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Preservation by Operation: Experience of the Restoration and Operation of Large Stationary Steam Engines and the Implications for the Professional Engineer.

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SUMMARY: *Restoring a superseded large stationary steam engine to an operational condition for educational and entertainment reasons is an attractive proposition to many, including professional engineers. Yet there are many problems in adapting such machines to work under off-design conditions in the context of a voluntary group in the culture of 21st century safety and responsibility. This paper discusses the experience gained over thirty five years at three such museums in London. In particular, the need for careful appraisal of how the engine will behave in its new role, the requirement to carry out the work within conservation guidelines, and the problems of maintaining and operating the engine after restoration is complete are reviewed.*

KEYWORDS: *steam engines conservation restoration risks*

1. BACKGROUND

Over the last 40 years many stationary steam engines have been the target of restoration projects. The sight of a stopped engine excites something irrational, even maternal, in the minds of engineer and non-engineer alike. Let's get it working again!

Today I want to consider this phenomenon, what it has achieved and, in particular, the rewards and hazards of being involved from the point of view of the professional engineer, that is, somebody with chartered status who, perhaps, should know better.

The views expressed in this paper are entirely my own and I am only talking about enthusiast run sites.

There are quite a few such sites in the UK running large stationary engines for pleasure. Most are water pumps, some are mill engines, a few are steam winders. Altogether 25 of them are demonstrated in steam on a regular basis.

At Kew Bridge Steam Museum there are five non-rotative Cornish cycle engines still in their working positions, with cylinders 64, 65, 70, 90 and 100 inches in diameter. Four have beams to connect the steam piston to the pump ram, the other is a “Direct-acting” or “Bull” type engine with the piston and pump ram on a common rod. There are also four large rotative water pumps brought in from other sites.

As long ago as 1932, the Metropolitan Water Board (MWB) discussed preserving the Bull engines at Hampton. It didn't happen, but the seed was sown. It is not surprising that the nest of Cornish engines at the Kew Bridge Works was earmarked for preservation when the steam pumping plant was replaced during World War II by centrifugal pumps and electric motors.

Figure 1. *Cornish engines at Kew Bridge, London*

The senior engineers behind this had no intention of allowing the Cornish non-rotative engines to be run again but the restoration team that arrived at Kew Bridge in 1974 had other ideas and brought the 64 inch (1600mm) engine of 1820 by Boulton & Watt back to life in 1975, followed by the 90 inch (2300mm) cylinder diameter engine of 1846 only nine months later. This team had cut their teeth restoring the 1812 and 1845 Cornish cycle beam engines at Crofton on the Kennet and Avon canal. These two are low-lift pumps which still perform the same task today. In July this year the replacement electric plant completely failed and for three days the early 19^{th} century steam pumps fulfilled their original purpose, not only filling the head reach of the canal but the coffers of the engine trust as well!

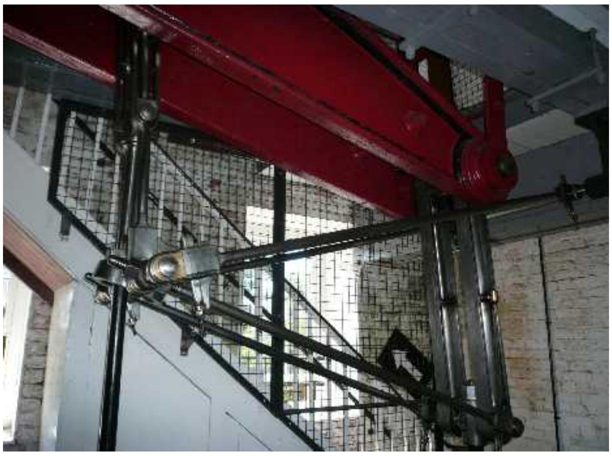

Figure 2. *Engine at Crofton*

Thames Water (TW), as successors to the MWB, were landed with a problem when their pumping station at Kempton Park was designated as a National Monument and they were required to keep and maintain the building and its contents. This plant was in service till 1980, having been commissioned in 1929. It contains the two largest triple expansion engines ever built in the UK plus two turbine-driven centrifugal units. The engines are 62 feet (18.9m) high and are fully visible when entering the building. The impact of their size is unforgettable. Each engine weighs about 800 tonnes and is probably the most sophisticated reciprocating steam engine ever built, certainly in the UK.

