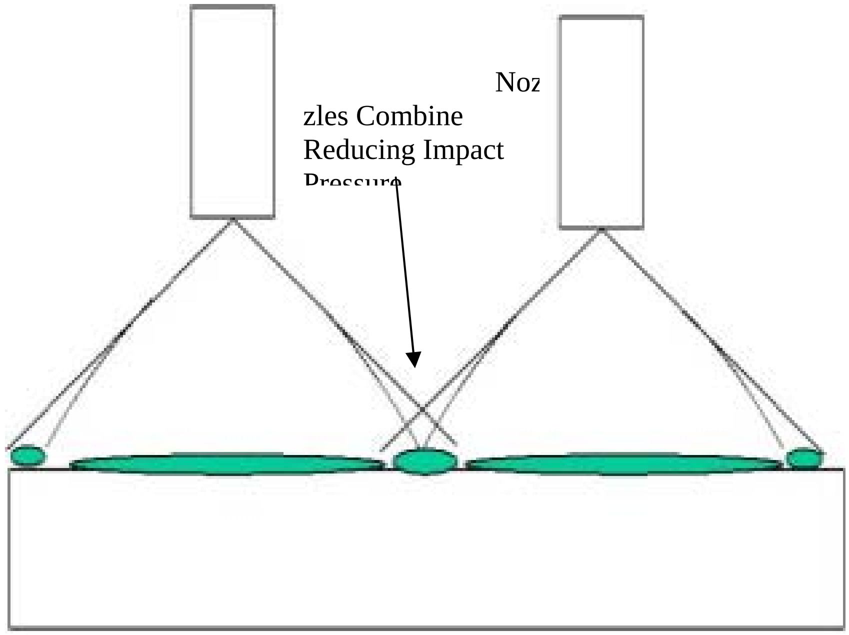


**Figure A4 Nozzles are Too far from Part Resulting in Nozzle Spray Impacting One Another and Reducing Impact Pressure**

## Machine Material Composition

Another important decision when purchasing a washer is the choice of materials used in the machine's fabrication. It is recommended that when purchasing an APW that the shop make a commitment to purchasing a stainless steel machine over a mild carbon steel machine. Mild carbon steel machines can rust significantly even when proper care of the machine is performed. Stainless steel machines can be expected to have a life cycle of approximately 20 years. Most carbon steel machines that have been used in military shop operations have seen an average life cycle of 5 years. Therefore, stainless steel machines can be expected to have a life cycle 4 times that of a mild carbon steel machine. In general, stainless steel machines cost 1.5 to 2 times what their carbon steel counterparts do. When purchasing an APW one should not have to pay more than double the price for a stainless steel machine as opposed to mild carbon steel.

An example is provided to demonstrate the savings in life cycle cost with a stainless steel machine over a 20-year span. An Equipment Manufacturing Corporation model 100E is used for the example. It is assumed maintenance of both versions of the machine should be similar and therefore are not calculated in this comparison.

Mild Carbon Steel Version of 100E

A purchase of the machine is made at the beginning of the 20-year period, this machine is then replaced at the beginning of the 6$^{th}$ year, the 11$^{th}$ year, and the 16$^{th}$ year.

4 purchases X $4,495=$17,980

Life cycle cost per year: $17,980/20 years=$899/year

Stainless Steel Version of 100E

A purchase of the machine is made at the beginning of the 20-year period,

1 purchase X $6,745=$6,745

Life cycle cost per year: $6,745/20 years=$337.25/year

Though the mild carbon steel machine seems to be the bargain upfront, the shop over a 20-year period would have to spend 2.67 times what the shop with the stainless steel machine would spend. In addition, there are several intangibles that make the stainless steel machine the more attractive choice such as not having to clean with rusty water or deal with the unpleasing aesthetic appearance of a rusting machine.

While the purchase of stainless steel machines is recommended, budget constraints sometimes preclude it, therefore where possible both the price for the mild carbon steel version as well as the stainless steel version have been listed at the end of this guide.

## Pump Assembly

Most manufacturers usually offer the lowest powered pump motor they can in their standard package. This is in order to keep costs down and make the equipment an attractive purchase. As a result, the pump selected is not always the best pump for a particular cleaning application. The majority of pump performance data available is taken from pump curves that assume an optimum application and do not account for pump suction and discharge losses that can affect the actual performance. As a result, sizing a pump for a particular application is not always easy. For most applications a pump upgrade will not be necessary, but for higher-pressure (tougher adhering soils) applications the vendor should be consulted to determine if a pump upgrade is needed.

## Secondary Cleaning

Sometimes cleaners are not as effective as desired. This is not always due to a poor performing cleaning system, but the impossibility of overcoming the physics of the cleaning problem. For example, many wheel and tire shops throughout the Air Force have to clean wheel rims that have a significant amount of burnt-on carbon brake dust deposits. This brake dust adheres firmly to the part surface and some of the brake dust will not be removed no matter how high the pressure or temperature is unless the paint system underneath is removed as well. The small boundary layer that remains on the wheel however can be easily removed with a small amount of agitation.

On several Air Force corrosion surveys, shops have been observed using the aqueous cleaning process followed by some amount of supplemental cleaning to finish removing dirt from a part. Sometimes, the supplemental cleaning process is not one that is authorized by technical orders and can even prove to be harmful to the substrate material.

For those shops that have to perform some amount of supplemental cleaning it is necessary for the aqueous parts washer to provide a secondary cleaning function. This is an option offered by vendors with the addition of a small pump attachment hooked up to a flow through brush that pulls cleaner from the APW bath reservoir. This ensures that only an approved cleaner will be used for the supplemental cleaning of the part.

## Insulation

The ideal operating temperature for most aqueous parts washers is around 160 degrees Fahrenheit. Most shops however tend to lower the operating temperature to slow water evaporation. Too high of an evaporation rate can quickly leave the heating elements exposed and burn them out during a surprisingly brief period of inattention. Also, during the summer months, the heat and humidity from the APW can make the shop uncomfortable. Cleaning effectiveness, however, suffers significantly at the lower temperatures. Some shops using this caveat raise the temperature above the maximum recommended temperature for their APW hoping to enhance cleaning effectiveness. However, too high a temperature severely reduces the lifespan of hoses and other rubber components of the APW itself creating maintenance problems. An uninsulated parts washer will increase building cooling costs and result in extremely hot surfaces that can scald and burn personnel.

An insulated parts washer provides several benefits compared to a standard parts washer. Insulation provides personal protection to maintenance personnel while also providing a more comfortable working environment. The insulation prevents excessive heat loss that can result in up to a 50 percent reduction in energy consumption costs. Insulation also allows for an APW to maintain the proper operating temperature under heavy usage conditions. For most part cleaning operations, the energy savings should easily offset the additional cost of insulation over the life of the machine.

## Bath Life Maintenance

The bath life depends on which parts are being cleaned, production loads, and what contaminants are being removed in an APW. Maintaining a clean bath usually is dependent on three separate systems: filters, oil separators, and sludge removal.

## Filtration Systems

Filtration systems are not always standard with an APW system, but they play an essential role in maintaining bath quality (and therefore cleaning efficiency) for extended periods of time. Filters are installed on APWs in order to remove particulate matter and further purify the cleaning solution. Filters keep the jet nozzles from clogging and stop sediment build-up in the bath tank bottom. In some cases, utilization of a filter enables the wastes from a bath to be classified as non-hazardous.

The majority of APW systems use a chip collector in-line with a sock filter to filter out the bath water. The chip collector catches large debris and the sock filter collects the smaller debris. This system approach to filtration is very effective for most cleaning applications; however, when using a powdered soap it might be necessary to remove the sock filter until after the soap has been thoroughly dissolved within the bath.

Several factors affect the performance of filters during the cleaning process. The frequency at which the filters are changed out can have an effect on how the wastes are classified upon testing. Another key factor is the porosity of the filter bag. A change from a filter porosity of 100 microns to 50 microns may result in typically hazardous cleaning baths being as non-hazardous waste. The smaller the micron size of the filter the greater the amount of soils will be collected; however, this also translates to a greater frequency of filter change out. For most Air Force maintenance shops, a 50-micron filter provides a good medium between the amount of soil collected and the frequency of filter change out. For most shops, a 50-micron filter will equate to the filter needing to be replaced every three months.

### Oil Skimmer

The majority of APW systems offered by vendors contain a rotating disc oil skimmer to remove and capture the top layer of oil from the cleaning bath and send it to a collector outside the APW. The majority of Air Force APW systems are also required to use a MIL-C-29602 emulsifying cleaner. An emulsifying cleaner means that the soils are put into solution with the rest of the bath, unlike non-emulsifying cleaners that do not bond with the soils therefore forcing them to the top of the bath where they can be skimmed off. As a result, the oil skimmer can only be used effectively when the system is not in use because as the bath cools, the soils held in solution at elevated temperatures will separate from the water at room temperature and float to the top. A rotating belt skimmer works similar to the rotating disc skimmer except it offers more surface area to pick up oil. As a result, rotating belt skimmers are usually up to 5 times as effective as disc skimmers at removing oil from a bath.

If possible an internal oil skimmer is preferable in order to eliminate the "chimney effect" that results from having an external opening in the APW. This opening allows heat to escape resulting in an increase in electricity consumption. The belt or rotating disc skimmer that is most common in aqueous parts washers requires access to the hot cleaning solution via a hole or slot in the side of the tank. The skimmer hole creates a "chimney effect" resulting in an increase of electricity consumption and a moderate loss of water through evaporation. By having a skimmer that leaves a thin layer of tramp oil on top of the solution at all times, some of this heat loss and evaporation can be reduced. A variable overflow weir oil skimmer system has no open access holes resulting in the elimination of heat and evaporation loss that results from the use of the belt or rotating disc oil skimmer.

### Sludge Removal

The majority of APWs produced today use a gravity-driven system for sludge removal in which the heavier weight sludge settles on the bottom of the tank requiring periodic cleanout by maintenance personnel. The difficulty of cleaning sludge from the tank is a major complaint of most maintenance shops. It is recommended that the APW you purchase contain a significantly sloped floor (greater than 20 degrees) that sends all the sludge to the drain end of the parts washer or that your APW contain a door that provides easy access to cleaning out the tank. This will result in easier acceptance of the APW by maintenance personnel. Several of the vendors offer a floor that has a gradual slope from the front to the back in order to promote the sludge traveling to the rear of the machine. This grade is usually between 5 and 10 degrees. This slope will encourage soils to travel to the back of the machine up to a certain point, but as the soils build up over time they will become more and more viscous and the soils will begin to remain at the front of the tank where there is usually limited access for cleanout.

## Fixturing/Parts Racks & Parts Baskets

When cleaning some parts it might be necessary to have parts racks to either hold the parts in a particular orientation or prevent them from being blown around the APW due to the pressures emitted from the nozzles. If any supplemental cleaning is required, the fixturing used should provide easy access to the parts so that the parts can be completely cleaned before being removed from the parts washer cabinet. For example, the initial parts racks with the Harry Major Machine APW provided the ability to place two main wheel halves upright in the parts washer cabinet.

**Figure A5 Original Parts Rack Designed to Hold 2 F-15C Main Wheel Halves Upright**

However, the parts racks did not allow easy access to the bottom of the wheel rims or the ease to turn the wheels inside the parts racks. New parts racks were designed that provided the intended functionality of supporting two main wheel halves within the cabinet while also providing easy access to the whole wheel. Rollers were also placed on the rack to allow the wheel rims to be turned easily within the parts racks without the concern for the paint system present on the rims being scratched.

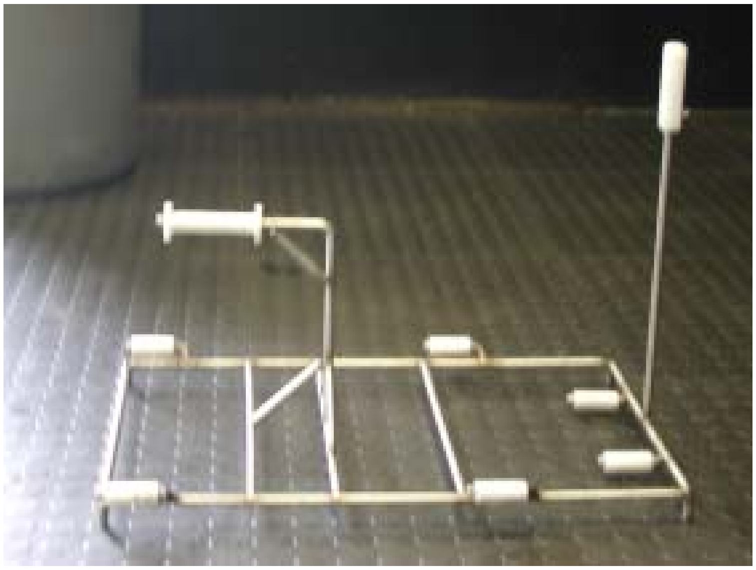

**Figure A6 Pats Rack Modified to Allow Easy Access to The Entire Wheel for Supplemental Cleaning Operations**

Any parts basket designed to hold numerous small parts must contain holes small enough to hold the parts but large enough so as not to be an impedance to the nozzle spray. Therefore the size of the holes in the parts basket must be slightly smaller than the small part being placed in the basket.

