Corrosion, wear and corrosive wear; the story of lubrication systems in large technology object storage and use

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My name is David Hallam; I'm currently Senior Conservator Research and Technology at the National Museum. That means that I'm in charge of our research programs and I'm also in charge of our technological conservation program. Before that I was Head of Conservation at Queensland Museum, and before that I spent 20 odd years at the Australian War Memorial and I love functional objects. I also like Volvos.

Now, recently, believe it or not, I bought an early Volvo. It was a 1974 Volvo, had very little mileage on it. It had only done 180,000 kilometers since 1974. It had been well maintained. It lived at Grafton. Now for those of you who are not from Australia, Grafton's a nice humid place. It sat for long periods between short journeys. The owner would take it out, take it for a short drive and park it in the garage again. It was always garaged and when I went to buy it I thought "Ripper - really original car!". And then I started reading through the documentation that came with it and I went "Oooo - this is going to be interesting". I got it ready for registration, put it through registration and started using it as my everyday car.

Surprise. It failed. All of the oil seals blew. Now, many conservators will tell you that this is an example of how use is damaging. Oh, but it were so simple. I have an even older Volvo. A 36-year-old Volvo. A very, very rare Volvo that has done 288,000 miles (that's 450,000 kilometers). It's been used regularly. It was owned by a pushbike-riding fanatic who only used this car when he was going to go on a long trip. So it wasn't used - and then he took it on a long trip. Then he parked it back in the garage again.

How many years would it take to do 450,000 kilometers in a museum maintenance program? 7800 years. Now, we're kidding ourselves if we believe our institutions will last that long. And my car's still going. Survival of the institutions is more likely to be the rate-limiting step to the preservation of my Volvo (in a museum) than wear.

The aim of this paper is to stimulate discussion. I'm not going to give you any answers, I'm going to give you some ideas of what we think are our answers. Most museum preservation practice has not really advanced significantly since the mid 1980s as far as technological object preservation goes. In Australia, most museum practice really came from chemical processing specifications that the National Air and Space Museum in Washington was using, and basically I shifted it across in the mid 1980's. It hasn't been modified much since then, but really I don't think our ideas on conservation have moved that much since then either. Working object practice in institutions is based on standard mechanical engineering workshop practice or migrated military inhibition practice. And again, it's not really been adapted to museums and long-term use of objects. We're still doing things the way we would in a garage, or in steam workshop – again we really have not progressed.

Our aim should be to find the rate limiting steps for maximising use and preservation. We believe that our conservation practice should be based on:

- an assessment of the relative risks of wear and corrosion in the museum's storage environment;
- an assessment of the risks associated with application of a maintenance program to the collection as a whole;
- the risks associated with the use of an individual object.

You need an assessment of the risks associated with the application of a maintenance program to the collection as a whole. Now, it took 15 years or so to get the maintenance program for the Australian War Memorial up and running, and congratulations. Why did it fall over before? Because there were too many risks to it and what Alison's[1] done is taken administrative steps to remove those risks. It's a great step forward.

You need to look at the risks associated with the actual object. Standardised plans for treating objects are great just so long as they're not used as blanket treatments. A race car engine is going to need totally, totally different preservation to my Volvo.

The other thing we really need to push is - in cultural institutions we acknowledge Aboriginal objects, we acknowledge how Aboriginal culture should be taken into account when dealing with those objects. When it comes to engineering culture we totally forget about it. It doesn't exist. We really need to concern ourselves with engineering culture - what do the engineers, what do the people who own those objects, the elders of that area, what do they want done with those objects? And this is something I think conservators don't do very well at all. We ignore the engineers. "Oh, they're just mechanics." Engineering is a science, every bit as complex as chemistry. We need to accept it and embrace it and bring it on board. This is why I believe an understanding for conservators of engineering and wear in museums is really important.

Mechanical engineers will tell you that the best way to preserve a mechanical system is to keep it operational, operated and maintained and I think they are right. But we can do even better by applying some conservation practice.

What are we conserving?

- Conservation of Form
- Conservation of Function
- Conservation of both Function and Form
- Rare trades and skills.
- Smell, movement and vibration.
- Passion, memories and feelings.

[1] Alison Wain Manager, Textiles, Technology and Objects Conservation, Australian War Memorial

You’ve got to conserve the lot.

Figure 1: Bean car arriving at the National Museum of Australia under it’s own power in 2000.

<u>What is the functional life span of the object?</u>
This may be three hundred years or only a decade. The key is to recognize the point at which wear and repair becomes desecration of the original. At some point it becomes better to preserve the original and create a replica for use. If you replace or repair enough of an item it is no longer the item you set out to preserve.

