Implementing Alternatives to Ozone Depleting Solvents
-Some Considerations-

by

Don E. Hunt

Chief, Quality Reliability and Engineering
Aerospace Guidance and Metrology Center
Newark Air Force Base, Ohio 43057-5149
United States of America

Commercial Phone: (614) 522-7220
DSN : 346-7220

March 12, 1991

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

DTIC QUALITY INSPECTED 2

19971210 084

New Text Document.txt

10 December 1997

This paper was downloaded from the Internet.

Distribution Statement A: Approved for public release;
distribution is unlimited.

Aerospace Guidance and Metrology Center
Newark Air Force Base, OH

Date: March 1991

IMPLEMENTING ALTERNATIVES TO OZONE DEPLETING SOLVENTS
-SOME CONSIDERATIONS-

Don E. Hunt

Chief, Quality Reliability and Engineering
Aerospace Guidance and Metrology Center
Newark Air Force Base, Ohio 43057-5149

ABSTRACT

The Aerospace Guidance and Metrology Center located at Newark Air Force Base in the state of Ohio, U.S.A., repairs inertial navigation and guidance equipment for the United States Air Force. The Center repairs thousands of the delicate, sophisticated electromechanical devices each year. The critical tolerances of many of the moving parts and other considerations mandate extensive "precision*' cleaning as well as general cleaning during the repair process. The principal solvents used for this cleaning are 1,1,2-Trichloro 1,2,2-trifluoroethane and 1,1,1-Trichloroethane. The Center has begun modifying its many cleaning processes to use known alternatives for these solvents. The Center has already converted several processes to deionized water and biodegradable detergents and has committed extensive internal resources to define and implement changes throughout its remaining processes. While this effort has not been easy, it has made visible some special considerations which will ease and expedite the transition in the future.

INTRODUCTION

The Aerospace Guidance and Metrology Center is located in the state of Ohio, U.S.A., at the Newark Air Force Base. It is a repair center in the U.S. Air Force Logistics Command.

The Center has two primary missions. The first is the repair of inertial guidance and navigation systems and components used by most missiles and aircraft in the U.S. Air Force inventory. The inertial systems and components of several foreign countries are also repaired at the Center. The secoad mission is the management of the U.S. Air Force Single Integrated Metrology and Calibration Program worldwide.

The Center is comprised of, for the most part, one large building covering approximately fifteen acres. Within this building are a large number of smaller structures totalling over 294,000 square feet of floor space. These structures have strictly controlled environments and contain a vast array of complex repair operations.

The sophisticated electromechanical devices that form the nucleus of inertial systems are extremely susceptible to minute contamination. Particles five microns or less in size can cause a system to fail. As a result, great care must be taken to assure a clean repair environment. Of course, during the repair process it is necessary to carefully clean the parts being assembled.

The Center's industrial processes require extensive use of solvents to meet these cleaning needs and for other specific purposes. Among the solvents used are CFC-113, specifically Freon 113, and 1,1,1-Trichloroethane. Freon 113, a chlorofluorocarbon (1,1,2-Trichloro 1,2,2-trifluoroethane) is a trademark of E.I. Du Pent Nemours and Co., Inc.

Once used, Freon 113, like many of the solvents, is considered a hazardous waste. The Center reprocesses most of the Freon 113 it uses to virgin quality through a sophisticated distillation system, but a significant portion is lost through evaporation and hazardous waste disposal. Historically, the Center has used over two million pounds of Freon 113 annually. Of this amount, over six hundred thousand pounds have been purchased to replace that which was lost.

Freon 113, in addition to being a hazardous waste, is a serious threat to the atmosphere. Its impact on the ozone layer has generated action to curb its production and use worldwide.

Freon 113 now costs the Center $2.37 per pound ($31.05 per gallon). This is 395% of the cost a year ago ($0.60 per pound). In addition, the cost of recovery of vapors from the Center-s industrial processes, the cost of hazardous waste disposal, and the cost of reprocessing used Freon 113 contribute to the total cost of its use. The cost of using Freon 113, the threat of even higher cost resulting from reduced availability in the future, and the environmental issues have caused the Center to take an aggressive role in finding alternatives for this and other hazardous solvents.