## Cleaning Materials

Though the cleaning chemicals are usually purchased separately from the APW itself, the choice of cleaning chemistry impacts the APW in several ways. Cleaning performance, service duty requirements, corrosion of parts, and hydrogen embrittlement are all import concerns when choosing the proper chemistry. Your bath chemistry may be limited according to the particular part substrate being cleaned in your shop and the technical orders for cleaning those parts should be addressed before selecting a cleaning solution. The cleaning solution in most aqueous parts washers contains a mixture of surfactants, corrosion inhibitors, emulsifiers, and other additives. (Note: Just because the manufacturer of your APW recommends a certain cleaning solution does not mean it is authorized for use by the military.)

Currently for cleaning operations other than aircraft landing gear components only cleaners qualified to military specification MIL-C-29602 "Cleaning Compounds for Parts Washers and Spray Cabinets" are authorized. These cleaning compounds are classified as one of two types: Type I (Water Soluble Liquid Concentrate) and Type II (Water Soluble Powder). The qualified Type I soaps are Ardrox 6333A (Brent America, Inc.), Armakleen-M-HP-2 (Church and Dwight Co., Inc.), Aquaworks-G-2 (Church and Dwight Co., Inc.), Daraclean 282 GF (W. R. Grace), and Turco Liquid SprayEze (Turco Products, Inc.). The qualified Type II soaps are Natural Orange without d-limonene (Giant Cleaning Systems, Inc.) and Turco Aviation (Turco Products, Inc.). Caution must be taken when using one of the Type II soaps to ensure that the cleaning compound is thoroughly mixed in with the aqueous solution. If not, the remaining powder residue can cake on both parts and the interior of the washer cabinet resulting in corrosion.

## Drying Cycle

A drying cycle is sometimes needed in order to remove residual water and condensation present on a part after the wash cycle. While several technical orders have a requirement for a drying cycle it has been our experience that the majority of the water of the part will evaporate in ambient air. Consult your shop specific technical orders and weapon system SPO for more guidance.

## Fresh Rinse Cycle

In several of the Air Force technical orders where aqueous cleaning is authorized a fresh water rinse cycle is required. The thought behind this is that a fresh water rinse is needed to remove any of the remaining soap/detergent that might be remaining on the part. A disadvantage to a fresh water rinse though is that it may wash away any rust inhibitor as well from the surface of the part being rinsed. Consult your shop specific technical orders and weapon system SPO for more guidance.

## Maintenance Shop Summary

Each maintenance shop will have different cleaning requirements. Below is a summary of things to consider when procuring an APW for the various shops.

## Aerospace Ground Equipment (AGE) Shop

Age shops when performing minor maintenance are usually tasked to clean small parts and components, which for the most part won't require a large model washer. For those parts immersion tanks with agitation, and smaller footprint aqueous parts washers with parts basket, hooks or racks to contain or support the parts during the automatic washing cycle should suffice.

Some available options you may want to consider are particulate filtration and oil skimmer that will help remove waste and add to the life of the cleaning solution. The ability to add locking casters to some models making them mobile will only add to the benefits received.

An attractive option to the typical aqueous parts washer is made by Graymills that allows high pressure cleaning solution to be blasted over the part using a hand held nozzle. The part is placed in the cabinet and by using the rubber gloves attached to the cabinet door, you can direct a stream of the cleaning solution directly on the parts wherever needed, by using the hose attached inside the cabinet which dispense the cleaning solution from a holding tank. Theses type of washer also comes in various sizes and tank capacity to accommodate the parts being cleaned.

For times when major maintenance is required and parts as large as engine blocks, heaters, radiators and transmissions require washing, all washer manufacturers have washers large enough to accommodate those parts. When selecting this type of washer some of the things to consider are the soils to be removed, material(s) from which the parts are manufactured, size, weight, and configuration of the parts to be cleaned, type of cleaning fluid and the process currently used:(solvent, water-based, etc.), nozzle configuration & locations (height and distance from parts) and whether it is to be manual or automatic. You will also want a washer equipped with a filtration and oil removal system for a cleaner wash, better results, and due to environmental concern, a system equipped with a water evaporator (where allowed) will help reduce hazardous waste.

### Armament/Munitions/Weapon Shop

Armament shops usually are tasked to clean unpainted metal components. As a result, minimum filtration is required. For price and performance the EMC models are hard to beat. Their stainless steel models are only 1.5 times what they charge for mild carbon steel. Enviroquip machines also appear to be another reasonable choice especially if the shop needs to reduce its overall waste volume by using the enclosed water evaporator.

### Hydraulics Shop

Due to the magnesium components in brake housings and the fact that the aqueous cleaner Daraclean 235 was not approved for magnesium components many hydraulic shops have returned to solvent cleaning of parts. However, now that Calla 296 has been approved for use with magnesium components an aqueous cleaning solution is available and authorized.

Immersion with agitation is another option, this will allow you to immerse the parts in the cleaning solution for a length of time determined by the cleaning standard set by the shop or technical order. After cleaning, the part can be rinsed and dried upon removal from the tank.

### Vehicle Shop

The vehicle shop as with the AGE shop basically has the same concerns when it comes to parts washers. The type of soil to be removed is along the same lines, oil, dirt, grease, grime, fluids - gas, diesel, transmission etc. For the most part the guidelines involved in selecting a washer for the AGE shop can be used for the vehicle shop. The washers may be bigger due to the size of the engines, transmissions, generators, and radiators but the requirements remain the same. For small parts, a system such as the JRI Industries JR-1 model should be considered.

## Wheel and Tire (R&R) Shop

The key criterion in selecting parts washers for the wheel and tire shop appears to be nozzle pressure. The machines that seem to perform best are those made by Harry Major Machine and the MART Corporation. Both are very expensive systems but perform significantly better than other models according to conversations with shop personnel. The Harry Major Machine models are rated at the top of the list due to the fact the design eliminates the need for supplemental cleaning processes therefore reducing the likelihood that unapproved cleaners will be introduced into the cleaning process and also for the numerous user-friendly options that come standard with the machine. The drawback to other vendor models outside of Harry Major is that they are not specifically designed to accommodate the cleaning of Air Force wheel rims. The MART machines would be extremely more effective for these applications if the spray bars could be adjusted to be closer to the wheel surfaces. For those shops more concerned about a budget compared to cleaning performance, the purchase of mild carbon steel Better Engineering top-loading machines is recommended.

## Selection Process

Unlike when the aqueous parts washers were first procured, machines were chosen that would meet the specific requirements of a particular shop. Also, the parts washers were chosen to meet all the requirements in each shop’s specific technical orders and it was confirmed that aqueous cleaning was authorized for each shop. As mention at the beginning of this guide the washers mention in this guide were the ones, which were evaluated or considered during the project period and any oversight is solely the responsibility of the authors and is not intentional. When using this guide you are advised to perform your own research on the equipment to ensure that you are aware of new developments, which may have or has been made in the aqueous cleaning process. The facts, figures and prices presented in the following guide are as of 2001 and may not be current at the time of this publication. They are to be used only as a guide and are not intended to be taken to still be applicable. Please contact the vendors of interest for the latest in military pricing.

Better Engineering

8361 Town Center Court
Baltimore, Maryland 21236
Tel: (410) 931 –0000
Toll free: 1-800-929-3380
Fax: (410) 931-0053

## TOP LOADING WASHERS

| Model Top Load | Footprint [WxDxH] (inches) | Work Area inches | Work Height (inches) | Pump Pressure (PSI) | Power Required | Pump Size (HP) | Tank Capacity (Gallons) | Weight Capacity (lbs) |
|---|---|---|---|---|---|---|---|---|
| T-2500-P | 42 X 53 X 50 | 25 D | 18 | 50 | 230V/3P | 3 | 50 | 500 |
| T-5000-P | 70 X 91 X 62 | 50 D | 31 | 60 | 220V/3P | 7.5 | 200 | 1500 |
| T-5000-PCS | | 50 D | 31 | 60 | | 7.5 | 150 | |
| T-6000-P | 80 X 100 X 62 | 60 D | 31 | 60 | 220V/3P | 10 | 260 | 2500 |
| T-6000-PCS | | 60 D | 31 | 60 | | 10 | 200 | |
| T-7000-P | 91 X 109 X 62 | 70 D A | 31 | 60 | 220V/3P | 10 | 320 | 2500 |
| T-7000-PCS | | 70 D | 31 | 60 | | 10 | 225 | |
| **Additional Information on APW Models** | | | | | | | | |
| Model | Heat (kW) | Full Load Amps | Heat Up Time (Hr) | Pump Flow (GPM) | List Price | GSA Price | GSA Stainless Price | N.S.N. |
| T-2500-P | 9 | 48 | 1 | 50 | $7,042. | $5,916.50 | $13,016.30 | |
| T-5000-P | 27 | 90 | 1 1/2 | 150 | $20,423 | $17,157.85 | $34,315.70 | 4940-01-338-7138 |
| T-5000-PCS | 18 | | | 150 | | | | |
| T-6000-P | 36 | 121 | 1 1/4 | 200 | $25,353 | $21,299.40 | $42,598.80 | 4940-01-393-1104 |
| T-6000-PCS | 27 | | | 200 | | | | |
| T-7000-P | 36 | 121 | 1 3/4 | 200 | $29,578 | $24,849.30 | $49,698.60 | |
| T-7000-PCS | 27 | | | 200 | | | | |

FRONT LOADING WASHERS

| Model Front Load | Footprint [WxDxH] (inches) | Work Area inches | Work Height (inches) | Pump Pressure (PSI) | Power Required | Pump Size (HP) | Tank Capacity (Gallons) | Weight Capacity (lbs) |
|---|---|---|---|---|---|---|---|---|
| F-3000 | 45 X 50 X 69 | 30 D | 36 | 45 | 230V/3P | 3 | 75 | 750 |
| F-3000-ZX | 45 X 50 X 69 | 30 D | 36 | | 230V/3P | 5 | 75 | |
| F-3000-P | 45 X 62 X 69 | 30 D | 36 | 60 | 230V/3P | 5 | 95 | 750 |
| F-3000-P-ZX | 45 X 62 X 69 | 30 D | 36 | | 230V/3P | 5 | 95 | |
| F-4000-P | 63 X 72 X 72 | 40 D | 40 | 60 | 230V/3P | 5 | 140 | 1500 |
| F-4000-LX-P | 63 X 72 X 92 | 40 D | 40 | 60 | 230V/3P | 7.5 | 140 | 1500 |
| F-4000-P-ZX | 63 X 72 X 72 | 40 D | 40 | | 230V/3P | 7.5 | 140 | |
| F-4000-LX-P-ZX | 62 X 72 X 92 | 40 D | 40 | | 230V/3P | 10 | 140 | |
| F-4000-PCS | | 40 D | 40 | 60 | | 5 | 100 | |
| F-4000-LX-PCS | | 40 D | 60 | 65 | | 7.5 | 100 | |
| F-5000-LX-PCS | | 50 D | 60 | 70 | | 10 | 150 | |
| F-5000-LX-P | 75 X 84 X 92 | 50 D | 60 | 60 | 230V/3P | 10 | 200 | 2500 |
| F-5000-LX-P-ZX | 75 X 84 X 92 | 50 D | 60 | | 230V/3P | 15 | | |
| F-6000-LX-P | 85 X 94 X 92 | 60 D | 60 | 60 | (230V?)440V/3P | 15 | 260 | 2500 |

| Additional Information on APW Models | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Model | Heat (kW) | Full Load Amps | Heat Up Time (Hr) | Pump Flow (GPM) | List Price | GSA Price | GSA Stainless Price | N.S.N. |
| F-3000 | 9 | 34 | 1 1/2 | 65 | $7,746.75 | $6,508.00 | $14,199.60 | 4940-01-361-6127 |
| F-3000-ZX | | | | | $9,014.00 | $7,573.12 | $16,447.87 | 4940-01-360-4096 |
| F-3000-P | 12 | 46 | 1 1/2 | 75 | $9,577.00 | $8,046.44 | $17,276.18 | 4940-01-445-9632 |
| F-3000-P-ZX | 12 | | | | $10,282.00 | $8,638.09 | $18,459.48 | 1730-01-448-8205 |
| F-4000-P | 18 | 61 | 1 1/2 | 100 | $14,789.00 | $12,424.65 | $25,677.61 | 4940-01-428-5831 |
| F-4000-LX-P | 18 | 67 | 1 1/2 | 150 | $16,056.00 | $13,489.62 | $27,689.22 | 4940-01-396-881 |
| F-4000-P-ZX | 18 | | | | $16,056.00 | $13,489.62 | $27,689.22 | 4940-01-361-6126 |
| F-4000-LX-P-ZX | 18 | | | | $17,324.00 | $14,554.59 | $29,582.50 | |
| F-4000-PCS | 18 | | | 100 | | | | |
| F-4000-LX-PCS | 18 | | | 100 | | | | |
| F-5000-LX-PCS | 18 | | | 150 | | | | |
| F-5000-LX-P | 27 | 97 | 1 1/2 | 200 | $16,627.00 | $17,749.50 | $35,499.00 | |
| F-5000-LX-P-ZX | 27 | | | | $23,240.25 | $19,524.45 | $39,048.90 | |
| F-6000-LX-P | 36 | 131 | 1 1/4 | 250 | $28,170.00 | $23,666.00 | $47,332.00 | |

