

Removal of Fouling, Jacket, and Driving Band Deposition and De-Coppering of Cannon Barrels with a New, Automated, Sealed-System Bore Cleaning Machine

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FIRST SLIDE: USAF Photo, Boeing C-17 at McMurdo

This photograph has nothing to do with Cannon or Guns. Many of you recognize this to be a Boeing C-17. This one is at McMurdo station in the Antarctic. My Company makes the support devices which are in the foreground. We have delivered over 10,000 heaters of this type or another type to the United States Air Force.

NEXT SLIDE: USAF Photo, Fairchild A-10, side view

Now we are getting a little closer to the topic at hand. I am sure that all of you recognize this as a Fairchild A-10, which is armed with 30mm cannon. Once again, the equipment in the foreground is manufactured for the United States Air Force by my company – Polartherm Oy of Finland.

NEXT SLIDE: USAF Photo, Fairchild A-10, frontal view

Now we can clearly see the GAU-8 cannon of the A-10, which is close to my topic today, which is the cleaning of medium and large caliber barrels. This image, by the way, is something which I hope that I never see in the rearview mirror of my Volvo as I am driving home.

NEXT SLIDE: *Washington with Cleaning Rod and Barrel*

Advances in Ammunition Performance to improve terminal ballistics have in part been brought about by higher velocities which are accompanied by an increase in conditions of interior ballistics – resulting in increased deposition of fouling, jacket, and/or driving band material – which becomes sintered.

Advances in Artillery and Rapid Firing Cannon have been astounding – and yet the methods for cleaning Cannon and Gun Barrels have remained mostly unchanged for many hundreds of years.

Cleaning a fouled cannon barrel is a labour intensive task. To minimize the effort and time required and to increase the removal of deposits without wear or other harm to the bore - an automated system was developed in Finland over the course of the past ten years.

The system and the solvent were granted United States Patent Protection this past 27 December (US Patent (8,083,858 B2) and may now be discussed.

We will take a quick look at the equipment and then will come back and talk about the technology.

NEXT SLIDE: *155mm System in use (QUICKLY)*

NEXT SLIDE: *Medium Calibre System (QUICKLY)*

NEXT SLIDE: *57mm Brush Set (QUICKLY)*

This project began with our search for a solvent which would allow for complete removal of built-up and sintered fouling whilst at the same time not having any effect on Ferrous Materials such as Barrels, and also be suitable for disposal without harm to the environment. We focused on Aqueous, rather than Petroleum or Synthetic Solvents.

NEXT SLIDE: Table of Experimental Results – Solvent

First, a study was conducted to establish the current state of technology by evaluating industrial, military and commercial substances available for weapon cleaning and, especially, non-mechanical copper removal.

Over time, jacket or driving band material builds up, especially in the angle between Land and Groove, and the flame temperature and pressure of repeated firing causes a sintering process in which the metal fouling becomes a glazed material which is near impossible to remove via conventional cleaning. We chose to address this problem.

The University of Jyvaskyla, Finland, was tasked to collaborate in the development of a solvent formula to efficiently remove sintered copper with no detrimental effect to the barrel base metal.

The goal of the research was to identify a solvent that would have the following primary qualities:

- Ability to efficiently dissolve/oxidize Copper beyond solvents now in use
- Not harmful to ferrous metals
- Not toxic

Ammonia is known and commonly used for removing copper. However, storing and handling of ammonia is very hazardous. Thus, the research concentrated on **other substances** with copper oxidizing properties.

Five different potential chemical combinations were identified which could be made into aqueous solvents:

- Oxalic Acid Variations – which were rejected due to inadequate dissolution of Copper.
- Sodium Nitrite Variations - These solvents effectively dissolved Copper but produced toxic gases in the process and were thus rejected.