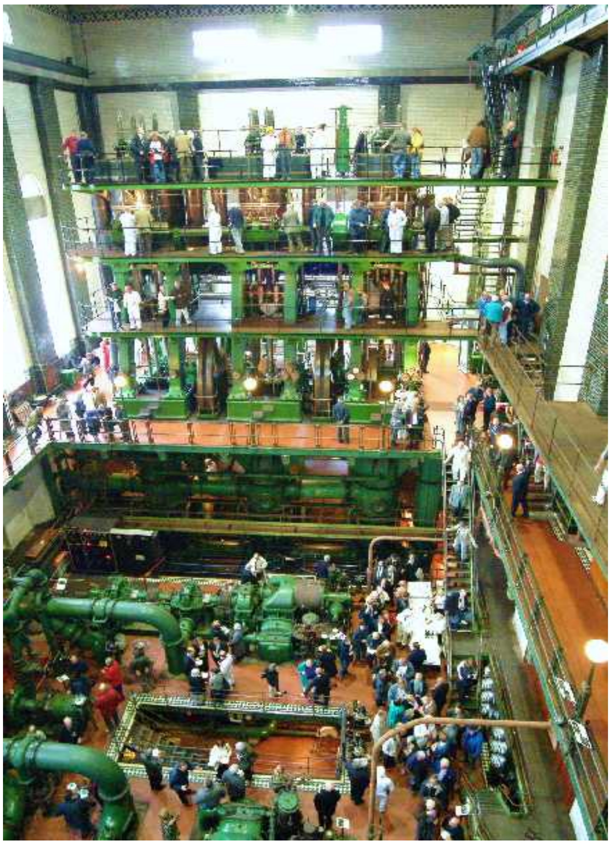

Figure 3. *Kempton Park engine*

TW decided that operation was the best way forward, agreed to provide steam and encouraged the formation of a new team of volunteers under the leadership of a very small group who had learned something from previous experience at Kew Bridge and Crofton. Their expertise was focussed on finance, fund-raising, legal agreements, insurance and the like. The technicalities of the engines appeared to be straightforward and there was no shortage of people wanting to be involved in that aspect. Discussions began in 1993 and one engine made its first revolutions under steam in its new incarnation in 2003.

All the restoration projects described have been a success, in that all the engines appear to the layman to be pumping as they always did. But each project has become more difficult, the constraining factors more demanding and the end result perhaps less overwhelming than before. Has the end of the road been reached?

There is one engine at Kew Bridge that has not yet been touched. It is the 100 inch engine; that is, the cylinder diameter is 100 inches, easily converted to 2540 millimetres though the accuracy to the last 10 millimetres must be doubtful. The stroke is around 11 feet (3.35 metres). It was last in steam in about 1957.

Figure 4. *Kew Bridge 100" engine*

There was a formal debate at the museum in June 2009 to bring out all the reasons for restoring, or not, the 100 inch engine. It was most illuminating that the enthusiasm of the "let's do it now faction", about half the audience, had waned considerably by the time they had considered the whole question objectively. Only six people still wanted to go ahead soon, 27 now wanted to preserve the engine as it was, but not to do any of the irreversible work that would be necessary to get the engine moving again.

This more down-to-earth approach stems from many factors which can be included under several headings

1. **Conservation**: The engine must be modified if it is to be steamed.
2. **Design standards**: Is the machine safe by current standards?
3. **Adapting the Design**: Operating conditions will be very different from those of the original design.
4. **Operation and maintenance**: Will well-meaning amateur enthusiasts cope safely?
5. **Risks and responsibility**: Who will take the blame when the accident occurs?