For the past three years, Center personnel have been engaged in an intensive evaluation of equipment, techniques, and processes to identify suitable alternatives for a variety of solvent uses. These solvent uses include, in addition to cleaning, leak testing and component cooling.

LEAK TESTING

Freon 113 is used in several processes at the Center as a "gross" leak checking medium. Assemblies which have been repaired and will subsequently be hermetically sealed with an inert gas internal to the assembly must be tested to assure the integrity of the external

shell, or case, of the assembly. One of the steps in doing this involves checking for the existence of gross leaks. To perform this check, the assembly is pressurized with inert gas and submerged in a tank containing Freon 113 or FC-77 Fluorinert Brand Electronics Liquid. (FC-77 is produced by 3M, St. Paul, Minnesota). The technician then watches for bubbles which indicate the presence and location of a leak.

After considerable experimentation, it was determined that the same quality of leak detecting ability, i.e. size and quantity of bubbles could be obtained using a mixture of surfactant and deionized water as the medium. The surfactant thus far found to be most effective for this purpose is Triton X-100 and the mixture strength is 0.2 percent. (Triton X-100 is manufactured by the Rohm and Hass Company, Philadelphia, PA.) After the assembly is removed from the tank, it is placed in a vacuum oven and thoroughly dried. The external surfaces of the assemblies which are currently leak checked do not require precision cleaning and, with the same frequency of change of the tank medium, the water and surfactant mixture results in no more surface contamination as a result of the dipping than does the Freon 113. Also, no corrosion has been noted as a result of this technique.

One leak checking process has been changed to use the water and surfactant mixture and is working very satisfactorily. The other processes are now being examined with the intent to change them in the near future.

COMPONENT COOLING

The Center repairs thousands of electronic circuit boards annually in addition to the repair of the extensive array of electronic test equipment used in its operations. One of the diagnostic techniques used to locate and identify faulty circuit components is thermal shock. This is typically done using an aerosol can of rapidly evaporating solvent. These aerosol cans of solvents are referred to generically as "freezing compounds". When the solvent evaporates, it quickly drops the temperature of the component upon which it was sprayed. Dichlorodifluoromethane (CFC-12) is one of the commonly used solvents for this purpose. These freezing compounds drop the temperature to approximately -60 degrees Fahrenheit.

The Center's engineers have tested a mechanical device using compressed air as an alternative in many situations for the solvent used to cool components. The device tested, called Component Cooler, was made by Exair Corporation, Cincinnati, Ohio. It uses a Vortex tube to produce cold air. At an input air pressure of 80 psig it will drop the output air temperature below -28 degrees Fahrenheit and the air pressure to approximately 2 psig. Testing to date indicates

that this temperature drop is sufficient to duplicate the vast majority of the faulty components identified with the freezing compounds. In addition, there is no measurable static charge resident in the discharged air. The freezing compound stream emitted from the plastic tube supplied with the cans has been found to have a consistent static charge ranging from 50 to 600 volts.

Battelle Memorial Institute, Columbus Operations, Columbus, Ohio will be conducting a thorough evaluation of the Component Cooler for use in diagnostic testing of electronic circuits on behalf of the U.S. Environmental Protection Agency during 1991. The testing will be done using the set up at the Center.

Another device being evaluated at the Center for use in component cooling for diagnostic testing purposes is made by the Brymill Corporation, Vernon, CT. It is named Cryogun and is a small hand held dewar containing liquid nitrogen. It is designed to give the technician complete and easy control over the discharge of a small stream of nitrogen through various nozzle arrangements. It has the advantage of being totally portable and convenient to use. It has the disadvantage at the present time of requiring very careful attention by the technician to avoid dropping the temperature to too low a value. It appears to have application for several non critical cooling processes at the Center, and, with some design changes, could have broad application. The discharged nitrogen gas from the Cryogun is also static free and has the additional advantage of being less hydrophilic then either the freezing compound or the air.