## Other Models

| Model | Work Area (inches) | Work Height (inches) | Power Required | Pump Size (HP) | Tank Capacity (Gallons) | Weight Capacity (lbs) | Heat (kW) | GSA Price |
|---|---|---|---|---|---|---|---|---|
| Impulse | 2 3.5" L X 17" W Work Racks | 12 | 230V/1P | 1 | 20 | | 4.5 | $ 2,768.70 |
| Impulse II | 25 D | 18 | 230V/1P | 3 | 50 | 500 | 6 | $3,956.70 |
| CE-2000 | 27 D | 36 | 230V/1P | 3 | 50 | | 6 | $4,674.04 |
| CE-3000 | 37 D | 48 | 230V/3P | 5 | 100 | | 12 | $8,164.77 |

| Optional Filtration Devices | | | | |
|---|---|---|---|---|
| Model | Description | List Price | GSA Price | GSA Stainless |
| ILS-11 | Strainer | | | |
| | 100 gpm for models with 2hp & 5hp pumps | $774.00 | $650.81 | $1,064.97 |
| | 200 gpm for models with 7.5 or larger pump | $1,619.00 | $1,360.79 | $2,129.94 |
| ILF-22 | Bag Filter | | | |
| | 100 gpm for models with 2hp & 5hp pumps | $774.00 | $650.81 | $1,064.97 |
| | 200 gpm for models with 7.5 or larger pump | $2,112.00 | $1,774.95 | $2,721.59 |
| | 20 gpm filter / ARC 22 | $774.00 | $650.81 | $1,064.97 |
| RFB-22 | Bag Filter for ILF-22 | | | |
| | 100 gpm filter bag | $11.26 | $9.46 | N/A |
| | 200 gpm filter bag | $14.08 | $11.83 | N/A |
| | 20 gpm filter bag | $8.45 | $7.09 | N/A |

| Optional Models with Increased Work Height | | | | |
|---|---|---|---|---|
| Model | Description | List Price | GSA Price | GSA Stainless |
| F3000-S | 48" TO 60" | $1,267.00 | $1,064.97 | $2,011.61 |
| F4000-LX | TO 75" | $2,112.00 | $1,774.95 | $3,372.41 |
| F4000-LX | TO 90" | $4,225.00 | $3,549.90 | $6,744.81 |
| F5000-LX | TO 75" | $3,521.00 | $2,958.25 | $5,620.68 |
| F5000-LX | TO 90" | $7,042.00 | $5,916.50 | $11,241.35 |
| F6000-LX | TO 75" | $4,225.00 | $3,549.90 | $6,744.81 |
| F6000-LX | TO 90" | $8,451.00 | $7,099.80 | $13,489.62 |
| Optional Models with Increased Weight Capacity | | | | |
| Model | Description | List Price | GSA Price | GSA Stainless |
| F3000 | 750LBS TO 1500LBS | $1,408.00 | $1,183.30 | $1,183.30 |
| F3000 | 750LBS TO 2500LBS | $2,112.00 | $1,774.95 | $1,774.95 |
| F4000'S<br>T-5000-P | 1500LBS TO 2500LBS | $1,056.00 | $887.48 | $887.48 |
| F-4000'S<br>OR LARGER | 500LBS TO 5000LBS | $9,859.00 | $8,283.10 | $14,199.60 |
| Optional Models with Insulated Tanks | | | | |
| Model | Description | List Price | GSA Price | GSA Stainless |
| F-3000'S & T-2000 | Insulate Tank Only | $704.00 | $591.65 | N/A |
| | Insulate Entire Unit | $1,408.00 | $1,183.30 | N/A |
| F-4000 | Insulate Tank Only | $1,126.00 | $946.64 | N/A |

| | | | | |
|---|---|---|---|---|
| F-5000 | Insulate Entire Unit | $2,253.00 | $1,893.28 | N/A |
| T-5000 | Insulate Tank Only | $1,408.00 | $1,183.30 | N/A |
| F-6000 | Insulate Entire Unit | $2,817.00 | $2,366.60 | N/A |
| T-6000 | Insulate Tank Only | $1,408.00 | $1,183.30 | N/A |
| T-7000 | Insulate Entire Unit | $2,817.00 | $2,366.60 | N/A |
| ARC-22 | Insulate Rinse Tank | $704.00 | $591.65 | N/A |
| Optional Models with Minor Pump Upgrade | | | | |
| Model | Description | List Price | GSA Price | GSA Stainless |
| F-3000, F-3000-P'S | From 3hp to 5hp | $704.00 | $591.65 | N/A |
| F-3000, F-3000-P'S | From 5hp to 7.5hp | $704.00 | $591.65 | N/A |
| F-4000-P'S | From 5hp to 7.5hp | $704.00 | $591.65 | N/A |
| F-4000-P'S | From 7.5hp to 10hp | $704.00 | $591.65 | N/A |
| F-5000-P | From 10hp to 15hp | $1,056.00 | $887.48 | N/A |
| T-5000-P | From 7.5hp to 10hp | $704.00 | $591.65 | N/A |
| T-5000-P | From 10hp to 15hp | $1,056.00 | $887.48 | N/A |
| T-6000-P | From 10hp to 15hp | $1,056.00 | $887.48 | N/A |
| T-7000-P | From 10hp to 15hp | $1,056.00 | $887.48 | N/A |
| Optional Models with Major Pump Upgrade | | | | |
| Model | Description | List Price | GSA Price | GSA Stainless |
| F-4000-P & Larger | Upgrade to 20hp | $6,901.00 | $5,798.17 | $9,821.39 |

| | | | | |
|---|---|---|---|---|
| F-4000-P & Larger | Upgrade to 25hp | $8,169.00 | $6,863.14 | $11,714.67 |
| F-4000-P & Larger | Upgrade to 30hp | $8,873.00 | $7,454.79 | $12,661.31 |
| F-5000-P<br>F-6000-P<br>T-6000-P<br>T-7000-P | Upgrade to 30hp | $10,422.00 | $8,756.42 | $14,909.58 |
| Optional Models with Natural Gas Heat | | | | |
| Model | Description | List Price | GSA Price | GSA Stainless |
| F-4000-P | 400,000 BTU RATING | $3,802.00 | $3,194.90 | $4,023.22 |
| F-5000<br>T-5000 | 400,000 BTU RATING | $3,802.00 | $3,194.90 | $4,023.22 |
| F-6000-P<br>F-4000-P | 400,000 BTU RATING | $3,802.00 | $3,194.90 | $4,023.22 |
| Optional Models with Air Drying Systems | | | | |
| Model | Description | List Price | GSA Price | GSA Stainless |
| 5 HP | Regenerative Blower | $5,634.00 | $4,733.20 | N/A |
| 10 HP | Regenerative Blower | $7,042.00 | $5,916.50 | N/A |
| 15 HP | Regenerative Blower | $8,451.00 | $7,099.80 | N/A |
| 20 HP | Regenerative Blower | $9,859.00 | $8,283.10 | N/A |
| | | | | |
| | | | | |
| Optional Models with Heaters for Air Drying | | | | |

| Model | Description | List Price | GSA Price | GSA Stainless |
|---|---|---|---|---|
| 12.8 KW | Heat Tube | $6,388.00 | $5,324.85 | N/A |
| 21 KW | Heat Tube | $7,746.00 | $6,508.15 | N/A |
| 35 KW | Heat Tube | $9,155.00 | $7,691.45 | N/A |
| 48 KW | Heat Tube | $9,929.00 | $8,283.10 | N/A |
| Other Optional Materials and Equipment | | | | |
| Option | | Cost | | |
| 1 Gallon Container of Liquid Rust Inhibitor | | $ 52.14 | | |
| Non-Recirculating, Automatic Rinse Cycle | | $1,778.70 | | |
| End of Cycle Beacon Light | | $ 326.70 | | |
| Small Parts Basket (15"L X 9"W X 6"H) | | $ 181.50 | | |
| Auto 24 Hr. 7 Day Timer to Control Skimmer & Heater | | $ 326.70 | | |
| Bag Filter for RFB-22 (Filter) | | $ 11.88 | | |
| Bag Filter | | $1,778.00 | | |
| Hydro-Air Rinse Gun for Manual Rinsing | | $ 118.80 | | |
| Steam Exhaust Blower with Automatic Control | | $1,184.70 | | |
| Low Water Shut-Off & Auto Water Fill | | $ 590.70 | | |
| 1 Gallon Container of Liquid Rust Inhibitor | | $ 52.14 | | |

MART
The MART Corporation
2450 Adie Road
Maryland Heights, MO 63043
(314) 567-7222

| Model | Footprint WxDxH (inches) | Work Area inches | Work Hght inches | Work Vol Cu Ft | Power Required | Pump Size (HP) | Tank Cap Gal | Sludge Cap Gal | Wght Cap lbs | Heat kW | Pump Flow GPM | Nozzle Flow GPM/N | Nozzle Pressure (PSI/N) | S Steel Option | GSA Cost W/O SS Opt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyclone 2.2 | 48 x 56 x 79 | 27 D | 38 | 12 | 240V/3P or 480V/3P | 3 | 77 | 30 | 600 | 22.5 | 100 | 7.7 | 36 | $6,339 | $10,489 |
| Cyclone 30 | 66 x 67 x 78 | 30 D | 40 | 16 | 240V/3P or 480V/3P | 10 | 130 | 37 | 1000 | A | 180 | 11.3 | 75 | $12,311 | $13,725 |
| Cyclone 30 High Profile | 66 x 67 x 78 | 30 D | 55 | 22 | 430V/3P or 480V/3P | 20 | 130 | 37 | 1000 | 45 | 269 | 13.5 | 107 | $14,253 | $17,177 |
| Tornado 40 | 79 x 74 x 83 | 41 D | 39 | 30 | 240V/3P or 480V/3P | 10 | 180 | 47 | 2000 | 45 | 180 | 11.3 | 75 | $13,750 | $15,760 |
| Tornado 40 High Profile | 79 x 74 x 105 | 41 D | 63 | 48 | 240V/3P or 480V/3P | 20 | 180 | 47 | 2000 | 45 | 269 | 13.5 | 107 | $15,689 | $20,346 |
| Tornado 60 | 106 x 91 x 93 | 60 D | 48 | 79 | 240V/3P or 480V/3P | 20 | 350 | 80 | 4000 | 80 | 269 | 13.5 | 107 | $19,344 | $26,588 |
| Tornado 72 | | | | | 230V/3P or 460V/3P | | | | | | | | | | $32,582 |
| Hurricane 52 Hi-Profile | | | | | 230V/3P or 460V/3P | 30 | | | | | | | | | $31,746 |
| Hurricane 60 High Profile | 106 x 91 x 120 | 60 D | 75 | 123 | 240V/3P or 480V/3P | 30 | 350 | 80 | 4000 | 80 | 343 | 14.3 | 121 | $21,573 | $36,389 |
| Hurricane 60 Extended | 106 x 91 x 120 | 60 D | 112 | 183 | 240V/3P or 480V/3P | 30 | 350 | 80 | 5000 | 80 | 343 | 14.3 | 121 | $30,919 | $44,723 |

| Model | Footprint WxDxH (inches) | Work Area inches | Work Hght inches | Work Vol Cu Ft | Power Required | Pump Size (HP) | Tank Cap Gal | Sludge Cap Gal | Wght Cap lbs | Heat kW | Pump Flow GPM | Nozzle Flow GPM/N | Nozzle Pressure (PSI/N) | S Steel Option | GSA Cost W/O SS Opt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hurricane 72 Hi-Profile | | | | | 230V/3P or 460V/3P | 30 | | | | | | | | | $47,961 |
| Hurricane 84 | 143 x 125 x 139 | 84 D | 75 | 241 | 240V/3P or 480V/3P | 30 | 740 | 151 | 15000 | 160 | 343 | 14.3 | 121 | $40,696 | $50,928 |
| Hurricane 100 | | | | | 230V/3P or 460V/3P | 30 | | | | | | | | | $58,700 |
| Hurricane 120 | | | | | 230V/3P or 460V/3P | | | | | | | | | | $103,957 |
| In Line Batch 40 | | 41 D | 30 | | 230V/3P or 460V/3P | 10 | | | 2000 | | | | | | $30,660 |
| In Line Batch 60 | | | | | 230V/3P or 460V/3P | | | | | | | | | | $53,835 |
| Hydroblast 6 Tumbler | | | | | 230V/3P or 460V/3P | | | | | | | | | | $15,937 |
| Hydroblast 11 Tumbler | | | | | 230V/3P or 460V/3P | | | | | | | | | | $18,069 |
| Hydroblast 20 Tumbler | | | | | 230V/3P or 460V/3P | | | | | | | | | | $27,570 |
| Lift-Door 40 | 102 x 63 x 141 | 41 D | 32 | 18 | 240V/3P or 480V/3P | 10 | 180 | 47 | 2000 | 80 | 269 | 13 | 107 | $16,650 | $28,300 |

| Options | Price | Options | Price |
|---|---|---|---|
| Hinged, Flip Up Turntable | $ 364.45 | Auto Rinse Cycle (Including Auto Steam Exhaust) | $ 1,522.55 |
| Hour Meter | $ 70.30 | SS Gas Heat Exchanger | $ 910.20 |
| Parts Basket | $ 357.05 | Steam Exhaust PVC Kit-6" | $ 173.90 |
| 7.5 HP Pump Assembly | $ 408.85 | Automatic Steam Exhaust | $ 867.65 |
| Natural Gas Heat Source | $ 580.90 | Cabinet Thermal Insulation | $ 566.10 |
| Turntable Jog | $ 86.95 | Single Phase Electrics | $ 963.85 |
| Pump Amp Meter | $ 362.60 | 500 LB Loading Boom w/ Electric Hoist & Trolley | $ 2,231.10 |
| 230V/480V w/ Natural Gas | $ 1,037.85 | Automatic Oil Skimmer | $ 690.05 |

| Standard |
|---|
| Oscillating Power Blast Manifold (PBM) |
| Electric heat |
| 24-hr clock door limit switch |
| Hi-Low water safety shut-off |
| Thermostatic control |
| Temperature gauge |
| 30 minute wash cycle timer |