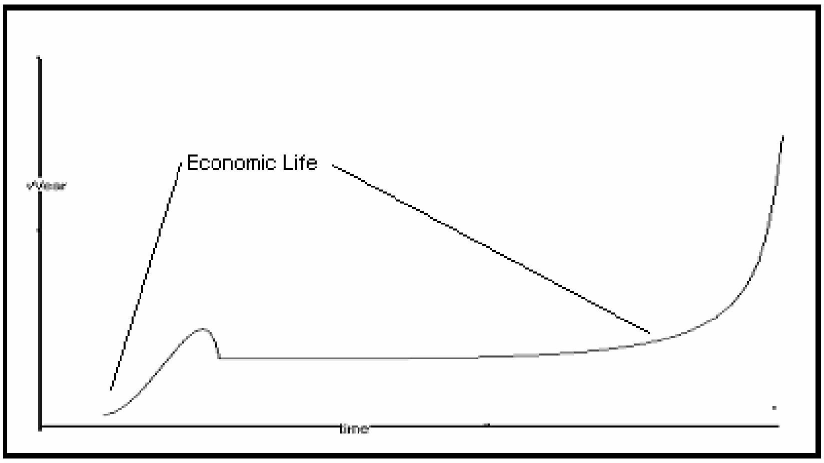

Figure 2: Diagram of life cycle of machinery.

Figure 2 shows wear on the vertical axis and time along the horizontal axis. Basically, if you have an engine, you'll get a little bump in the wear line when the engine is first run in, then the wear will stay pretty flat. This is the period of the economic life of the engine. Then, as the thing eventually starts to break down and reaches the end of its economic life, you get a great increase in wear. You'll get this for the object as a whole and you will get this for the components of the object. What I'm talking about is the preservation and use of the object while it is within its economic life.

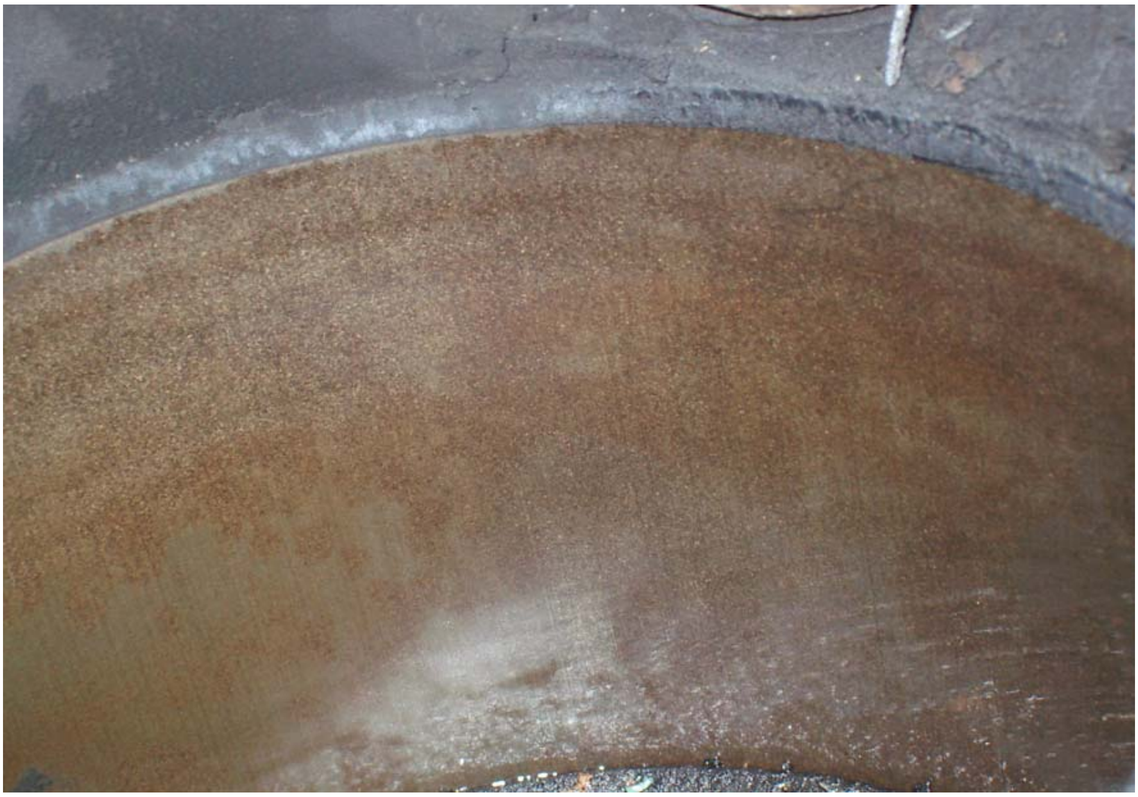

Figure 3: Rust on the inside of a cylinder in an engine from the National Museum collection.