CLEANING

The Center's repair processes, as mentioned above, require extensive cleaning. The overwhelming majority of the Freon 113 and 1,1,1-Trichloroethane used at the Center is used in these cleaning activities. The solvents are used in a wide variety of different types of cleaning operations. These can be summarized as flushing, bench, vapor decreasing, ultrasonic , and impingement spray booth operations. Flushing operations involve the flowing of solvent through the assembly or system being cleaned for a defined period of time. Bench operations encompass all cleaning activities accomplished by a repair technician at a work station using solvent for spot cleaning.

The Center has done extensive work testing aqueous processes as alternatives for ozone depleting solvents in the critical, or precision, cleaning of metal parts and assemblies of various compositions. The term "precision'" cleaning, as used at the Center, encompasses the removal of particles 10 microns or less in diameter, the preparation of surfaces for ensuing processes where the quality

of the ensuing process is dependent on the cleanliness of the surface, where wear between moving parts is a concern, and other special concerns involving "cleanliness".

This work has proven beyond any doubt that aqueous processes are, indeed, suitable for precision cleaning of parts and assemblies consisting of metals, epoxies, plastics, and other materials.

Many lessons were learned as a result of the thoroughness required to verify that the aqueous processes were suitable as substitutes for ozone depleting solvent based processes and, subsequently, "'proving" to management that this was the case. These lessons have caused the Center to not only consider the use of aqueous processes as its principal alternative for ozone depleting solvents, but also to change the basic philosophy of cleaning in its operations.

Prior to the aqueous process investigation, each technician at the Center did his own cleaning for the parts he was working with in the area where he was doing the work. This included all precision cleaning as well as all non-precision, or general, cleaning. Over many years with hundreds of technicians performing their own cleaning, as many different cleaning "techniques" developed as there were technicians. Such a situation is extremely difficult to control for consistency and uniform quality.

Now the Center has adopted a new approach. Precision cleaning will be done in a central Precision Cleaning Center. Only general cleaning will be done in the various production areas. The Cleaning Center concept provides several positive improvements to the repair operations. Of course, since fewer areas will be involved, it minimizes the expense involved in providing the equipment and facilities required for converting to aqueous based precision cleaning. It was learned early in the Center's efforts that the aqueous process worked extremely well for precision cleaning, but only if the various elements in the entire process were closely controlled; the centralized Cleaning Center concept makes this much easier to monitor. Also significant is the fact that a very small number of people will be doing the cleaning. This permits a significantly higher degree of quality control in the operation; the cleaning is uniform and consistent. Long term benefits in the reliability of the repaired items are expected to result from this change in concept.

One Precision Cleaning Center has been put into operation and another is planned to go into operation in 1991. The Cleaning Center concept is still evolving and imprpvements are being added as they are developed.

The Cleaning Center is situated in an environment that is maintained to better than a Class 10,000 Clean Room particle count. (A Class 10,000 Clean Room is defined as having less than 10,000 particles which are 0.5 microns in diameter or larger per cubic foot.)

The flooring is an elevated platform composed of two foot square panels that are static electricity dissipative. The technicians wear static electricity dissipative shoes which are put on when entering the Cleaning Center and removed when leaving it. To qualify as static electricity dissipative, the floor and the shoes must have a resistance to ground in the range of 1 to 1,000 megohms. The combination of static dissipative flooring and shoes reduces the incidence of electrostatic charges on the technicians, and, as a result, the effect of electrostatic fields is reduced as a mechanism for recontaminating the parts which have been cleaned.

The Cleaning Center is supplied with deionized water for all of its cleaning operations. The deionized water is maintained to a minimum resistivity of 15 megohms. The quality of the water is critical to the process. The Center's research found that when the water fell below 10 megohms resistivity, the parts being cleaned showed signs of corrosion, stains, and tarnish. These problems were not exhibited when the water resistivity was above 10 megohms.