CLAM

P.O. BOX 6688
LAKELAND, FL 33807

PH:(800) 933-5081

FAX: (863) 647-3082

| Model | Footprint [WXDXH] | Work Area | Work Height | Pump Press PSI | Power Req | Pump Size (HP) | Tank Cap Gal | Heat (kW) | Heat Time Hr | Pump Flow GPM | GSA Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MW1624 | | 2 3.5"L X 17"W | 12” | | 230V/1P | 1 | 20 | 4.5 | | | $2,768.70 |
| MW1636 | | 25 D | 18 | | 230V/1P | 3 | 50 | 6 | | | $3,956.70 |
| C24E | 42X53X50 | 25 D | 18 | 50 | 230V/3P | 3 | 50 | 9 | 1 | 50 | $5,474.70 |
| C50E | 70X91X62 | 50 D | 31 | 60 | 220V/3P | 7.5 | 200 | 27 | 1.5 | 150 | $15,638.70 |
| C100E | | 50 D | 31 | 60 | | 7.5 | 150 | 18 | | 150 | |
| C150E | 80X100X62 | 60 D | 31 | 60 | 220V/3P | 10 | 260 | 36 | 1.25 | 200 | $20,324.70 |
| C250E | | 60 D | 31 | 60 | | 10 | 200 | 27 | | 200 | |
| C350E | 91X109X62 | 70 D | 31 | 60 | 220V/3P | 10 | 320 | 36 | 1.75 | 200 | $23,096.70 |
| C24ES | | 70 D | 31 | 60 | | 10 EA | 225 | 27 | | 200 | |
| C50ES | 45X50X69 | 30 D | 36 | 45 | 230V/3P | 3 | 75 | 9 | 1.5 | 65 | $6,134.70 |
| C80ES | 45X50X69 | 30 D | 36 | | 230V/3P | 5 | 75 | | | | $7,190.70 |

| Model | Footprint [WXDXH] | Work Area | Work Height | Pump Press PSI | Power Req | Pump Size (HP) | Tank Cap Gal | Heat (kW) | Heat Time Hr | Pump Flow GPM | GSA Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C100ES | 45X62X69 | 30 D | 36 | 60 | 230V/3P | 5 | 95 | 12 | 1.5 | 75 | $7,652.70 |
| MWSRS1430 | 45X62X69 | 30 D | 36 | | 230V/3P | 5 | 95 | 12 | | | $8,312.70 |
| MWSRS1636 | 63X72X72 | 40 D | 40 | 60 | 230V/3P | 5 | 140 | 18 | 1.5 | 100 | $11,744.70 |
| MWSRS1660 | 63X72X92 | 40 D | 40 | 60 | 230V/3P | 7.5 | 140 | 18 | 1.5 | 150 | |
| MW1624 | | 2 3.5"L X 17"W | 12” | | 230V/1P | 1 | 20 | 4.5 | | | $ 2,768.70 |
| MW1636 | | 25 D | 18 | | 230V/1P | 3 | 50 | 6 | | | $3,956.70 |
| C24E | 42X53X50 | 25 D | 18 | 50 | 230V/3P | 3 | 50 | 9 | 1 | 50 | $5,474.70 |
| C50E | 70X91X62 | 50 D | 31 | 60 | 220V/3P | 7.5 | 200 | 27 | 1.5 | 150 | $15,638.70 |
| C100E | | 50 D | 31 | 60 | | 7.5 | 150 | 18 | | 150 | |
| C150E | 80X100X62 | 60 D | 31 | 60 | 220V/3P | 10 | 260 | 36 | 1.25 | 200 | $20,324.70 |
| C250E | | 60 D | 31 | 60 | | 10 | 200 | 27 | | 200 | |
| C350E | 91X109X62 | 70 D | 31 | 60 | 220V/3P | 10 | 320 | 36 | 1.75 | 200 | $23,096.70 |
| C24ES | | 70 D | 31 | 60 | | 10 EA | 225 | 27 | | 200 | |
| C50ES | 45X50X69 | 30 D | 36 | 45 | 230V/3P | 3 | 75 | 9 | 1.5 | 65 | $6,134.70 |
| C80ES | 45X50X69 | 30 D | 36 | | 230V/3P | 5 | 75 | | | | $7,190.70 |

| Model | Footprint [WXDXH] | Work Area | Work Height | Pump Press PSI | Power Req | Pump Size (HP) | Tank Cap Gal | Heat (kW) | Heat Time Hr | Pump Flow GPM | GSA Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C100ES | 45X62X69 | 30 D | 36 | 60 | 230V/3P | 5 | 95 | 12 | 1.5 | 75 | $7,652.70 |
| MWSRS1430 | 45X62X69 | 30 D | 36 | | 230V/3P | 5 | 95 | 12 | | | $8,312.70 |
| MWSRS1636 | 63X72X72 | 40 D | 40 | 60 | 230V/3P | 5 | 140 | 18 | 1.5 | 100 | $11,744.70 |
| MWSRS1660 | 63X72X92 | 40 D | 40 | 60 | 230V/3P | 7.5 | 140 | 18 | 1.5 | 150 | |

## CUDA CLEANING SYSTEMS

51804 INDUSTRIAL DR
CALUMET MI 49913
PH: (800) 780-2832
FAX: (906) 482-3344

| Model | Footprint [WXDXH] (inches) | Work Area inches | Work Height inches | Pump Pres (PSI) | Power Req | Pump Size (HP) | Tank Cap Gal | Weight Cap lbs | Heat (kW) | Full Load Amps | Pump Flow (GPM) | GSA Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ZIP-2216 | 34X44X50 | 22 D | 16 | 30 | 230V/1P | 1 | 25 | 500 | 4.5 | 28 | 28 | $ 2,308.60 |
| H20-2518V | 47X47X60 | 25 D | 18 | 45 | 230V/1P | 3 | 42 | 500 | 6 | 38 | 50 | $ 3,498.60 |
| H20-2530 | 45X48X74 | 25 D | 30 | 45 | 230V/1P | 3 | 40 | 500 | 6 | 40 | 50 | $4,178.60 |
| H20-2836 | 50X51X76 | 28 D | 36 | 45 | 230V/1P | 3 | 50 | 750 | 6 | 40 | 50 | $4,828.00 |
| H20-2848 | 50X51X88 | 28 D | 48 | 50 | 230V/3P or 460V/3P | 5 | 50 | 750 | 6 | 27, 14 | 110 | $5,844.60 |

| Model | Footprint [WXDXH] (inches) | Work Area inches | Work Height inches | Pump Pres (PSI) | Power Req | Pump Size (HP) | Tank Cap Gal | Weight Cap lbs | Heat (kW) | Full Load Amps | Pump Flow (GPM) | GSA Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H20-3636 | 59X63X83 | 36 D | 36 | 50 | 230V/3P or 460V/3P | 5 | 100 | 2500 | 15 | 51, 25 | 110 | $7,986.60 |
| H20-3648 | 59X63X95 | 36 D | 48 | 50 | 230V/3P or 460V/3P | 7.5 | 100 | 2500 | 15 | 56, 28 | 200 | $10,876.60 |
| H20-4866 | 66X75X109 | 48 D | 66 | 50 | 230V/3P or 460V/3P | 7.5 | 130 | 2500 | 18 | 67, 32 | 200 | $12,954.00 |

| Options | Cost | Options | Cost |
|---|---|---|---|
| 5 HP 3 Phase to 7.5 HP 3 Phase Pump | $ 880.60 | Ball Valve and Hose Kit | $ 64.60 |
| Fresh Water Rinse to Drain-Models 3636 & 3648 | $1,965.20 | Autofill and Heater Safety Switch | $ 291.72 |
| Rubber Coated Containment Ring | $ 221.00 | Removable Fine Mesh Insert for Clean-Out Tray | $ 87.72 |
| Standard 8" X 30" Filter W/ Sump Sweep | $1,408.96 | Large Parts Basket w/Lid-Models 3636 & 3648 | $ 190.40 |
| Auto 24 Hr. 7 Day Timer to Control Skimmer & Heater | $ 272.00 | Side Mount Fold-Up Detail Tray Kit Complete | $ 408.00 |

| Standard for H2O Models |
|---|
| 170 degree F water temperature |
| 0-60 minute wash cycle timer w/hold |
| 12 hour heater timer |
| 0-30 minute oil skimmer timer |

EQUIPMENT MANUFACTURING CORPORATION (EMC)

14930 MARQUARDT AVE
SANTA FE, SPRINGS CA 90670
PH: (888) 833-9000
FAX: (562) 623-9342

| Model | Footprint [WXDXH] (inches) | Max Load inches | Power Req Amps | Pump Size HP | Tank Cap Gal | Weight Cap lbs | Heat kW | Pump Flow GPM | Stainless Steel | Machine Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1426-110 | 38 X 20 X 37 | 14 X 26 X 15 T | 110V/1P | | 25 | 500 | 1.65 | 80 | $1,000.00 | $1,995.00 | $2,995.00 |
| 1426-220 | 38 X 20 X 37 | 14 X 26 X 15 T | 220V/3P or 220V/1P | | 25 | 500 | 13.5 | 120 | $1,150.00 | $2,295.00 | $3,445.00 |
| 50E | 44X44X72 | 28D X 30 | 40 | 1.5 | 50 | 750 | 13.5 | 120 | $ 1,750.00 | $3,495.00 | $ 5,245.00 |
| 80E | 32X44X80 | 28 D X 38 | 40 | 1.5 | 80 | 750 | 13.5 | 120 | $ 2,000.00 | $3,995.00 | $ 5,995.00 |
| DS80E | 32X44X80 | 28 D X 74 | 40 | 1.5 | 80 | 750 | 13.5 | 120 | $ 2,750.00 | $5,495.00 | $ 8,245.00 |
| 100E | 48X38X80 | 34 D X 38 | 40 | 1.5 | 100 | 750 | 13.5 | 120 | $ 2,250.00 | $4,495.00 | $ 6,745.00 |
| 100G | 48X38X80 | 34 D X 38 | 40 | 1.5 | 100 | 750 | 13.5 | 120 | $ 2,745.00 | $5,490.00 | $ 8,235.00 |
| T100E | 48X38X80 | 34 D X 50 | 40 | 1.5 | 100 | 750 | 13.5 | 120 | $ 2,750.00 | $5,495.00 | $ 8,245.00 |
| T100G | 48X38X80 | 34 D X 50 | 40 | 1.5 | 100 | 750 | 13.5 | 120 | $ 3,245.00 | $6,490.00 | $ 9,735.00 |
| DS100E | 48X38X80 | 34 D X 74 | 40 | 1.5 | 100 | 750 | 13.5 | 120 | $ 3,250.00 | $6,495.00 | $ 9,745.00 |

| Model | Footprint [WXDXH] (inches) | Max Load inches | Power Req Amps | Pump Size HP | Tank Cap Gal | Weight Cap lbs | Heat kW | Pump Flow GPM | Stainless Steel | Machine Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 150G | 50X60X80 | 46 D X 38 | 40 | 5 | 150 | 1200 | 27 | 280 | $ 3,500 | $6,995 | $ 10,495 |
| T150G | 50X60X80 | 46 D X 50 | 40 | 5 | 150 | 1200 | 27 | 280 | $ 4,000 | $7,995 | $ 11,995 |
| 200G | 62X72X80 | 58 D X 38 | 40 | 5 | 200 | 1200 | 27 | 280 | $ 4,750 | $9,495 | $ 14,245 |
| T200G | 62X72X80 | 58 D X 50 | 40 | 5 | 200 | 1200 | 27 | 280 | $ 5,500 | $10,995 | $ 16,495 |

| Standard | Options | Cost |
|---|---|---|
| Fully Insulated Tank & Door | Gas Heat (Model 100 Only) | $ 995.00 |
| Funnel Floor | Parts Tree | $ 150.00 |
| Low Water Shutoff System | Roller Top Parts Cart | $ 500.00 |
| Overhead Suspended Turntable | Parts Basket (10" X 10" D) | $ 40.00 |
| Patented Oil Skimmer | Parts Basket (12" X 16" D) | $ 75.00 |
| 7 Day Heating System Timer | | |
| Off-the-Shelf Replacement Parts | | |