- Ammonium Carbonate, Ammonium Peroxide Sulphanate, Ammonia.
This variation was developed as a reference for maximum Cu dissolving capability. It is environmentally hazardous and has no practical use.
- Ammonium Peroxide Sulphanate, Hydrogen Peroxide, and DTPA.
These solvents were rejected due to inadequate dissolution of Copper.
- Hydrogen Peroxide, Ammonium Oxalate, Sodium Hydroxide.
This Aqueous Solvent proved to have the best Copper removal properties while not producing any harmful gases or wastes.

Fourteen variations of this solvent were tested before settling on one which is relatively weak in concentration and is buffered with the addition of Citric Acid.

NEXT SLIDE: Solvent No. 17

Solvent 17, consisting of Ammonium Oxalate, Citric Acid Monohydrate, Sodium Hydroxide and weak Hydrogen Peroxide proved to have the best overall performance. In later research, this solvent was further developed and proprietary ingredients to ensure removal of other fouling such as propellant residue and by-products of deflagration and to improve performance in ambient temperatures down to Minus 10 Degrees C.

The solvent currently in production use is the above “Solvent 17” in a 16% concentration in water.

Samples of Copper, Iron, Carbon Steel Zinc, Aluminum and Nitrile Rubber were immersed in the solvent in a laboratory vibration rack for a total period of 20 hours at various temperatures. Material losses from the samples were measured at 2, 4, 6 and 20 hours.

The best Copper and Zinc removal results were had with agitated solvent and no effect was had on Iron, Steel, Aluminium, or Rubber

The copper removal reaches a plateau after four (4) hours. This is due to the oxidized layer accumulating on the sample surface within the first 2 to 3 hours preventing the solvent from reaching the free copper beneath. In practical

applications with our barrel cleaning machines, the oxidized layer is brushed off constantly, exposing the otherwise insulated copper.

NEXT SLIDE: Main Principal and Components

Let us now examine how we put this Solvent to work in an automated sealed system.

Key to this system is that the Solvent itself is used as a HYDRAULIC FLUID causing a brush unit to reciprocate the length of the bore. This also assures that the solvent is always agitated or in motion and constantly replenished.

The main components are the PUMP, with control unit and solvent tank, the reciprocating BRUSH UNIT, and weapon specific Breech and Muzzle Adaptors which seal the system, allow pressure to be applied, and prevent leakage.

NEXT SLIDE: Simultaneous Chamber and Bore Cleaning

In most cases, there are actually two (2) brush units. The length and time for the chamber stroke is less, but the chamber brush travel is limited by the throat, which is as it should be.

NEXT SLIDE: Principle of Copper Removal

The action of the Brush Unit is somewhat different from conventional cleaning. In our equipment, the Brushes do not cleaning by scouring. Instead the brush action is only intended to remove the oxides as they form at the surface. Indeed, it is possible to use NYLON BRUSHES, and the same cleaning effect is had, but with an increase of cleaning time by 50%. The total cleaning time for a medium calibre barrels is from 20 to 45 minutes, depending on the choice of brush and other factors.

NEXT SLIDE: United States Patent

This is our new patent. As I said, this patent covers both the equipment as well as the solvent.

NEXT SLIDE: 155mm System in use

We will now look at some of this equipment in detail, which exists in versions from 155mm down through medium calibres to as small as 12.7mm or .50 calibre / half inch.

This is the system IN FULL OPERATION on a 155mm Gun. You can see the Pump and Control Unit in front of the Muzzle. The two Soldiers are merely leaning on the muzzle, taking a break. They are contributing nothing. The machine is programmed to do its work automatically.

NEXT SLIDE: Pump and Control Unit

This is a close up of the pump and programmable control unit with the covers removed. This also includes a filter system which removes particulate matter. Because this is a sealed system in which the solvent is continuously recycled, we are able to analyze the cleaning fluid to determine what has been removed. We did a field test in which twenty (20) rounds of 155mm was fired through a clean barrel, and we recovered 254 grams of elemental copper. Knowing the composition of the driving band alloy, we could extrapolate that up to the total mass of driving band material removed.

NEXT SLIDE: 155mm Muzzle Adaptor

NEXT SLIDE: 155mm Breech Adaptor

NEXT SLIDE: 155mm Brush and Drying Set

This is a collection of brushes and drying tampons for 155mm.