A low volume, rapid recovery hot water system heats the deionized water to 155 degrees Fahrenheit for use in the Cleaning Center. The water is filtered through 0.2 micron absolute filters before use.

The principal cleaning device in the Cleaning Center is a self contained cleaning system that cleans with ultrasonic energy using biodegradable detergents and water in a cylindrical cleaning chamber. The ultrasonic cleaning action is produced via cavitation by a cylindrical space-laminated magnetostrictive nickel design transducer which forms the cleaning chamber. The ultrasonic cleaner operates nominally at a frequency of 20 kHz with a uniform power intensity of 400 watts per gallon. The cylindrical cleaning chamber is 10 inches in diameter and 14 inches deep. Adjustable timers control wash and rinse cycles. A solution of pure water and detergent from one of two holding tanks is pumped into the cleaning chamber to begin the wash cycle. The solutions in the two holding tanks are continuously filtered through 0.5 micron absolute filters and are maintained at 160 degrees Fahrenheit. When the wash cycle is complete, the detergent and water are drained back to the holding tank. Deionized water is passed over the parts during the rinse cycle to flush away detergent and loosened particles. The ultrasonic action continues during the rinse cycle. (Two sources for ultrasonic cleaning equipment with these characteristics are Magnasonic Systems, Inc. , Xenia, Ohio, U.S.A., and Friess Equipment, Inc., Akron, Ohio, U.S.A.)

An aqueous spray booth is also located in the Cleaning Center. It contains a reservoir of heated water and detergent solution. When used, the solution is passed through a 0.2 micron filter. After use, the solution is returned to the reservoir for reuse. The spray pressure is variable between 0 and 160 psig. After spraying with the solution of water and detergent, the technician can rinse with heated deionized water. The spray booth with specially designed nozzles permits precleaning of recessed screw holes and other irregularities in a part's geometry prior to final cleaning in the ultrasonic cleaning equipment.

The parts are removed from the cleaner and are placed in a Class 100 laminar flow booth. (Air through a Class 100 laminar flow booth has less than 100 particles 0.5 microns in diameter or larger per cubic foot.) In the laminar flow booth, the parts are blown dry with dry, heated nitrogen. The nitrogen is filtered through a 0.5 micron filter and passed through a nuclear ionizing element to neutralize any electrostatic charge in the nitrogen or on the surfaces it comes in contact with. The parts are then transferred to a vacuum oven where they are completely dried. The vacuum oven is operated at a nominal 160 degrees Fahrenheit and a vacuum of 30 inches of mercury. The drying time used for most parts is one hour. After drying, the parts are placed in a second Class 100 laminar flow booth where they are packaged.

The Center's evaluation of the aqueous process has demonstrated conclusively that with the proper quality of deionized rinse water, proper water temperature, proper filtering of rinse water and detergent solutions, proper timing of wash and rinse cycles, proper selection of detergent, and proper orientation and loading of parts in the ultrasonic cleaning chamber, no degradation, either chemical or metallurgical, results In either the near or long term.

Several ozone depleting solvent based cleaning processes for gyroscopes have been successfully changed to aqueous cleaning at the Center. The gyroscope parts cleaned with the aqueous process include gimbal rings, float shell halves, fill tubes, end bell covers, and gaskets. In addition, miniature precision instrument bearing assemblies from most of the inertial guidance and navigation systems repaired at the Center are now cleaned using the aqueous process. The various parts consist of copper, jewels, various epoxies and plastics, and alloys of iron, aluminum, and beryllium together with other materials.

CONSIDERATIONS

Finding alternatives to the use of ozone depleting solvents in the Center's processes has been difficult, getting the processes changed has been difficult, and the effort has been slow in evolving.

However, some considerations have surfaced along the way which are being exploited to permit the effort to gain momentum at the Center. Many aspects of these considerations should be applicable to any organization striving to implement alternatives to the use of ozone depleting solvents, especially in the area of cleaning. These considerations are broken into six categories: policy, qualification, documentation , adaptation of existing equipment, funding, and benefits.