GRAYMILLS CORPORATION
3705 North Lincoln Ave
Chicago, Il 60613-3594
Ph: (773) 248-6825
Fax: (773) 477-8673

| TEMPEST Model | Footprint [LXWXD] (inches) | Turn Table dia inches | Part Height Clearance inches | Pump Pressure (PSI) | Power Required | Pump Size HP | Tank Cap Gal | Parts Load Max (lbs) | Heat (kW ) | Full Load Amps | Pump Flow (GPM) | List Price |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TLP-A | 31X29.5X37 | 15 | 15 | 20 | 115V/1P | 3/4 | 12 | 50 | 2 | 16.6 | 13 | $1,995.00 |
| TLP-B | 31X29.5X37 | 15 | 15 | 20 | 230V/1P | 3/4 | 12 | 50 | 2 | 16.9 | 13 | $2,050.00 |
| FL31-1000 | 58X55X66 | 31 | 36 | 52 | 230(1or3P) | 3 | 120 | 1000 | 12 | | 35 | |
| FL36-2000 | 67x65x82 | 36 | 48 | 80 | 230(1or3P) | 5 | 150 | 1500 | 18 | | 85 | |
| FL48-3000 | 79x78x95 | 48 | 60 | 75 | 230(1or3P) | 7.5 | 300 | 1500 | 36 | | 120 | |
| TL2 | 38X43X49 | 21 | 31 | 42 | 230(1or3P) | 1.5 | 32 | 500 | 6 | | 24 | |
| TL5 | 75X94X68 | 50 | 36 | 75 | 230(1or3P) | 10 | 300 | 1500 | 36 | | 150 | |
| TL7 | 91X111X76 | 72 | 36 | 75 | 230(1or3P) | 15 | 500 | 2000 | 54 | | 200 | |
| Drum mount DH 336 | 39x31x43 | 36x22x9 | 9 | Sub-mersible | 115 / 1P | | 20-30 | 100 | 1.4 | | 300(gph) | $1,093.00 |
| Handi-Kleen PH522 | 43x31x40 | 31x22x17 | 17 | Sub-mersible | 115 / 1P | | 30 | 150 | 1.4 | | 300(gph) | |
| TL1 | 40x33x50 | 19 | 18 | 20 | 115 /1P | 3/4 | 16.5 | 250 | 4.5 | | 20 | |

## HARRY MAJOR MACHINE

Harry Major Machine
24801 Capital Boulevard
Clinton Township, MI 48036
(586) 783-7030

| Model | Footprint WXDXH inches | Work Area inches | Work Height inch | Power Req | Pump Size HP | Tank Cap Gal | Weight Cap lbs | Heat kW | Pump Flow GPM | Nozzle Pressure PSI/N | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S600 | 59x61x79 | 19.6X19.6X19.6 | 40 | | 3hp | 94 | 165 | 18 | 211 | 130 | $59,832.00 |
| S600 w/ rinse | 59x61x79 | 19.6X19.6X19.6 | 40 | | 3hp | 94 | 165 | 18 | 211 | 130 | $66,011.00 |
| S1000 | 88x103x79 | 39X39X39 | 40 | | 3hp | 94 | 165 | 18 | 211 | 130 | $76,501.00 |
| S1000 w/ rinse | 88x103x79 | 39X39X39 | 40 | | 3hp | 94 | 165 | 18 | 211 | 130 | $82,679.00 |

| Options | Price |
|---|---|
| Vertical Rotate | $ 1,140.00 |
| Horizontal Rotate | $ 1,140.00 |
| Load/Unload Trolley | $ 2,595.00 |
| Stainless Steel Basket | $ 1,245.00 |

HYDROBLAST

10250 SE Mather Rd

Clackamas OR, 97015

Ph: 800-332-1590

Fax: 503-496-1151

| Model | Footprint [WXDXH] (inches) | Work Area (inches) | Work Height (inches) | Power Requirements | Pump Size (HP) | Weight Capacity (lbs) | Heat (kW) | Full Load (Amps) | Pump Flow (GPM) |
|---|---|---|---|---|---|---|---|---|---|
| 35 | 32 X 24 X 59 | 25 D | 30 | 220V/1P | 1.5 | 700 | 6 | 32 | 80 |
| 50 a | 42 X 32 X 59 | 28 D | 30 | 220V/1P | 2 | 950 | 9 | 50 | 100 |
| 80 | 50 X 32 X 70 | 28 D | 36 | 220V/1P | 3 | 1250 | 10.5 | 60 | 124 |
| 100 | 50 X 40 X 85 | 36 D | 50 | 220V/3P | 5 | 1450 | 13.5 | 50 | 170 |
| 100T | 56 X 47 X 100 | 36 D | 60 | 220V/3P | 7.5 | 2000 | 13.5 | 55 | 215 |
| 175 | 63 X 48 X 96 | 44 D | 60 | 220V/3P | 7.5 | 2500 | 27 | 95 | 260 |
| 200 | 75 X 60 X 96 | 56 D | 60 | 220V/3P | 10 | 3500 | 30 | 110 | 330 |
| 300 | 94 X 87 X 119 | 70 D | 60 | 220V/3P | 20 | 4500 | 45 | 160 | 425 |

## JRI INDUSTRIES

JRI Industries, L. L. C.
2958 East Division
Springfield, MO 65803
(417) 866-8855

| Model | Footprint [WXDXH] (inches) | Work Area inch | Work Height inch | Power Required | Pump Size (HP) | Tank Cap Gal | Weight Cap lbs | Heat kW | Pump Flow GPM | Nozzle Pres PSI/N | Stainless Steel Option | Machine Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JR-1 | 31 X 29.5 X 37 | 15 D | 15 | 110V/1P or 230V/1P | 0.75 | 12 | 50 | 2 | 13 | 28 | $1,250 | $1,700 | $2,950 |
| TL-1 | | 19 D | 18 | | 1.5 | 18 | 250 | 4.5 | | | | | |
| TL-2 | | 21 D | 31 | | 1.5 | 32 | 500 | 4.5 | | | | | |
| TL-25 | | 25 D | 32 | | 3 | 80 | 1000 | 9 | | | | | |
| TL-31 | | 31 D | 31 | | 3 | 125 | 1000 | 12 | | | | | |
| TL-42 | | 42 D | 36 | | 7.5 | 220 | 1500 | 18 | | | | | |
| TL-50 | | 50 D | 36 | | 10 | 290 | 1500 | 36 | | | | | |
| TL-60 | | 60 D | 36 | | 15 | 390 | 1500 | 36 | | | | | |
| TL-72 | | 72 D | 36 | | 15 | 530 | 2000 | 36 | | | | | |
| TL-84 | | 84 D | 36 | | 20 | 680 | 2500 | 54 | | | | | |
| PCS 2532 | | 25 D | 32 | | 3 | 95 | 500 | 9 | | | | | |

| Model | Footprint [WXDXH] (inches) | Work Area inch | Work Height inch | Power Required | Pump Size (HP) | Tank Cap Gal | Weight Cap lbs | Heat kW | Pump Flow GPM | Nozzle Pres PSI/N | Stainless Steel Option | Machine Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PCS 3136 | | 31 D | 36 | | 3 | 140 | 1000 | 12 | | | | | |
| PCS 3148 | | 31 D | 48 | | 5 | 140 | 1000 | 12 | | | | | |
| PCS 3642 | | 36 D | 42 | | 5 | 180 | 1500 | 18 | | | | | |
| PCS 3648 | | 36 D | 48 | | 5 | 180 | 1500 | 18 | | | | | |
| PCS 3660 | | 36 D | 60 | | 7.5 | 180 | 1500 | 18 | | | | | |
| PCS 4255 | | 42 D | 55 | | 7.5 | 240 | 1500 | 18 | | | | | |
| PCS 4260 | | 42 D | 60 | | 7.5 | 240 | 1500 | 18 | | | | | |
| PCS 4272 | | 42 D | 72 | | 10 | 240 | 1500 | 36 | | | | | |
| PCS 5060 | | 50 D | 60 | | 15 | 300 | 1500 | 36 | | | | | |
| PCS 5072 | | 50 D | 72 | | 15 | 300 | 1500 | 36 | | | | | |
| PCS 6060 | | 60 D | 60 | | 15 | 400 | 1500 | 36 | | | | | |
| PCS 6072 | | 60 D | 72 | | 15 | 400 | 1500 | 36 | | | | | |
| PCS 7260 | | 72 D | 60 | | 15 | 550 | 2000 | 36 | | | | | |
| PCS 7272 | | 72 D | 72 | | 15 | 550 | 2000 | 36 | | | | | |
| FL 250 | | 25 D | 32 | | 3 | 95 | 500 | 9 | | | | | |
| FL 500 | | 31 D | 36 | | 3 | 140 | 1000 | 9 | | | | | |

| Model | Footprint [WXDXH] (inches) | Work Area inch | Work Height inch | Power Required | Pump Size (HP) | Tank Cap Gal | Weight Cap lbs | Heat kW | Pump Flow GPM | Nozzle Pres PSI/N | Stainless Steel Option | Machine Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FL 1000 | | 36 D | 42 | | 5 | 180 | 1500 | 18 | | | | | |
| FL 1500 | | 42 D | 55 | | 7.5 | 240 | 1500 | 18 | | | | | |

| Options | Price |
|---|---|
| Low Water Shut-Off | $ 240.00 |
| Oil Absorbent Pads | $ 65.00 |
| Oil Removal System | |
| Portable Cart | |
| Small Parts Basket | |
| Programmable Timer | |

## LANDA

Phillip Kircher
Government Sales Manager
Ph: (800) 984-2612
Fax: (904) 772-6596

| Model | Footprint [WXLXH] (inches) | Work Area inch. | Work Height inch. | Pump PSI | Power Req | Pump (HP) | Tank Cap Gal | Weight lbs | Heat (kW) | Load Amps | Pump (GPM) | Stainless Steel | GSA Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SJ-100A | 41X52X72 | 24 D | 36 | 50 | 230V/1P | 2 | 85 | 1000 | 9 | 32 | 40 | $5,397.00 | $4,370.00 | $9,767.00 |
| SJ-100B | 41X52 72 | 24 D | 36 | 50 | 230V/3P | 2 | 85 | 1000 | 9 | 27 | 40 | $5,397.00 | $4,443.00 | $9,840.00 |
| SJ-100C | 41X52X72 | 24 D | 36 | 50 | 460V/3P | 2 | 85 | 1000 | 9 | 20 | 40 | $5,397.00 | $4,443.00 | $9,840.00 |
| SJ-150A | 47X57X80 | 30 D | 40 | 50 | 230V/1P | 3 | 104 | 1500 | 9 | 45 | 50 | $5,997.00 | $5,105.00 | $11,102.00 |
| SJ-150A (gas) | 47X69X93 | 30 D | 40 | 50 | 230V/1P | 3 | 104 | 1500 | 115,000 BTU | 20 | 50 | | | $0.00 |
| SJ-150B | 47X57 80 | 30 D | 40 | 50 | 230V/3P | 3 | 104 | 1500 | 9 | 35 | 50 | $5,997.00 | $5,178.00 | $11,175.00 |
| SJ-150B (gas) | 47X69X93 | 30 D | 40 | 50 | 230V/3P | 3 | 104 | 1500 | 115,000 BTU | 12 | 50 | | | $0.00 |
| SJ-150C | 47X57X80 | 30 D | 40 | 50 | 460V/3P | 3 | 104 | 1500 | 9 | 25 | 50 | $5,997.00 | $5,178.00 | $11,175.00 |
| SJ-150C (gas) | 47X69X93 | 30 D | 40 | 50 | 460V/3P | 3 | 104 | 1500 | 115,000 BTU | 8 | 50 | | | $0.00 |
| SJ-250B | 54X63X80 | 36 D | 40 | 50 | 230V/3P | 5 | 140 | 1500 | 13.5 | 42 | 100 | $6,597.00 | $6,023.00 | $12,620.00 |
| SJ-250B | 54X75X93 | 36 D | 40 | 50 | 230V/3P | 5 | 140 | 1500 | 154,000 | 28 | 100 | | | $0.00 |

| Model | Footprint [WXLXH] (inches) | Work Area inch. | Work Height inch. | Pump PSI | Power Req | Pump (HP) | Tank Cap Gal | Weight lbs | Heat (kW) | Load Amps | Pump (GPM) | Stainless Steel | GSA Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (gas) | | | | | | | | | BTU | | | | | |
| SJ-250C | 54X63X80 | 36 D | 40 | 50 | 460V/3P | 5 | 140 | 1500 | 13.5 | 32 | 100 | $6,597.00 | $6,023.00 | $12,620.00 |
| SJ-250C (gas) | 54X75X93 | 36 D | 40 | 50 | 460V/3P | 5 | 140 | 1500 | 154,000 BTU | 14 | 100 | | | $0.00 |
| SJ-350B | 62X72X100 | 42 D | 60 | 45 | 230V/3P | 7.5 | 175 | 2000 | 18 | 60 | 125 | $8,397.00 | $9,790.00 | $18,187.00 |
| SJ-350B (gas) | 62X85X115 | 42 D | 60 | 45 | 230V/3P | 7.5 | 175 | 2000 | 183,000 BTU | 36 | 125 | | | $0.00 |
| SJ-350C | 62X72X100 | 42 D | 60 | 45 | 460V/3P | 7.5 | 175 | 2000 | 18 | 40 | 125 | $8,397.00 | $9,790.00 | $18,187.00 |
| SJ-350C (gas) | 62X85X115 | 42 D | 60 | 45 | 460V/3P | 7.5 | 175 | 2000 | 183,000 BTU | 20 | 125 | | | $0.00 |
| SJ-5A | 40X24X40 | 26X16X12 | 15 | | 230V/1P | 0.75 | 40 | 500 | 4.5 | 23 | 90 | | $1,540.00 | $1,540.00 |
| SJ-5B | 40X24X40 | 26X16X12 | 15 | | 230V/3P | 0.75 | 40 | 500 | 4.5 | 22 | 90 | | $1,613.00 | $1,613.00 |
| SJ-5D | 40X24X40 | 26X16X12 | 15 | | 120V/1P | 0.75 | 40 | 500 | 1.65 | 20 | 90 | | $1,393.00 | $1,393.00 |
| SJ-10A | 46X4 X36 | 26X15X7 | 15 | 40 | 230V/1P | 1.5 | 64 | 250 | 4.5 | 27 | 20 | $2,160.00 | $2,018.00 | $4,178.00 |
| SJ-10B | 46X42X36 | 26X15X7 | 15 | 40 | 230V/3P | 1.5 | 64 | 250 | 4.5 | 22 | 20 | $2,160.00 | $2,091.00 | $4,251.00 |
| SJ-10C | 46 X42X36 | 26X15X7 | 15 | 40 | 460V/3P | 1.5 | 64 | 250 | 4.5 | 20 | 20 | $2,160.00 | $2,091.00 | $4,251.00 |
| SJ-10G | 46X42X36 | 26X15X7 | 15 | 40 | 208V/1P | 1.5 | 64 | 250 | 4.5 | | 20 | $2,160.00 | $2,018.00 | $4,178.00 |
| SJ-10H | 46X42X36 | 26X15X7 | 15 | 40 | 208V/3P | 1.5 | 64 | 250 | 4.5 | | 20 | $2,160.00 | $2,091.00 | $4,251.00 |

