Using Aqueous Chemistry to Clean Aircraft Engine Tubing

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This paper chronicles the development of an aqueous cleaner that removes carbon, coke and fuel varnish from engine tubing, and will also describe the testing process to get its approval by the engine manufacturer and this presentation will describe the problem of removing carbon, coke and fuel varnish buildup in engine tubing caused by elevated temperatures, and describe the development of a cleaning chemistry that will remove the contaminants without damaging the tubing. The procedure for the cleaning process will be described.

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Introduction of a “new and improved” cleaning technique involves two distinct steps. The first is the development of a high quality cleaner and/or technique for the application. This would seem to be the main part of the process, but a second step is equally important. This involves the testing and acceptance of the new cleaner and/or technique. This paper chronicles not only the development of an aqueous cleaner that removes carbon, coke and fuel varnish without damaging engine tubing, but also describes the testing process required to get its approval by the engine manufacturer.

Over the years turbine engines have become larger, have developed greater thrust, and as a result have gotten hotter. The more heat around the tubing the greater the problem with buildup of carbon, coke, and fuel varnishes inside the tubing. The result is an unacceptable restriction in flow, necessitating periodic cleaning of the tubing. Even as this cleaning has become more necessary, the deposits have become harder to remove and the cleaning process has become both more difficult and more likely to damage the tubing.

At the same time this problem with cleaning of accessory components was becoming more serious, in Belgium there was a scientist working on developing a better, safer cleaner. Two main forces drove his research. First, there was simply a need for cleaners that were more environmentally friendly. Second, once the Montreal Protocol on “Substances That Deplete the Ozone Layer” was established in 1987, the interest grew from a “want” to a “need” for more environmentally friendly cleaners.

The solution to finding a product that would meet these requirements was to get away from petroleum and chlorinated products and create a cleaner based on water. This was not a new concept. The Ebers Papyrus, a medical document from about 1500 B.C., describes combining animal and vegetable oils with alkaline salts to form a soap-like material. While being quite environmentally friendly, these cleaners unfortunately were not particularly effective then or now.

It was clear that for effective aqueous cleaning a high-pH liquid would be required. The trick would be to figure how to use the very effective cleaning capacity of such a liquid yet eliminate many of the negatives attributed to caustic cleaners – such as health and environmental hazards and metal loss.

Another enhancement would be if the cleaner was a splitter rather than an emulsifier. The cleaner would thus be able remove contaminants without creating the emulsified by-products of traditional cleaners. As an added plus, the contaminants removed would also remain essentially intact, and should thus be relatively easy to remove from the cleaning bath. The result of this research was an aqueous cleaner with a pH of about 12.5 and a NFPA[*] hazard rating of zero for Health, Reactivity, and Flammability. The cleaner turned out to be very effective in breaking up the structure of petroleum base contaminants without attacking metals or other substrates.

The cleaner was thus developed, and what seemed to be the hardest task was accomplished. However, the next step was to introduce this product into the aircraft engine overhaul market. Unfortunately, this process is best described as "you can’t get there from here". The Catch-22 is that a turbine engine overhaul facility will not generally use a cleaner unless it has been approved by the engine manufacturer, and conversely an engine manufacturer will not approve a cleaner unless it has been tested on engine parts by an engine overhaul facility.

How could this stalemate be broken? In trying to get the new cleaner accepted – or at least evaluated – our strategy was to start in the middle and work in both directions. First we would have to complete required testing standards to prove the product's performance since we knew an engine manufacturer would not even

[*] National Fire Protection Association

look at a cleaning product until certain specific tests were done. Next we had to find a willing engine overhaul facility that had a unique cleaning problem and convince them to evaluate our product.

First we had the required tests performed. They are:

SAE ARP 1755B
Effect of cleaning agents on aircraft engine materials (Stock Loss Test Method)

ASTM F 519-97 Type 1A.1
Standard Test Method for mechanical Hydrogen Embrittlement Evaluation of Plating Process and Service Environments (Passive Chemicals)

ASTM F 945-98
Stress Corrosion of Titanium Alloys

We were confident that the product would meet these requirements, and indeed passing the required testing turned out to be the easy part. All it takes is money and time. It is, however, important to pick a testing company that is well known and respected in the industry. *

Once the testing was complete and the cleaner had passed the next step was to find an engine overhaul facility that would work with us, and an engine manufacturer to evaluate the effectiveness of our cleaner on actual engine turbines. This is by no means an easy task. You must convince someone that your product is truly better than any of the products they are already using, and even then they have to be willing to take the time and effort to develop a procedure, assign personnel and finally do the testing.

In our case we chose to approach United Airlines (UAL) because we had been doing business with them for over 30 years – providing them sealants and dispensing equipment – and had an established credibility with them. We made significant arguments about the desirability of the product; it is biodegradable, presents no hazards to employees, offers no hazards to substrates, and has no odor. The fact that the agent is a splitter rather than an emulsifier means that contaminants such as oil will float to the top of the cleaning bath for easy removal, meaning that the bath is not loaded with the contamination and thus will last much longer than traditional cleaners. However, even with this set of persuasive advantages, it was difficult to convince anyone to give us an opportunity to demonstrate the cleaner on actual parts. The first demonstration came when we had an opportunity to clean a Flame Arrester Assembly from a GE CFM 56 engine. This flame arrester operates at 1350ºF and becomes coated with coke and carbon from the exhaust gasses produced from the synthetic turbine oil vapors in the gearbox. The part cleaned easily without any damage to its metal structure. The second demonstration was successfully cleaning a Fan Blade Spacer off this same engine. This spacer is coated with five layers of molydisulfide and then baked. This part was also cleaned easily with no damage to the metal substrate and no degradation of the etched identification numbers, which remained easy to read. However, we were disappointed to learn that even though neither the Flame Arrester nor the Fan Blade Spacer had an approved chemical cleaning process at that time, there was still no interest in pursing further testing of our product to develop one for these parts.