1. **Policy**

It is absolutely imperative, if a wide spread implementation of alternatives is to succeed, for the top management of an organization to commit the resources and the personal interest required to make it happen. One of the requirements of this commitment is the establishment of a comprehensive policy for the organization which will act as a focal point for all subsequent actions.

The Aerospace Guidance and Metrology Center has adopted a policy for the elimination of ozone depleting solvents from its industrial processes. The Center's policy is a three phase plan. In the first phase, now completed , all of the processes using ozone depleting solvents were identified and qualified. During the second phase, the processes using ozone depleting solvents will be separated into two groups. The first group will include those processes for which alternatives have been identified, either for the process itself or for the ozone depleting solvents used within the process. The second group will include those processes for which an alternative has not yet been identified. This separation will be achieved by actually implementing alternatives, where possible, with the remaining processes forming the second group. This effort is to be completed by 1993. In the third phase, Department of Defense laboratory facilities and/or industry will be used to research and find alternatives for those processes in the second group where an alternative could not be identified. The third phase is to be completed in 1995.

The Center has committed considerable resources to carry out this policy. Teams composed of engineers, scientists, and technicians have completed surveys designed to obtain information about the Center-s cleaning processes. This information includes the location of each process, the part or assembly being cleaned, the material involved, the solvent used, and much more. This information has been compiled in an extensive data base. The data base will allow the sorting of the data by various factors to make the search for, and

implementation of, alternatives easier and more efficient. Other teams are in the process of testing and evaluation necessary to extend the implementation of aqueous cleaning throughout the Center.

2. Qualification

One of the most necessary and critical factors leading to the successful implementation of an alternative to an existing, proven process is the qualification of the alternative. This was, and still is, the case in the Center's efforts to change its cleaning processes to aqueous cleaning to eliminate ozone depleting solvents.

Extensive proof was required at many levels of management that the parts being cleaned were in no way adversely affected, either metallurgically or chemically, by the process and that the resulting cleanliness was at least as good as that obtained using the ozone depleting solvent based processes. Obtaining satisfactory "proof" proved to be difficult.

While it was difficult to determine the chemical and metallurgical impact of an alternative process and compare it to the results of the solvent based process, it was possible using the normal methods available in a good physical science laboratory. The determination of the degree of cleanliness, however, was another matter entirely.

At the Center, various techniques were used to compare the cleanliness achieved in the alternate and in the existing processes. These techniques range from unaided visual inspections and subjective evaluations by technicians who through the years have developed a **feel" for the cleanliness of a part, to techniques involving microscopy, particle counters, and/or the results of functional tests. While the engineering community has, in general, been satisfied with the results of the cleanliness valuations thus far conducted, the methods used and the subsequent results are still open to question and somewhat subjective.

Quantifying the degree of cleanliness is an extremely difficult task. There has been little done in the past several years to provide a basis of comparison when dealing with precision cleaned metal parts. Techniques such as electron microscopy are effective in qualifying the cleanliness of parts with small flat surfaces; however, even the effectiveness of this technique is often reduced because the point of measurement is removed from the process location. This means the cleaned item must be transported through various contaminating environments before the evaluation can take place.

The problem of comparing the cleaning effectiveness of alternatives is further compounded when the item being cleaned is composed of severe geometries such as dead end threaded holes, small diameter tubes, the inside surfaces of delicate pressure compensating bellows, the inner races and balls of miniature precision bearings and etc.

The Center is currently engaged in working out the final details of a statement of work with Battelle Memorial Institute, Columbus Operations, Columbus, Ohio, for a contract which is expected to resolve this difficulty. The contract should be let in late June or early July, 1991 and should be completed within the ensuing year. Under the contract, Battelle will adapt a process developed for another purpose to provide a means to compare one cleaning process to another with respect to the degree of cleanliness attained to an expected accuracy of over 99.9 percent. The Battelle method will introduce stable isotopes onto the surfaces of the parts to be cleaned. The isotopes will mirror the actual contaminant(s) to be removed in the cleaning process. The stable isotopes are not radioactive and will not require special handling. The measurements in the Battelle method will require only a precision balance, a gas chromatograph with mass spectrometer (GCMS), and standard absorption spectrometry equipment. In the event those items are not present in a facility using the method, the measurements could be made elsewhere without affecting the accuracy of the test. The stable isotopes are relatively inexpensive to acquire and pose no hazard other than the hazard of the base material, itself. If this technique proves to be as effective as preliminary discussions indicate, it may become the basis of a long needed standard for comparing cleaning mediums as well as cleaning equipment.