| Model | Footprint [WXLXH] (inches) | Work Area inch. | Work Height inch. | Pump PSI | Power Req | Pump (HP) | Tank Cap Gal | Weight lbs | Heat (kW) | Load Amps | Pump (GPM) | Stainless Steel | GSA Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SJ-15A | 49X48X42 | 32X21X7 | 18 | 45 | 230V/1P | 2 | 80 | 350 | 6 | 35 | 35 | $2,310.00 | $2,606.00 | $4,916.00 |
| SJ-15B | 49X48X42 | 32X21X7 | 18 | 45 | 230V/3P | 2 | 80 | 350 | 6 | 27 | 35 | $2,310.00 | $2,679.00 | $4,989.00 |
| SJ-15C | 49X48X42 | 32X21X7 | 18 | 45 | 460V/3P | 2 | 80 | 350 | 6 | 25 | 35 | $2,310.00 | $2,679.00 | $4,989.00 |
| SJ-15G | 49X48X42 | 32X21X7 | 18 | 45 | 208V/1P | 2 | 80 | 350 | 6 | | 35 | $2,310.00 | $2,606.00 | $4,916.00 |
| SJ-15H | 49X48X42 | 32X21X7 | 18 | 45 | 208V/3P | 2 | 80 | 350 | 6 | | 35 | $2,310.00 | $2,679.00 | $4,989.00 |

| Options | Part No. | Cost | Options | Part No. | Cost | Options | Part No. | Cost |
|---|---|---|---|---|---|---|---|---|
| Automatic Water Fill | | $150 | Steam Exhaust Fan | 21-285 | $312 | Intermediate Height Spray Bar | | $330 |
| Scrub Tub With Brush | | | Adjustable Thermostat | 21-135 | $36 | Parts Tree, 30" | 21-272 | $102 |
| Stainless Steel Upgrade | | | Automatic Oil Skimmer | 21-180 | $285 | Small Parts Basket | 21-140 | $45 |
| Bag Filtration System | | | Adjustable Height Spray | | $261 | Hour Meter | 4-050822 | $14 |
| Pressure Gauge | | $30 | Double Basket | | $356 | Temperature Gauge | 4-0505 | $32 |
| Drum Cleaning Option | | | Wastewater Evaporator System | | | Pump/Motor Upgrades | | |
| Porta Kleen | PK-100D | $1,077 | Wastewater Drum Evaporator | 21-190 | $500 | | | |

Mi-T-M

www.mitm.com

ph: (800) 553-9053

| Model | Footprint [WXDXH] (inches) | Work Area inch | Work Height inch | Power Required | Pump Size (HP) | Tank (Gal) | Weight Cap (lbs) | Heat (kW) | Full Load Amps | Pump Flow GPM |
|---|---|---|---|---|---|---|---|---|---|---|
| APW-35-E | 42X40X57 | 25 D | 30 | 220V/1P | 1.5 | 35 | 700 | 6 | 40 | 80 |
| APW-35-ESS | 42X40X57 | 25 D | 30 | 220V/1P | 1.5 | 35 | 700 | 6 | 40 | 80 |
| APW-80-E | 42.5X46X84 | 28 D | 40 | 220V/1P | 3 | 80 | 1250 | 10.5 | 60 | 105 |
| APW-80-ESS | 42.5X46X 84 | 28 D | 40 | 220V/1P | 3 | 80 | 1250 | 10.5 | 60 | 105 |
| APW-80-G | 55X46X94 | 28 D | 40 | 220V/1P | 3 | 80 | 1250 | 125K BTU | 15 | 105 |
| APW-80-GSS | 55X46X94 | 28 D | 40 | 220V/1P | 3 | 80 | 1250 | 125K BTU | 15 | 105 |
| APW-100-E | 56X47X 88 | 36 D | 50 | 220V/3P | 5 | 100 | 1450 | 13.5 | 40 | 170 |
| APW-100-G | 68X47X102 | 36 D | 50 | 220V/3P | 5 | 100 | 1450 | 142.5K BTU | 15 | 170 |
| APW-100T-E | 56X47X100 | 36 D | 60 | 220V/3P | 7.5 | 100 | 2000 | 13.5 | 55 | 215 |
| APW-100T-G | 68X47X114 | 36 D | 60 | 220V/3P | 7.5 | 100 | 2000 | 142.5K BTU | 25 | 215 |
| APW-175-E | 66X54X113 | 44 D | 60 | 220V/3P | 7.5 | 175 | 2500 | 30 | 95 | 260 |
| APW-175-G | 78X54X120 | 44 D | 60 | 220V/3P | 7.5 | 175 | 2500 | 250K BTU | 25 | 260 |
| APW-200-E | 80X66X113 | 56 D | 60 | 220V/3P | 10 | 200 | 3500 | 36 | 110 | 325 |

| Model | Footprint [WXDXH] (inches) | Work Area inch | Work Height inch | Power Required | Pump Size (HP) | Tank (Gal) | Weight Cap (lbs) | Heat (kW) | Full Load Amps | Pump Flow GPM |
|---|---|---|---|---|---|---|---|---|---|---|
| APW-200-G | 92X66X120 | 56 D | 60 | 220V/3P | 10 | 200 | 3500 | 300K BTU | 30 | 325 |
| APW-300-E | 94X87X119 | 70 D | 60 | 220V/3P | 20 | 300 | 4500 | 45 | 160 | 425 |
| APW-300-G | 106X87X120 | 70 D | 60 | 220V/3P | 20 | 300 | 4500 | 450K BTU | 30 | 425 |
| APW-400-E | 60X48X48 | 18 X 12 | | 220V/3P | 3 | 90 | 400 | 15 | 60 | 80 |
| APW-400-ESS | 60X48X48 | 18 X 12 | | 220V/3P | 3 | 90 | 400 | 15 | 60 | 80 |
| APW-500-E | 108X62X60 | 24 X 18 | | 220V/3P | 5 | 160 | 1000 | 30 | 90 | 135 |
| APW-500-ESS | 108X62X60 | 24 X 18 | | 220V/3P | 5 | 160 | 1000 | 30 | 90 | 135 |
| APW-500-G | 108X62X60 | 24 X 18 | | 220V/3P | 5 | 160 | 1000 | 200K BTU | 25 | 135 |
| APW-500-GSS | 108X62X60 | 24 X 18 | | 220V/3P | 5 | 160 | 1000 | 200K BTU | 25 | 135 |

| Options | | |
|---|---|---|
| Inline Draft Reducer | Multiple-Basket Turntable | Fresh-Water Rinse |
| Small- and Large-Parts Baskets | Low-Water Shutoff | Insulation Package |
| Chip Tray | Center-Spray Bar | |
| 24-hour/7-day Timer | Custom-Parts Tree | |
| Digital Thermostat | Drying Systems | |

## PETERSON

5425 Antioch Dr
Shawnee Mission, Kansas 66202-1094
Ph: (800) 225-6308
Fax: (913) 435-8970
www.petersonmachine.com

| Model | Footprint [WXDXH] inches | Work Area inches | Work Height inches | Pump Pres PSI | Power Required | Pump Size (HP) | Tank Cap Gal | Weight Cap lbs | Heat (kW) | Full Load Amps | Pump Flow (GPM) | GSA Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SC2233E | 47X69X65 | 22 D | 33 | 50 | 230V/1P | 3 | 50 | 350 | 4 | 32 | 70 | $ 3,995.00 |
| SKS2233E | 56X84X67 | 22 D | 33 | 60 | 230V/1P | 5 | 95 | 350 | 9 | 60 | 75 | $6,080.00 |
| D30SE | 42X52X79 | 26 D | 38 | 60 | 230V/1P | 5 | 85 | 600 | 9 | 62 | 75 | $8,200.00 |
| SKS2842E | 52X61X80 | 28 D | 42 | 60 | 230V/3P | 7.5 | 135 | 1000 | 12 | 48 | 120 | $9,880.00 |
| SKS2850E | 52X61X88 | 28 D | 50 | 60 | 230V/3P | 10 | 135 | 1000 | 12 | 54 | 200 | $11,352.00 |
| D54G/E | 66X78X108 | 36 D | 54 | 60 | 230V/3P | 15 | 280 | 1200 | 24 | 104 | 200 | $18,050.00 |

PRECISION METAL WORKS
703 East Platt St
Maquoketa IA, 52060
Ph: 800-272-5438
Fax: 563-652-4126

| Model | Footprint [WXDXH] (inches) | Work Area inch | Work Height inch | Pump Press PSI | Power Req | Pump Size HP | Tank Cap Gal | Weight Cap lbs | Heat (kW) | Full Load Amps | Pump Flow (GPM) | GSA Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 110 | 40X34X52 | 24 D | 18 | 40 | 230V/1P | 2 | 25 | 300 | 4.5 | 32 | 36 | $ 2,363.00 |
| 112 | 52X40X65 | 26 D | 32 | | 230V/1P | 3 | 50 | 500 | 6 | 42 | 50 | $3,389.00 |
| 113 | 52X46X65 | 26 D | 32 | 45 | 230V/1P | 3 | 70 | 500 | 6 | 42 | 50 | $3,674.00 |
| 412 | 60X41X78 | 26 D | 40 | 60 | 230V/3P | 5 | 70 | 800 | | 45 | 90 | $5,447.00 |
| 412ST | 60X61X78 | 26 D | 40 | 60 | 230V/3P | 5 | 125 | 800 | | 45 | 90 | |
| 612 | 72X52X84 | 36 D | 42 | 60 | 230V/3P | 7 1/2 | 120 | 1000 | 12 | 50 | 110 | |
| 812A | 76X66X102 | 36 D | 54 | 65 | 230V/3P | 15 | 225 | 1000 | 18 | 82 | 190 | $10,260.00 |
| 812B | 80X70X108 | 40 D | 60 | 65 | 230V/3P | 15 | 240 | 2000 | 18 | 82 | 200 | $11,844.00 |
| 812C | 88X78X108 | 48 D | 60 | 65 | 230V/3P | 15 | 330 | 2000 | 18 | 82 | 210 | $14,567.00 |
| 812D | 96X84X108 | 54 D | 60 | 65 | 460V/3P | 15 | 400 | 2000 | 36 | 70 | 225 | $17,417.00 |
| 812E | 110X96X108 | 60 D | 60 | 65 | 460V/3P | 20 | 500 | 2000 | 36 | 70 | 270 | $19,634.00 |
| 812F | | | | | | | | | | | | $23,433.00 |
| 812G | 120X108X108 | 72 D | 60 | 65 | 460V/3P | 20 | 725 | 2000 | 54 | 90 | 300 | |

# ORISON MARKETING L.L.C.

17 Windmill Circle
Abilene, TX 79606
(915) 692-1135
(800) 460-2403

| Model | Footprint [WXDXH] (inches) | Spray Jets | Weight (shipping) | Pump HP | Power Required | Circuit Breaker | GSA PRICING | Stainless Steel |
|---|---|---|---|---|---|---|---|---|
| Hustler A-40 | 43x33x59 | 61 | 575 | 1.5 | 208/240/1P | 40 Amp | $4,599.00 | $9,099.00 |
| General G-80 | 47x37x71 | 78 | 850 | 3 | 208/240/3P | 40 Amp | $6,489.00 | $13,308.00 |
| The Hoss T-100 | 61x54x83 | 96 | 1350 | 5 | 208/240/3P | 60 Amp | $8,894.00 | $18,608.00 |

## Bath Treatment System Candidates

EMC WATER EATER

| EMC WATER EATER Model | Max Evap Rate (GPH) Batch, Auto | Footprint [LXWXH] (inches) | Tank Height inches | Power Required | Tank Capacity (Gallons) | Weight (lbs) | Heat (kW) | Full Load Amps | Cost |
|---|---|---|---|---|---|---|---|---|---|
| 85E | 6, 4 | 41 X 23 X 46 | 30 | 240V/3P | 85 | 450 | 11 2/5 | 40 | $2,995.00 |
| 85E-SS | 6, 4 | 41 X 23 X 46 | 30 | 240V/3P | 85 | 450 | 11 2/5 | 40 | $3,995.00 |
| 125E | 14, 10 | 38 X 35 X 54 | 36 | 240V/3P | 125 | 600 | 27 | 68 | $4,995.00 |
| 125E-SS | 14, 10 | 38 X 35 X 54 | 36 | 240V/3P | 125 | 600 | 27 | 68 | $5,995.00 |
| 120G | 17, 12 | 43 X 35 X 54 | 36 | 120V/1P | 120 | 700 | 200K BTU | 13 | $5,995.00 |
| 120G-SS | 17, 12 | 43 X 35 X 54 | 36 | 120V/1P | 120 | 700 | 200K BTU | 13 | $6,995.00 |
| 240G | 26, 18 | 73 X 35 X 54 | 36 | 120V/1P | 240 | 800 | 285K BTU | 13 | $8,995.00 |
| 240G-SS | 26, 18 | 73 X 35 X 54 | 36 | 120V/1P | 240 | 800 | 285K BTU | 13 | $10,995.00 |
| 375G | 55, 40 | 73 X 35 X 77 | 54 | 120V/1P | 375 | 1100 | 400K BTU | 13 | $15,995.00 |
| 375G-SS | 55, 40 | 73 X 35 X 77 | 54 | 120V/1P | 375 | 1100 | 400K BTU | 13 | $17,995.00 |

| Options | Cost | Options | Cost | |
|---|---|---|---|---|
| Auto Fill System | $1,795.00 | 70 GPM Combination Fill & Cleanout Pump | $ 795.00 | Recommended |
| 440V Power | $ 300.00 | Hose Assembly | $ 195.00 | Recommended |