NEXT SLIDE: Medium Calibre System

This is a smaller version of the same system for medium calibre cannon. This happens to be a 20mm barrels from an M61A1 aircraft cannon. In these smaller calibres, the system has a motor driven reciprocating rod with four brush units, rather than hydraulic operation.

NEXT SLIDE: Close Up - Medium Calibre System

Here is some detail. In this smaller system – not being hydraulic - there is a pump which feeds fresh solvent into the bore at a constant rate, and then recovers the solvent through a filter system, which is also the case in the 155mm system. The next slide will show the solvent recovery tube.

NEXT SLIDE: Another Close Up - Medium Calibre System

During the development of this smaller system, 26 Barrels in 20mm which had been declared “unserviceable” were obtained from F/A-18 Hornet Aircraft, which are armed with the M61A1 Cannon.

These 26 barrels had been cleaned with the conventional methods, according to the standard protocol, using mechanical brushing.

However, even after repeated cleaning, these barrels did not pass inspection criteria and were declared unserviceable.

The 26 “unserviceable” barrels were cleaned for 45 minutes each in the automated system and then independently re-inspected at Depot as per the Standard Evaluation Criteria. Subsequently, 25 of the barrels then passed the inspection and were returned to service. What had been judged to be unserviceable bores, were in fact, only fouled to the point that conventional cleaning was no longer effective. **The newly cleaned barrels were well within standard and did not require replacement.** No new wear was imparted to the bores as a result of the cleaning and none was observed in the inspections.

NEXT SLIDE: 57mm Unit Details

This is a medium sized unit intended for Naval Guns, in this case 57mm. This is the pump and control unit, once again with the covers removed.

NEXT SLIDE: 57mm Hose Reels

These reels contain enough hydraulic hose that barrels may be cleaned in the gun – removal of the barrel is not required.

NEXT SLIDE: 57mm Set

This is the complete 57mm set including Breech and Muzzle Adaptors which seal the unit, and also both the Chamber and Bore Brushes.

NEXT SLIDE: Detail - 57mm Set

Here is some detail.

NEXT SLIDE: 12.7mm Comparison

These are two 12.7mm or .50 calibre M2 barrels which each had 500 rounds of M-20 APIT fired through them. The barrel on the bottom was cleaned for 30 minutes via conventional means with a Bronze Brush and so-called “CLP”.

The lower barrel was cleaned for 20 minutes in our system.

NEXT SLIDE: Indian Barrel Before

This is a Field Gun which has been thoroughly cleaned using the conventional cleaning protocol. I suppose that you can see the evidence of copper – and this is after thorough cleaning, without skipping any steps or being in a hurry.

NEXT SLIDE: Indian Barrel After

This is that same barrel – after an additional cleaning in our System, to which we have given the name CLEAR BORE.

NEXT SLIDE: More Research!

We have sold several of these and we are in the final courtship stage of a large order outside of the USA, but we are at the same time continuing our research. We are interested in cooperating with agencies who might let us conduct controlled tests of cleaning on barrels with a high round count. Please contact us if you have high round count or unserviceable barrels and you would not mind having them cleaned – we want the data as to what fouling is removed.

NEXT SLIDE: T&E Loan

We are also willing to let agencies conduct their own evaluation. We would be pleased to make a loan agreement of a medium calibre or large calibre system to a qualified agency for 30 days or more. Please contact POLARTHERM.

NEXT SLIDE: Contact Information

I would like to show you a very short film, this is less than two minutes. This is the complete cleaning of 57mm Naval Gun in which case the operators chose to remove the barrel. The film has been edited to show the installation of the system, a few cycles of cleaning, and the removal of the system and the drying of the barrel. While I start the film, I will give you our contact information.

ROLL FILM: *Cleaning 57mm Naval Gun*

RETURN TO SLIDES: *Questions?*

(While answering questions, advance to next slide with CONTACT INFORMATION)

NEXT SLIDE: *Contact Information*

Thank you for your time and attention.