Another qualification issue being addressed by the Center concerns the potential for corrosion from residue following cleaning of mildly activated rosin (RMA) flux on surfaces which are subsequently covered with a protective coating.

For example in one of the Center-s processes, aluminum covers for displacement gyros with a copper strip plated on their mating surfaces are soldered together using a 600 watt soldering iron. RMA flux is used in this operation, and flux residue is burned onto the aluminum in the vicinity of the soldered joint. The current cleaning process is to use isopropyl alcohol immediately after soldering to remove the flux residue. The unit is then subjected to a pressurized Freon 113 spray to rinse away any remaining residue. Following rinsing, the unit is painted with an epoxy based paint.

Center personnel have determined that MSI-7000, a biodegradable detergent developed by Magnasonic Systems, Inc., Xenia, Ohio, used at full strength removes the flux from the aluminum covers as well as isopropyl alcohol. Further, the Center-s Physical Science Laboratory has verified that the surface cleaned with MSI-7000, with no further

treatment, results in paint adherence equivalent to the adherence of paint on the surface after the isopropyl alcohol and Freon 113 rinse procedure.

A contract is expected to be let in late June or early July, 1991 to Battelle Memorial Institute, Columbus Operations, Columbus, Ohio, for a study to be made of the corrosion potential of the unrinsed residue of MSI-7000 on various surfaces following surface treatment such as painting and, in the case of circuit boards, conformal coating. In other words, if the surface has RMA type flux wiped from it using full strength, undiluted MSI-7000, and then, without rinsing, the surface is painted, what corrosion may be expected over time? With the correct paint or conformal coating, there is evidence to indicate there will be no corrosion. The Battelle study will be thorough and will address aluminum and steel gyro casing materials and the metals common to circuit boards in conjunction with the particular paints and conformal coating materials used at the Aerospace Guidance and Metrology Center. The results of this study may provide the basis upon which many RMA flux residue removal processes at the Center will be changed.

3. Documentation

It is extremely important when implementing change to have complete and thorough documentation of all aspects of the proposed alternative. The importance of the documentation is proportional to the number of levels and the diversity of the engineering and management approval process.

The task of the engineers at the Center for documentation of ozone depleting alternatives is compounded by two facts. First, there are virtually thousands of parts and assemblies for which process alternatives must be individually justified. Second, each of the processes is part of some workload which is being performed for a "customer" located at some remote location in another state distant from Ohio. That customers engineering and management community, in addition to the Center's engineering and management community, must be convinced to authorize the change.

Experience gained in the last three years has generated a generic "final project report" for use in the implementation approval process. The report is designed to address all areas of concern in an easy to reference format. It is also designed to reduce the burden of creative writing normally confronting the engineer in report writing. It is loaded on a computer in a template fashion with the portions that will be consistent with each report already in place. Also, maximum use of attachments will further reduce the generation process. For example, one of the attachments will be a bibliography of existing technical documents. If the report is

addressing the cleaning of a part made of beryllium and a previous study has been conducted which addressed the chemical and metallurgical effects of the same cleaning process on beryllium, the document in the bibliography attachment will be referenced. It is expected that this generic final project report will increase the output of the engineers and provide a consistent level of quality and completeness to the reports. The report format is simple to adjust and will permit change as required and experience dictates.