## LANDA WATER BLAZE

| Model | Max Evap Rate (GPH) | Footprint [LXWXH] (inches) | Power Requirements | Tank Capacity (Gallons) | Weight (lbs) | Heat (kW) | Full Load (Amps) |
|---|---|---|---|---|---|---|---|
| HBE-10B | 6 to 8 | 58 X 41 X 64 | 230V/3P | 55 | 980 | 20 4/5 | 57 |
| HBE-10C | 8-Jun | 58 X 41 X 64 | 460V/3P | 55 | 980 | 20 4/5 | 28 |
| HBG-15D | 10 to 15 | 78.5 X 33 X 65 | 120V/1P | 70 | 1215 | 200K BTU/hr | 3 |
| HBG-30D | 25 to 30 | 65 X 53 X 70 | 120V/1P | 100 | 1435 | 375K BTU/hr | 3 |
| WB-25A | 30 | 73 X 30 X 74 | 220V/1P | 76 | 885 | 285.5K BTU | 20 |
| WB-50A | 60 | 73 X 30 X 80 | 220V/1P | 76 | 895 | 571K BTU | 20 |
| WB-125A | 120 | 79 X 50 X 81 | 220V/1P | 170 | 1690 | 1142K BTU | 30 |

| Options | Part # | Options | Part # |
|---|---|---|---|
| Auto Fill System | | Anti-Foam Kit | 7-8116 |
| HBG air diaphragm pump | 30-815 | Oil Skimmer | 30-8161 |
| HBG centrifugal pump | 30-835 | Propane Kit | |
| HBE 230V models | 30-838 | HBG-15 | 7-8118 |
| HBE 460V models | 30-839 | HBG-30 | 7-8119 |

MART EQ-1

| Model | Mixing Capacity (Gallons) | Collection Capacity (Gallons) | Cost |
|---|---|---|---|
| 250 | 125 | 125 | $7,238.96 |
| 375 | 125 | 350 | $9,153.62 |
| 500 | 125 | 375 | $10,014.25 |

| Options | Cost | Options | Cost | Options | Cost |
|---|---|---|---|---|---|
| Locking Casters | | Holding Tanks | | Magic Dust | |
| 250 | $902.10 | 300 Gallon | $2,730.48 | 50 lbs | $7.96/lb |
| 375 | $1,804.20 | 500 Gallon | $3,236.40 | 100 lbs | $7.25/lb |
| 500 | $2,269.20 | 1000 Gallon | $4,538.40 | 250 lbs | $6.51/lb |
| Transfer Pump & Cart Assembly | $2,771.40 | Final Polishing System | $2,672.51 | 500 lbs | $5.50/lb |
| Filter Media 250 YARDS | $126.72 | Filter Media 250 YARDS | $126.72 | | |

# Appendix B Operational Guidance

## EMC 100E-SS

Operational Cautions

- **Do not** operate the APW until the cleaning solution has reached the required temperature. Agitation of the solution prior to reaching elevated temperatures will result in excessive foaming of the cleaning solution.
- **Do not** leave parts unattended in the wash cabinet. Once the cleaning cycle is complete, the inside environment of the cabinet will become very hot and humid. Parts left unattended or not removed within the required time, will develop corrosion.
- To avoid flash corrosion, parts should be dried upon removal from the APW. Parts should then be lubricated according to the proper lubrication requirements.

Adding Soap to the APW

- Fill the APW with water to the proper level.
- Set thermostat to 160 degrees Fahrenheit and bring the water up to the operating temperature.
  - Liquid Soap
  - Add the proper amount to the tank at the manufactures recommended mixing ratio.
  - Powder Soap
  - Place the place powder soap in a pan on the turntable.
  - Run the washer for 30 minutes or until the soap is completely dissolved in the solution.

The following is a step-by-step Operational Procedures checklist that provides the proper control settings and parameter readings for daily equipment start-up/production operation/shutdown. **Always operate the APW at 160 degrees Fahrenheit using the Armament Shop approved aqueous cleaner unless receiving approval from NCI.**

Setting the Water Level

- Fill and maintain the water level in the APW above the center of the wash-area filter screen under the turntable.
- Open the APW door and fill the tank using the hose.

- The maximum water level is up to the lower spray manifold or in the range of the 2” ball valve Variable Weir Oil Skimmer.

- The APW is equipped with a Low Water Shut Off System. **If the APW fails to operate check to see if the water level in the APW maybe too low. Be sure not to let the water level drop too low as the heating elements can be damaged.**

Setting the Seven Day Timer

- Locate the Seven Day Timer on the rear of the control box. This timer allows personnel to set what times the APW is to be operational.

- In order to set the desired ON times, pull out the red and black “tripper” pins for the desired times.

- Turn the dial clockwise so that the correct time of day lines up with the TIME arrow.

- Set the thermostat on the front of the control box to 160 degrees Fahrenheit if it is not already set at this temperature. The red light will be on while the APW is heating up and will go off when the desired temperature is reached.

Starting the Wash Cycle

- Open the APW door and place the parts to be cleaned on the turntable. If necessary, use parts baskets or racks to hold or contain loose or small parts.

- The wash cycle timer is a 30-minute timer knob and indicator light located on the upper front of the control box.

- Close the APW door and secure the latch.

- Set thermostat to 160 degrees Fahrenheit and bring the water up to the operating temperature. The indicator light will turn on indicating that the APW is heating up. The light will go off when 160 degrees is reached.

- Rotate the timer switch clockwise to 30 minutes. The pump and turntable will activate and the red indicator light should come on indicating that the wash cycle timer is on. **Never open the APW door before turning off the wash cycle timer.**

- Upon completion of the wash cycle open the APW cabinet and briefly rinse the part with the rinse wand on the exterior of the cabinet.

- Upon removal from the APW dry parts and lubricate according to shop lubrication requirements.

Operating the Oil Skimmer

- After the APW has been shutoff and had a chance to cool make sure that the water level is the range of the 2” ball valve Variable Weir Oil Skimmer.

- Make sure there is a container located underneath the Oil Skimmer opening at the side of the APW ready for the oil to drain into.

- Before next operating the APW open the ball valve and adjust to the depth of the floating oil, so oil not water runs out into your container. **Remember to close the valve back before starting the washer.**

Performing the Titration Test

- Once every 2 weeks, perform a titration test on the bath and record the bath chemistry information on the second Data Sheet provided.

1. For anything that is not covered in the Operational Procedures checklist either refer to the manufacturer’s Operations Manual or applicable technical data.

Maintenance

- Weekly Maintenance

- Low Level Switch

  - The APW is equipped with a Low Water Level Shutdown Float Switch located inside the cabinet near the front lower left below the water level mounted to the thermostat sleeve. **This is located right next to the heater elements so make sure the APW is cool before inspecting.**

  - The float switch ball is a 2” diameter chrome/silver ball. Check this for free up and down movement.

  - This float switch ball must be kept clean to allow free movement. If the float switch ball must be cleaned remove the clip on the top of the shaft and remove the float to clean the shaft.

  - Reinstall the float switch ball making sure that the stamped “NO” or “O” is in the UP position. **Caution: Inverting the float switch ball position will reverse the On-Off function.**

- Spray Manifold

  - Clean any blocked holes in the spray manifold by using a blast of air or a small wire to poke out debris clogging the spray holes.

- ♦ Remove the wash out plug located in the upper right corner of the manifold. Close door and operate the wash cycle timer for 30 seconds. Replace wash out plug.

♦ Filter Screen (Wash-Area Screen)

- ♦ Located underneath the turntable, this flexible sheet of perforated steel simply slides in and out along the side support rails. **Usually only needs to be cleaned out when changing out the solution (See below).**

♦ Monthly Maintenance (Or As Needed)

♦ Draining and Changing the Solution

- ♦ In order to drain the tank open the 2” Drain Valve located at the bottom left side of the APW.
- ♦ Pull out and wash off the Filter Screen
- ♦ Hose out any debris left after draining using the available hose connections. Vacuum out and remove and remaining sludge.
- ♦ Close the 2” Drain Valve and fill with fresh water and soap solution as outlined in Adding Soap to the APW

## JRI Industries JR-1

Operational Cautions

- **Do not** operate the APW until the cleaning solution has reached the required temperature. Agitation of the solution prior to reaching elevated temperatures will result in excessive foaming of the cleaning solution.
- **Do not** leave parts unattended in the APW. Once the cleaning cycle is complete, the inside environment of the cabinet will become very hot and humid. Parts left unattended or not removed within the required time, will develop corrosion.
- To avoid flash corrosion, parts should be dried upon removal from the APW. Parts should then be lubricated according to the proper lubrication requirements.
- Never allow the heating element to be exposed to air when the power is on. This will cause significant damage to the heating elements.

Adding Soap to the APW **(Currently this is not a valid step in the Test Plan)**

- Fill the APW with water to within 2” beneath the turntable support bar.
- Set thermostat to 150 degrees Fahrenheit.
- Flip the toggle switch to the “Heater” position. The washer will take 20-30 minutes to come up to operating temperature.
- Open the APW. Add the approved aqueous soap to the APW at manufactures recommended mixing ratio. Close the APW.
- Flip the toggle switch to the “Wash” position. You should hear the pump start its operation. Allow the soap to mix with the water for approximately 2 minutes.

The following is a step-by-step Operational Procedures checklist that provides the proper control settings and parameter readings for daily equipment start-up/production operation/shutdown. **Always operate the APW at 150 degrees Fahrenheit using the Propulsion Shop approved aqueous cleaner unless receiving approval from NCI. At the time of this revision the only cleaner allowed in hot water.**

Setting the Water Level

- Fill and maintain the water level in the APW to within 2” beneath the turntable support bar.

- The maximum water level is up to the bottom of the turntable support bar.

- The APW is equipped with a Low Water Shut Off System. **If the APW fails to operate check to see if the water level in the APW maybe too low. Be sure not to let the water level drop too low as the heating elements can be damaged.**

Starting the Wash Cycle

- Before plugging in the APW, make sure your toggle switch is in the off position. This is the middle position on your toggle switch.

- Open the APW and place the parts to be cleaned in the parts basket.

- Close the APW door and secure the latch.

- Flip the toggle switch to the “Heater” position. The washer will take 20-30 minutes to come up to operating temperature.

- Flip the toggle switch to the “Wash” position. Let run for 10 minutes.

- Upon removal from the APW dry parts and lubricate according to shop lubrication requirements.

Performing the Titration Test

- Once every 2 weeks, perform a titration test on the bath and record the bath chemistry information on the second Data Sheet provided.

For anything that is not covered in the Operational Procedures checklist either refer to the manufacturer’s Operations Manual or applicable test data.

Maintenance

- Tank Cleaning

  - Do not clean the tank until the APW has had a chance to cool to room temperature.

  - Turn the toggle switch to the off position.

  - Disconnect the power to the machine.

  - Drain the tank by removing the screw-in plug located at the front left bottom corner of the APW.

- Remove all sediment and sludge from the tank unit by using a scoop, shop vacuum, or water hose.

- Refill the machine with water and soap as discussed in <u>Adding Soap to the APW</u>.

- <u>Nozzle Maintenance</u>

    - Unscrew the nozzles.

    - Inspect for damage or plugging.

    - Clean orifices with small wire and/or air.

    - Replace nozzles, be sure to tighten properly.

- <u>Surface Cleaning</u>

    - Rinse any soap residue on the painted surfaces of your APW with water and a wet shop rag. By cleaning the surface of your machine you will increase the life and the finish of the APW.

## Harry Major Machine SWASH S500

Operational Cautions

- **Do not** operate the APW until the cleaning solution has reached the required temperature. Agitation of the solution prior to reaching elevated temperatures will result in excessive foaming of the cleaning solution.

- **Do not** leave parts unattended in the wash cabinet. Once the cleaning cycle is complete, the inside environment of the cabinet will become very hot and humid. Parts left unattended or not removed within the required time, will develop corrosion.

- To avoid flash corrosion, parts should be dried upon removal from the APW. Parts should then be lubricated according to the proper lubrication requirements.

Turning on the APW (To be performed every morning)

- Switch ON the main switch at the rear of the machine. The machine will automatically run a systems check. After the systems check, the APW control panel will indicate any problems or that the machine is ready for operation.

- Select EXPERT from the control panel.

- Turn the oil skimmer and heaters on by pressing start next to each operation.

- After the APW has heated up (usually about 1 hour), turn off the skimmer and return to the main menu on the control panel.