So why are we trying to run these engines? Have we a real purpose? Or are we just having a bit of fun with our big toys? If it is the latter, should we be doing it? Are the risks, the costs and the effort (usually unpaid) justified? Before engineers rush to start work, some of these points are worth thinking about.

2. CONSERVATION

Few would disagree that the best way to conserve large steam engines is to get them back into working order and run them.

With the exception of the canal feeders, these engines can only be run if they are modified – principally to reduce fuel consumption to a manageable cost and to avoid problems with disposal of the output. They must have any asbestos removed (encapsulating the material is not really an option in a public venue), they must use modern packing and jointing materials and they must be fenced off. The result is no longer an authentic experience of the conditions that the engines were used in.

Guidance is readily available on how to approach the conservation of a machine and what should or, more importantly, should not be done when designing the adaptation necessary for safe operation in a museum mode. If funding is to be obtained from State sources, or even from private philanthropic bodies, a knowledge of the principles is important. It is only too easy for an application to be rejected because of some transgression, probably brought about by over enthusiasm to do a thorough job. Based on my fairly extensive contacts amongst those responsible for restoring and operating steam plant, I fear that few are as aware as they need to be of the background and structure of "the business".

At international level there is "The International Committee for the Conservation of the Industrial Heritage", generally known as TICCIH. At their meeting in Russia in July 2003, the delegates agreed on the Nizhny Nagil Charter of the Industrial Heritage. Although this is at very high level, with connections to UNESCO, national and local bodies will take their tone from this international body.

Under "Maintenance and Conservation" the Charter states that "all interventions should be reversible and have a minimal impact. Any unavoidable changes should be documented and significant elements that are removed should be recorded and stored safely".

Most of the restorations at Kew Bridge predate this Charter and there is very little record of what was done. A significant amount of the work was irreversible. Here is the cast iron steam supply pipe for Kew Bridge's Bull engine which had to be replaced in steel to meet modern insurance requirements. The discarded pipe is neither protected nor interpreted.

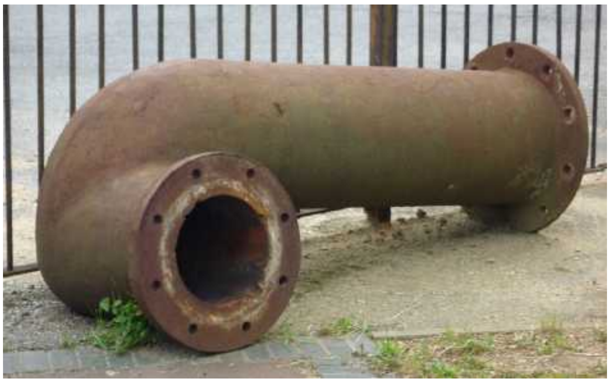

Figure 5. *Kew Bridge steam pipe*

Operating elderly machines also runs the risk of considerable damage. In the UK we have an engine of the Newcomen type, built in 1795 and still in its original engine house though much of the engine itself is not original. It is a very significant engine and was at work till 1923 when it was preserved by the mine owner. In due course it became the property of the National Coal Board who arranged to steam it, reputedly for a visit of the Newcomen Society, in 1953. It was mishandled and suffered a severe over-stroke which damaged the base of the cylinder. No attempt has been made to repair it and it is now in the hands of the local authority, seldom available for viewing and showing signs of neglect.

Restoring a steam engine to a working condition involves a clear understanding of the constraints and risks if a satisfactory compromise is to be reached.

Although not a museum engine, Figure 6 gives some idea of the forces involved when a Cornish non-rotative engine gets out of hand.