The subject headings in the generic final project report are as follows:

Project Title
Project Number
Test Period
Project Location
Background
System
Scope of Project
Cleanliness Evaluation Method
Current Cleaning Process
Composition of Test Items
Contaminant Identification
Detergent Selection
Water Quality
Cleaning Equipment
Material Requirements
Cleaning Procedure
Component Degradation Evaluation
Cleaning Evaluation and Results
Recommendations

Attachments:
- -List of reference documents
- -Project specific documents

4. Adaptation of existing equipment

One of the questions that always arises in discussions about implementing process changes from solvent based cleaning to aqueous based cleaning concerns the expense of acquiring new equipment to make the process change possible. While some new equipment is undoubtedly going to be necessary, it should not need to be extensive.

Much of the equipment already in use for solvent based cleaning can be readily converted for use with aqueous based processes. This equipment includes vacuum ovens, laminar flow booths, spray booths,

and ultrasonic cleaners. The spray booths and ultrasonic cleaners will require some modifications, but those are easily designed and installed by a competent and innovative engineering/technician staff.

The Center-s personnel have modified a limited number of spray booths and an ultrasonic cleaner to function with water and detergent. The costs were minimal and the results very satisfactory. It is expected that this modification process will be extensive in the future.

5. Funding

Often, the unavailability of "funding" is heard cited as a reason to procrastinate in the effort to eliminate ozone depleting solvents from a facility-s industrial processes. However, the cost of CFC-113 and the definite future cessation of its production make procrastination unacceptable when survival of the facility is the issue.

The Center considers the implementation of alternatives for ozone depleting solvents in its processes to be imperative for its survival. In that context, it used "in house" resources in manpower and materials to support the effort. These resources, paid for by the Depot Maintenance Industrial Fund (DMIF), are devoted to production support in any case, and this effort is considered to be vital production support. All of the implementation effort has been in this category.

That is not to say, however, that other sources of funding have not been sought and used to expedite the process. Defense Environmental Restoration Account (DERA) funds were sought and acquired to purchase three ultrasonic cleaners of the type described in the section above titled CLEANING for use in the Center-s two Cleaning Centers. It is important to note, however, that part of the justification that helped the Center to acquire that funding was the effort it had already expended in its own behalf.

DERA funding has also been acquired to fund the two pending contracts with Battelle Memorial Institute discussed above, i.e. the development of a quantitative measurement of cleanliness and a thorough study of the corrosive effects of residue following RMA flux removal on assemblies which are subsequently covered with a protective coating.

6. Benefits

Many positive benefits resulted from the change to aqueous cleaning. One of the benefits was that process time was reduced for cleaning the parts. For example, cleaning of the gimbal rings was a manual operation taking about 15 minutes per ring. The aqueous process cleans 24 rings in 25 minutes.

The cleanliness of the parts has been at least as good as, and in some cases better than, the results from the old solvent based processes for cleaning. For example, the yields from the process used to refurbish precision bearing assemblies have increased from 25% to 65% for every type of bearing after conversion to aqueous cleaning.

The processes changed to the aqueous cleaning process have already had a significant impact on the use of solvents at the Center. The consumption of Freon 113 has decreased by over 30 gallons per day, and the consumption of 1,1,1-Trichloroethane has decreased by over 25 gallons per day.

The conversion to aqueous cleaning has been embraced by the workforce and by management. Using hazardous solvents is tedious and potentially harmful. Both technicians and management view the changes to aqueous processes as a positive improvement because exposure to hazardous materials is reduced.

Part of the improvement described above generated from the simple fact that for the first time in a long time, scarce engineering resources were devoted to the process of cleaning. This is an additional benefit of making such a drastic change to the way business is done. Drastic changes in any large industry will invariably require significant engineering resources, and engineering talent applied to any process on a large scale should result in improvement in the process.

CONCLUSION

The efforts at the Aerospace Guidance and Metrology Center have shown that processes using ozone depleting solvents for cleaning and other processes can be changed. It is interesting to contemplate that the changes, when made, result in improvements in the processes, product yields, and labor time. This has, indeed, been the case at the Center.

While many of the considerations addressed by the Center are focused toward its specific processes and management requirements, they should be applicable in general to any industrial activity addressing the elimination of ozone depleting solvents from its operations.