- You are now ready to begin operation of your machine. **Never start the wash operation of the APW without heating the machine up to at least 140 degrees Fahrenheit. Temperatures below this will result in excessive foaming of the cleaning solution.**

Turning off the APW (To be performed every evening)

- Make sure that no parts are in the machine parts cabinet.

- Switch OFF the main switch at the rear of the machine.

Adding Soap to the APW (To be performed as needed)

- Make sure the water supply is off.

- If the tank has been cleaned out, add 20 gallons of Calla 296 to the reservoir by pouring the soap in underneath the parts tray. If the tank already contains solution add enough soap to increase the concentration to a 20% Calla 296 solution.

- Turn the water supply on. The APW will automatically be filled to the proper level.
- Set thermostat to 160 degrees Fahrenheit and bring the water up to the operating temperature.
- Run the washer for 10 minutes or until the soap is completely mixed in the solution.

The following is a step-by-step Operational Procedures checklist that provides the proper control settings and parameter readings for daily equipment start-up/production operation/shutdown. **Always operate the APW at 160 degrees Fahrenheit using the Wheel and Tire Shop approved aqueous cleaner unless receiving approval from NCI.**

Setting the Water Level

- The APW is equipped with an auto-fill feature and as long as the water supply is open, the water level will be kept at a proper level at all times.

Starting the Wash Cycle

- Before beginning the wash cycle make sure that the waste tanks are below the allowable limit. If not, empty the waste tanks into the hazardous waste storage and return the empty waste tanks to the APW.
- Raise the APW guillotine door. Line up the arrows on the parts tray and the turntable. Pull out the parts tray.
- Place the parts to be cleaned on the turntable. If necessary, use parts baskets or racks to hold or contain loose or small parts. Push in the loaded parts tray. Lower the APW door.
- Set the wash cycle by choosing one of four wash cycle programs from the touch screen control pad. If wash settings are correct, press GO on the display. Currently, the programming is set for a 2-minute wash followed by a two minute dry. If this wash cycle is changed please contact the personnel at the bottom of this document to inform them of the change.
- Make sure the APW door is closed before beginning operation. The APW contains a safety feature that will not allow the APW to start until the door is closed and secure.
- Upon completion of the wash cycle, raise the APW door and pull out the parts tray. If there are any areas on the part that still require cleaning remove the brush attached on the left side of the APW. Turn on the flow of solution through the brush by turning the toggle switch on the left of the front of the APW to

ON. Move the brush over the areas to be cleaned until obtaining the desired cleanliness. Turn the toggle switch to OFF and replace the brush in its holder on the left side of the APW.

- Upon removal from the APW parts tray, finish drying off parts.

Operating the Oil Skimmer

- The oil skimmer should be operated when the APW is turned on at the beginning of each week according to the procedures described in Turning on the APW. However, if the cleaning efficiency of the machine appears to be decreasing significantly, select the EXPERT display on the control panel. Turn off the heaters and turn on the oil skimmer. Allow the APW bath to cool. Continue to run the oil skimmer for one hour after the bath has reached room temperature.

- After this hour, select the EXPERT display and turn the heaters on. After the APW has reached the operating temperature, turn off the oil skimmer and the APW should be ready for operation. If the cleaning efficiency is still very low it may be time to clean out the APW bath. Follow the procedures outlined in the MART EQ-1 operational guidelines to clean the APW bath.

Performing the Titration or Hydrometer Test

- Once every 2 weeks, perform a titration or hydrometer test on the bath to check for the proper cleaner concentration.

2. For anything that is not covered in the Operational Procedures checklist either refer to the manufacturer's Operations Manual or applicable technical data.

Maintenance

- Weekly Maintenance (Can Be Performed During Start Up Each Monday)

- Oil Skimmer

  - Upon start-up at the beginning of each week make sure to turn the oil skimmer on while the APW is heating up to operating temperature. Follow the procedures described previously in the start up of the APW.

- Waste Tanks

  - If one of the waste tanks is approaching the allowable limit, remove the nozzle from the waste tank, rotate the waste tanks so that the empty tank is now where the full waste tank was, and insert the waste nozzle into the tank.

- Filter Baskets Inside Wash Area
    - Located on the right side of the APW wash area are two filter baskets that are designed to catch large particles such as paint chips and large soils. Remove these baskets, empty any material that has accumulated in the baskets, and return the filter baskets to their original positions.
- Filter Strainer for Pump Attached to Brush
    - Open the left doors of the APW.
    - Unscrew the strainer and empty any trash that has accumulated.
    - Screw back into place.
    - Close the left doors of the APW.
- Monthly Maintenance (Or As Needed)
- Filter Basket
    - Located at the rear of the machine. Open the rear access doors.
    - Loosen filter lid securing nuts. Turn lid clockwise to release. Remove lid.
    - Remove filter basket. Clean basket and return to filter body.
    - Refit and secure lid.
- Draining and Changing the Solution
    - Turn off the water supply, and then turn off the machine according to operations described previously.
    - In order to drain the tank, open the rear access doors and attach the quick disconnect from the wall-mounted hose to the drain valve.
    - Open the drain valve and follow the procedures described on how to operate the MART EQ-1.
    - After the solution has been removed from the machine, open the left side access doors.
    - Unscrew the handles to the side access tank. Open the access tank door.
    - Remove any sludge in the tank using either a shop vacuum or some other method.

- Close the access door and screw the handles to the tank door back securely.

## EMC Water Eater 85E-SS Wastewater Evaporator

Operational Cautions

- Only process non-flammable water-based solutions that do not emit hazardous or toxic materials when heated to 212 degrees Fahrenheit in the EMC Water Eater.

- Always make sure to disconnect the machine from the wall power outlet before servicing the EMC Water Eater.

- Make sure no flammable materials are in the general area of the heating elements of the EMC Water Eater.

Adding Solution to the EMC Water Eater

- Make sure the solution to be added to the Water Eater is at room temperature.

- Insert the filter end of the green hose into the solution.

- Flip the Pump switch up to the on position. This switch must be held in the on position to continue operation.

- Fill the EMC Water Eater to 50-75 percent of its capacity. The level of the solution in the EMC Water Eater should be no higher than the height of the 2” ball valve Variable Weir Oil Skimmer.

The following is a step-by-step Operational Procedures checklist that provides the proper control settings and parameter readings for daily equipment start-up/production operation/shutdown. **Always operate the EMC Water Eater at 220 degrees Fahrenheit (the maximum on the thermostat dial) unless receiving other guidance from NCI.**

Operating the Water Eater Wastewater Evaporator

- Make sure the Water Eater is filled with non-flammable water-based solution. The liquid level must be high enough to cover the displacement switch polyethylene weight.

- Make sure the access cover is in place.

- The maximum water level is up to the range of the 2” ball valve Variable Weir Oil Skimmer.

- The EMC Water Eater is equipped with a Low Water Shut Off System. **If the EMC Water Eater fails to operate check to see if the water level in the Water Eater may be too low.**

- Turn the thermostat to the maximum setting (220 degrees Fahrenheit). This will activate the exhaust blower.

- Flip the "Heat' switch up to the on position. Initial heat up will take from 1 to 3 hours depending on the fill level and the average room temperature.

- Once the Water Eater begins evaporating it will continue to operate as long as the solution level is high enough to cover the polyethylene weight **AND** the high temperature override has not been tripped. When the polyethylene switch is unsupported by water, the switch arm located on top of the control box will activate the microswitch shutting off the heating system. The lower "Heat" indicator light will also turn off. The exhaust fan and top indicator light will remain on until the thermostat dial is manually turned off. **NOTE: Turning the thermostat dial to OFF will always shut down the Water Eater.**

<u>Operating the Oil Skimmer</u>

- After the EMC Water Eater has been filled and before the heater has been turned on make sure that the water level is in the range of the 2" ball valve Variable Weir Oil Skimmer.

- Make sure there is a container located underneath the Oil Skimmer opening at the side of the EMC Water Eater ready for the oil to drain into.

- Before next operating the heater on the Water Eater open the ball valve and adjust to the depth of the floating oil, so oil not water runs out into your container. **Remember to close the valve back before starting the washer.**

For anything that is not covered in the Operational Procedures checklist either refer to the manufacturer's Operations Manual or applicable technical data.

<u>Maintenance</u>

- <u>Monthly Maintenance (Or As Needed)</u>

- Cleaning Out the Water Eater Tank

  - After evaporating out as much of the solution as possible allow the remaining contents to cool.

  - Remove the access cover.

  - Vacuum out and remove any remaining sludge. Make sure there is no solids buildup on the tank floor. **Excessive solids buildup will initiate a high heat condition, causing shutdown from the High Temperature Thermostat.**

- Inspect and thoroughly clean the tank floor.

- Inspect for any loose fittings, fasteners, and mounting bolts. Tighten any that require it.

- Inspect displacement arm switch for up and down movement. Make sure up and down movement is unrestricted.

- To add more solution for processing follow the steps laid out in the Adding Solution to the EMC Water Eater.

## MART EQ-1 250

Operational Cautions

- Always make sure that valves are in the proper positions and hoses are connected to the proper outlets.
- Always make sure to disconnect the machine from the wall power outlet before servicing the MART EQ-1.

Adding Solution to the MART EQ-1

- Make sure the solution to be added to the MART EQ-1 is at room temperature. **Note: Room temperature is desired, but it is a must that the solution is below 125 degrees Fahrenheit.**
- Make sure that the quick disconnect end of the green hose from the transfer pump is connected to the fill port.
- Insert the suction end of the green hose into the solution.
- Make sure that the ball valve to the airline connection on the transfer pump assembly is open. Insert the air line into the connection on the transfer pump assembly.
- Immediately the pump will begin to transfer the liquid. Use the knob on the transfer pump next to the air line connection to regulate the rate at which the solution is pumped into the EQ-1. If the pump is making a lot of noise adjust the knob so that the noise is minimized. This will eliminate any cavitation in the pump.
- Make sure to fill the upper reservoir up to the T in the sight tube and to not fill the upper reservoir past the fill line visible on the side of the machine next to the sight tube.
- After the bath has been transferred turn the ball valve to the air line connection to off. Disconnect the air line from the transfer pump assembly. Close the ball valve on the air line connection.

The following is a step-by-step Operational Procedures checklist that provides the proper control settings and parameter readings for daily equipment start-up/production operation/shutdown.

| | Standpipe Valve | Bottom Valve | Rinse Valve | Drain Valve |
|---|---|---|---|---|
| Open | \| | \| | \| | ------------ |
| Closed | --------------- | --------------- | -------------- | \| |

Operating the MART EQ-1

- **Note: Before operating the MART EQ-1 make sure that all the valves are in the CLOSED position.**

- **Note: Make sure filter paper is covering the lower reservoir at all times.**

- Make sure to wear a facemask to protect from inhalation of the Magic Dust. Measure out 2-3 pounds of Magic Dust to insert into the machine for every 100 gallons of solution. The measuring scoop holds approximately 2 pounds. The MART EQ-1 has a tank capacity of 125 gallons. The MART aqueous parts washer has a tank capacity of 180 gallons. So for every full 125 gallons processed approximately 2.5 to 3.75 pounds should be used or approximately 1 ¼ to 1 7/8 cups should be used.

- Turn the mixer on for 10-15 seconds then add the predetermined amount of Magic Dust in the top opening of the EQ-1. Continue to run the mixer for 3 minutes.

- Shut off the mixer and observe the waste in the sight tube. You should see a dramatic separation of encapsulated waste from the solution. Allow the waste and solution to continue to separate for 5 minutes.

- Move the left lever to open the standpipe valve. Clarified solution should flow out and through the filter paper.

- Once the standpipe valve flow has been reduced to a trickle, move the right lever to open the bottom valve and release the encapsulated waste. As the waste begins to build up on the paper you may wish to slowly move the filter paper forward so that flow isn't stopped. It also may be your desire if the waste is great enough to turn off the bottom valve and create a small burrito before continuing with the operation.

- Once the encapsulated waste has drained out pull the filter paper forward and wrap like a burrito. You may want to pull the burrito to the front of the machine and squeeze out any excess solution so the burrito will dry more quickly.

- Cut the filter paper and remove the burrito and carefully place it in the drying tray to air out.

- The final step is to run the rinse for about 10 seconds to flush out any traces of encapsulated waste on the upper reservoir. Make sure the standpipe valve and drain valve are closed and the bottom valve and rinse valve are open. Turn on the pump for approximately 15 seconds. Let any remaining encapsulated waste flow out on the filter paper and make another small burrito.

Returning the Clarified Solution Back to the MART Aqueous Parts Washer

- After the solution has been cleaned by the MART EQ-1, disconnect the hose connected to the fill port and reconnect it to the drain port. Make sure that the end of the other hose from the transfer pump assembly is inserted into the MART APW bath.

- ♦ Turn on the pump on the EQ-1. This will transfer the solution back to the parts washer. **Note: Do not turn on the air line supplying the transfer pump. In fact, if directions were followed this should have been disconnected following transfer of the bath to the EQ-1.**

- ♦ After the solution has been returned to the MART aqueous parts washer remove the hose from the bath. Approximately 75% your soap should still remain in the solution. Add enough soap to the bath to once again have the proper soap concentration. You are now ready to operate your MART aqueous parts washer again.

Troubleshooting

- ♦ If the mixer or pump does not appear to be turning on unplug the machine and remove the covering from the electrical panel. Hit the reset switch on the breaker. Plug the machine back in and see if the mixer or pump works, if it doesn't contact the personnel below.

For anything that is not covered in the Operational Procedures checklist either refer to the manufacturer's Operations Manual or applicable technical data.

Maintenance