Okay, I said I was going to talk about corrosion, corrosive wear and wear. What's this funny thing called corrosive wear? Anyone know who Ricardo is?

Basically Harry Ricardo[2] is an engineer, a very famous one. English engineer, did a lot of experiments on lubrication and fuels. Was really interested in what happened when an engine fired - what happened inside the cylinders - and was trying to work out how wear occurred. He was really, I suppose, in a way one of the first real tribologists, which are people who study wear. He realized that lubricants covered the inside of a cylinder, but

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[2] Ricardo, Harry R. "The Ricardo Story The autobiography of Sir Harry Ricardo, Pioneer of Engine Research" 2nd ed Society of Automotive Engineers Warrendale, PA 1992 isbn 1-56091-211-1

he couldn't work out what actually was happening in there and was trying to develop an engine which you could actually look inside and stop suddenly. And then one day one of his experimental engines blew up and the cylinder flew off and hit the roof and came down and landed and smashed into pieces and he could actually see where the piston had been, and he could see instantaneously a corrosion ring formed. What had happened was the explosion from the fire from the propellant had burnt the oil off and literally caused an instantaneous layer of rust to form on the inside of the engine.

Now, this is something that we don't actually see happen in modern engines. We don't get corrosive wear in modern engines basically because the fuels we use today are quite different (they're not nearly as acidic), and because the lubricants that we use have a much higher film strength and literally bond to the metal surface inside the engine.

Figure 4: Corrosive gel on Volvo rocker covers after an engine has been run without coming up to temperature.

What we do get in modern engines is corrosion, and this is because quite often what we do with an engine is we drive a vehicle into a storage area and switch it off, turn off the fuel and walk away. We're left with all the acidic residues and the moisture from the firing inside the cylinders, and the oil that's there is really ineffective as a long term, protective coating. Oils are designed to be lubricants, they are not designed to be a coating and we end up with corrosion. The moisture and oil form literally a mayonnaise. This is what happens when you use a vehicle and you only use it for a very short time.

I’ve talked about wear and how long a vehicle would have to operate in order to wear itself out. A much worse thing that can happen, and happens often inside a museum, is corrosion and it really damages vehicles. It’s probably happening in every museum we know of, it’s avoidable, and I would almost say it’s criminally neglectful.

Figures 5 and 6 show our Land Rover. It’s done 3,802 miles since 1958. A thousand of those miles have been done in the museum service. It’s been filled with a standard lubricating oil. The lubricating oil has been changed about every year. Last time it was used, it was used for the royal tour. We were starting a maintenance program on it and we thought “Well, we’ll whack an introscope down and see what’s happened inside it”. It had sat for about two years.

Figures 5 and 6: Corrosion inside the National Museum Landrover cylinders

You can see there the corrosion. If we had kicked that engine over, what would have happened? The piston would have gone up and scraped the corrosion off. What’s corrosion? An oxide. What are oxides used as? Abrasives. What size are they? Very small - small enough to go through the filter. So what you’ll end up with is this very fine abrasive slurry, that won’t be picked up by the filter, rotating round and round inside the system. And that’s exactly what happened with my Volvo. I ended up with this nice abrasive slurry and it went through and it ripped out all of the oil seals and did a whole lot of damage.

In the museum, if we had kick started the Land Rover, the same thing would have happened. Okay, how have we overcome that? We use nothing but inhibited oils, we don’t use any standard lubricating oils in our institution.

Why did we come to this conclusion? We’ve come to this because we’ve actually done some product testing. We tested the oils as coatings not as lubricants. We intend over the next year to do a whole lot more product testing of oils as coatings We’re also going to be doing some work on maintenance cycles because we don’t know whether the maintenance cycle for that Land Rover with an inhibited oil in it should be one year, five years or ten years.   And that’s going to make a big of a difference to our planning cycles. We’re also trying to work on a concept of what we’re calling Just Noticeable Wear and I’ll talk about that in a little because one of the things we want to make sure is that our thoughts on automotive preservation are spread wide and to that end we're currently working on a manual for museums.

I talked about research, here's something that people might be interested in. We've actually been doing some oil testing using Electrochemical Impedance Spectroscopy (EIS).