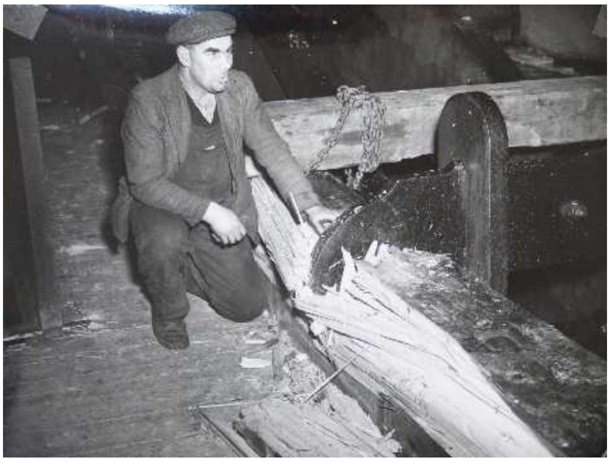

Figure 6. *Smashed spring beam*

3. DESIGN STANDARDS

Kew's 19th century Cornish engines are made of cast and wrought iron, with some parts of brass or bronze. By 1820, Boulton and Watt had a long track record of making such engines with 40 years of experience to draw on. But the use of cast iron for the beam was less than 20 years old, forced on them by the cost of timber.

The two halves of the beam look right, but what design calculations were used? Were they just laid out on the foundry floor by the Head Moulder according to his eye and instinct? I can find very little evidence of real stress analysis or component testing in the 19th century. The evidence given to the enquiries into the Hartley Colliery disaster in 1863 (204 dead) and the Tay Bridge in 1879 (75 dead) are remarkable for their lack of information on how the failed cast iron components were designed and then tested both during and after manufacture. Coincidentally, there were failures of cast iron beams at Kew Bridge in both 1863 and 1879.

Figure 7. *Maudslay beam*

Until 1879 the only beam failures were due to overstroking and impact. One beam half fractured on the now scrapped eastern 1820 Boulton and Watt engine and was replaced in 1863. From photographs it appears to have been a like-for-like replacement. This was not the policy adopted in 1888 when a similar accident befell the 1838 Maudslay engine. This time the replacement half beam was twice as thick as the original. So somebody must have had doubts about the strength of the beams though the accidental cause of these breakages was clear.

When a half beam on the100 inch engine failed in 1879 after only seven years service there was no apparent cause. The crack started in the top flange, close to the centre of the beam, developed through the web and had reached the lower flange when it was spotted and the engine stopped, fortunately without any serious consequences.

The repair consisted of holding the cracked parts in position by a light doubling plate and enclosing each half beam in a system of wrought iron bars with a bridle. The bars were tensioned to put the cast iron into compression by flogging up cotter bars in the joints. One of the fire welds on the wrought iron bars failed three years after installation and this too was repaired. The engine ran like that for a further 63 years under full load.

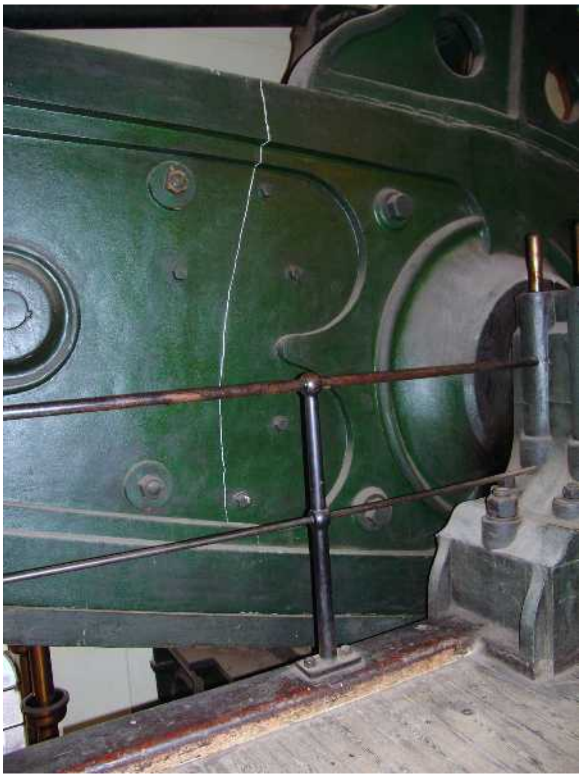

Figure 8. *Crack in 100" beam*

Now the debate is whether this engine should be restored simply for the education and entertainment of visitors, and for the gratification of those who will undertake the work. The engine had been tested under load for 63 years, and this load will be substantially reduced for museum operation. "What's the problem?" is the normal reaction. Technically, there isn't one, yet I personally feel uneasy about putting this beam back into service, even in museum conditions. How do we know the crack is arrested? Are there any other cracks or stress raisers in the beam? Is the wrought iron trussing effective? The evidence of the strain gauge test on the 90" engine's beam is that the wrought iron system has long since relaxed and is not applying any compression forces.