Our next attempt to establish a testing and qualification process began with demonstrating the cleaning capability on engine tubing. A lubricant supply tube to the number 5 bearing was being removed from service because of restriction in the tube from coke and carbon buildup. The tube was examined with a borescope and it was almost completely blocked.

The supply tube was placed in an ultrasonic cleaner filled with our cleaner and cleaned for 15 minutes. After rinsing the tube, it was again examined with the bore scope and it was found that there was no residual coke or carbon remaining. Many UAL engineers at the demonstration felt that this cleaning process would solve existing problems and save money on parts that were currently being scrapped.

What is the current status? Now, one year later, a testing procedure has been established to evaluate the effectiveness of our cleaner on engine accessory parts. However, surprisingly none are the accessory parts included in our cleaning demonstrations of the Fan Blade Spacer, Flame Arrester, or supply tubing!

How does this testing and qualification process advance? At the time that the overhaul facility agrees to do the testing, the engine manufacturer will issue a six-month conditional letter based on the laboratory testing results. Alternatively, the testing at the engine overhaul facility could be done on their own engineering authority.

This testing procedure has three principle sections. The first test has nothing to do with the cleaner but rather it is to determine if ultrasonic energy has any negative effect on the part. The second test is to establish that there is no negative effect on the part from the cleaner, such as stock loss. The last test is to evaluate the effectiveness of the cleaner in removing the contaminants.

The testing procedures to be used in evaluating the new cleaner are as follows:
Requirements for testing:

- One new nozzle set (set includes: orifices, nozzles, restrictors, and visco jets.)
- Six sets of unserviceable nozzle parts
- Ultrasonic unit
- Chemical (our product) and (a competitor's new product)
- Access to a weighing scale
- Access to a 10X microscope
- Mechanical support for flow checking of parts

Testing stages:

1) Control Set (NEW PARTS)
    - Weighed and recorded
    - Crack check conducted and recorded
    - Ultrasonic cleaning (12 hour) **with water only** completed and recorded
    - Weighed after ultrasonic cleaning and recorded
    - Crack check conducted and recorded
    - Flow check conducted and recorded

   Note: Operating temperature for all ultrasonic operations is 49ºC (120ºF).

2) Control Set
    - Weighed and recorded
    - Crack check conducted and recorded
    - Flow check conducted and recorded
    - Ultrasonic cleaning (I hour) (with each chemical) completed and recorded
    - Weighed after ultrasonic cleaning and recorded
    - Crack check conducted and recorded
    - Flow check conducted and recorded

   Note: Control Set must be included in all other tests in the succeeding stages.

3) Unserviceable Set 1 (referred to in test data sheet as Used Set)
Weighed and recorded
Crack check conducted and recorded
Flow check conducted and recorded
Ultrasonic cleaning (l hour) (with each chemical) completed and recorded
Weighed after ultrasonic cleaning and recorded
Crack check conducted and recorded
Flow check conducted and recorded

Note: Unserviceable Set 1 must be included in all other tests in the succeeding stages.

4) Unserviceable Set 2/ Unserviceable Set 1/ Control Set
Weighed and recorded
Crack check conducted and recorded
Flow check conducted and recorded
Ultrasonic cleaning (1 hour) (with each chemical) completed and recorded
Weighed after ultrasonic cleaning and recorded
Crack check conducted and recorded
Flow check conducted and recorded

Note: For the following test, do not include the Control Set or the Unserviceable Set 1.

5) Unserviceable Set 3
Flow check conducted and recorded,
a) Ultrasonic cleaning (I hour)
b) Flow check conducted and recorded (If flow check fails retry with another set)
Note: If flow check is successful re-test using four more sets.

6) Unserviceable Set 4 / Unserviceable Set 1 / Control Set
Weighed and recorded
Crack check conducted and recorded
Flow check conducted and recorded
Ultrasonic cleaning (with each chemical) completed and recorded
Weighed after ultrasonic cleaning and recorded
Crack check conducted and recorded
Flow check conducted and recorded

7) Unserviceable Set 5 / Unserviceable Set 1 / Control Set
Weighed and recorded
Crack check conducted and recorded
Flow check conducted and recorded
Ultrasonic cleaning (1 hour) (with each chemical) completed and recorded
Weighed after ultrasonic cleaning and recorded
Crack check conducted and recorded
Flow check conducted and recorded

8) Unserviceable Set 6 / Unserviceable Set I / Control Set
Weighed and recorded
Crack check conducted and recorded

Flow check conducted and recorded
Ultrasonic cleaning (l hour) (with each chemical) completed and recorded
Weighed after ultrasonic cleaning and recorded
Crack check conducted and recorded
Flow check conducted and recorded

Evaluate data collected from testing.

The results of this test program will be reported in the conference presentation.

Summary/conclusions

Introduction of a “new and improved” cleaning technique involves far more than the development of a high quality cleaner and/or technique for the application. An equally important and potentially much more difficult step is the testing and acceptance of the new cleaner and/or technique. This step must be successfully negotiated or even a superior cleaner and/or technique may never be adopted.