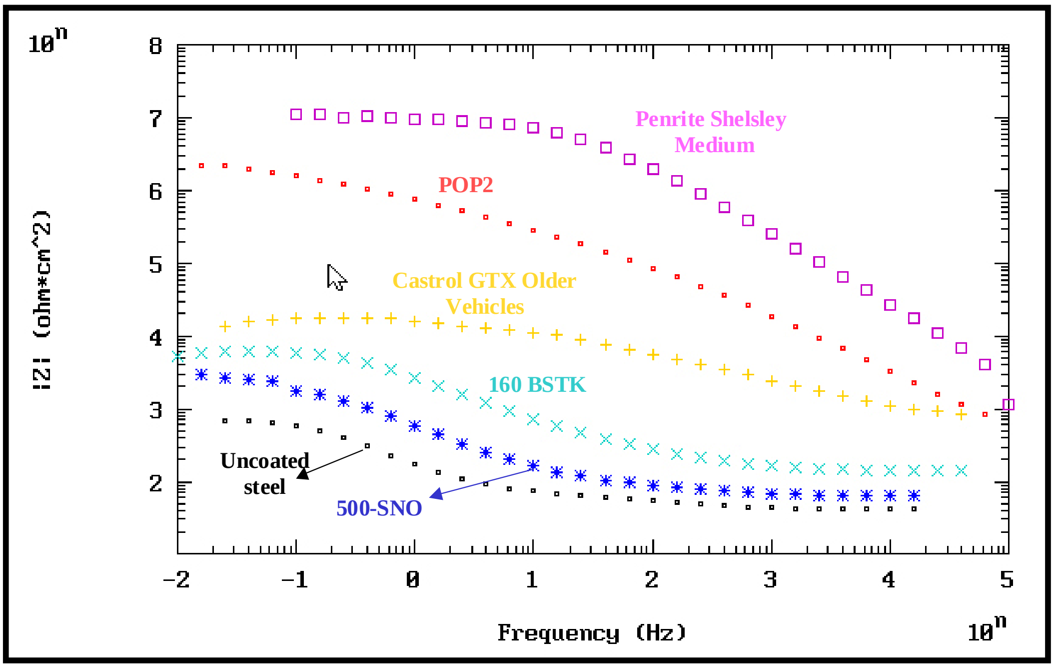

Figure 7: EIS spectra for various engine oils.

From bottom to top this shows:

- a piece of uncoated steel with no oil - that's the resistance it produces, it's a bit rough, corrodes reasonably easily;
- a piece of steel coated in a lubricating oil;
- a piece of steel coated in a base lubricant - a lubricant that has no additives in it (the same base that is used to make up the next oil);
- a classic vehicle oil, gives a little better corrosion protection;
- an inhibited oil formulated specially for us by Penrite - gives good protection;
- a Penrite inhibited classic vehicle oil.

Now the fascinating thing about this is the difference between the uncoated surface and the protection given by the most protective oil is ten thousand times. So we can say that this particular oil is several thousand times more protective than some of the least protective. That's quite an amazing amount. So just by using this kind of oil (and it doesn't have to be this particular brand) - an inhibited oil - we're getting massive amounts of protection, and this can totally change our maintenance plan. We've obviously also done salt spray tests and other kinds of tests on oils as coatings, and we're going to be continuing this over the next two to three years.

One of the other things we're trying to develop is a concept which we've taken basically from paper conservators. Paper conservators at the Victoria and Albert, when they display something, talk about Just Noticeable Fade and we're trying to get this concept into functional objects so we can talk about Just Noticeable Wear (JNW). We don't know yet exactly how it's going to work, but we want to be able to quantify the wear of objects and actually talk about what lifetimes we can get out of them, so that we actually know the rate of degradation that they're undergoing.

How should we be carrying out any running?

- warm start;
- run all systems up to full working temperature;
- run for a minimum time (30 minutes?) at varying load;
- dehumidify systems on closedown.

Okay, this is what we use in the museum and what we recommend other people use, and this is how we currently believe people should be running objects in museums. Notice that we're dead against running anything for a **short** period of time. We believe that things should be started warm, run for long enough to achieve full working temperature and stopped in a dehumidified environment. And they should be run under a varying load. We're currently investigating getting a dynamometer for our museum, so we can run them without actually leaving the building.

Maintenance is the core to everything. A program of structured maintenance is likely to substantially improve the probability of a mechanical object's survival, as the deterioration from wear and corrosion during controlled continuous use and maintenance cycles can be substantially less significant than the damage caused by neglect and periodic, interventionist rebuild cycles.

We've heard people talk about costs of maintenance. We believe that periodic running and maintenance is very cost effective. We estimate that a stable, running, 1930s vehicle, using appropriate inhibitors costs $500 a year to maintain for materials and labour. It's not really that much money. In principle, most functional objects are best preserved by preserving their ability to function and using that to conserve them. That's the only way you can get inhibitors inside for instance. This does not mean that they must be constantly functioning, or operate at maximum capacity. Mechanical objects should preferably be preserved in a state capable of operation, regardless of whether that operation happens once a day or once a decade.

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