These questions can be tackled but at what cost, both in cash and in damage to an historic artefact? The fact that the engine ran for 63 years in this condition is history itself. The suggestion, which has been made seriously, that it be welded, or a metalock repair applied, is just not a starter.

Similarly, there are parts in the engine which are subject to steam pressure. These parts cannot be pressure tested. They must be inspected, but even on such a large engine, access is difficult and dismantling is not easy. The cylinder is secured within the steam jacket by a rust joint. Removing that without damage is a task well beyond volunteers. It is known that the 90 inch engine was put back into steam in 1976 after being cold for 32 years without any real attempt to check these aspects out. Can this approach be used on the 100 inch in 2010? I doubt it. Perhaps relief valves should be installed - but that would immediately destroy the historic integrity of the engine.

The debate continues, but restoring this historic machine, now 140 years old, as with any other 19^{th} century engine, should be given some basic thought. It is not wise to assume that all will be well simply because the engine used to be satisfactory in the privacy of a publically owned water supply organisation which, as a State body, was not even formally subject to the Factory Acts.

4. ADAPTING THE DESIGN

Apart from the canal feeders at Crofton and Cromford, no other large preserved stationary engine in the UK is, or can be, operated under its intended design conditions.

There is the cost of fuel to consider. To raise steam in Kew's Lancashire boiler, warm the system and engine up, and run the 90 inch engine for 20 minutes, currently costs £195 in gas fuel. That means 24 paying visitors have to arrive before the cost of the fuel is covered for this engine alone. There are also the usual overheads for lighting, insurance, maintenance (engine and building), domestic costs and some paid staff to run the business side of the Museum. The Museum buildings are Grade I listed and these have to be repaired to traditional standards from one-off grants and income. The damage to newly overhauled roofs, fettled with valuable lead irresistibly attractive to thieves, must be made good as the museum has just discovered. It is not cheap to play with big engines and only too easy to find that the resultant entrance fee is more than the general public are willing to pay.

A Cornish type non-rotative beam engine must have a load. It is the only way to control the rate of descent of the pump plunger. But this does not mean that the pump needs to generate a full head and nearly 50% of the weight has been taken out of the balance box. As well as reducing the steam consumption, the lighter weight reduces the tensile stresses on the cast iron beam and the wrought iron piston rod. The downside is that the engine becomes much more sensitive to handle since the vacuum is now the dominant force on the piston. An unexpected improvement in vacuum can easily lead to an overstroke and impact on the catchwing blocks. It has been done on a number of occasions - so far, without damage, but the impact of stopping around 40 or 50 tonnes of elderly cast and wrought iron by hitting a couple of wood blocks is unpleasant for the driver and visitor alike.

The big engine at Kempton Park has brought these issues to the fore. The engine/pump unit is complete - after all it is still on its original site - and the intention is to run it exactly as it was in service. There is, of course, no place for the pumped water to go. In working days it carried the waste heat away to the reservoir. Nowadays, the water is recirculated, but only a limited temperature rise can be allowed because the cast iron condenser shell is firmly located between the solid concrete wall of the pump house and the bedplate. This calls for careful monitoring.

The greatly reduced flow of steam through the engine raised unexpected problems. The inlet and exhaust valves in the cylinder covers are of the spring-loaded poppet type, actuated by tappets and push rods from the camshaft. When working, the engine took steam at 200psig (14 bar) with a superheat of 150ºF (80ºC) and the exhaust steam from the HP and IP cylinders was reheated by live steam in large receivers on the back of the engine. The power generated was a mere 1008 water horse power (750kW). The design discharge head was 400 feet (120m); now it is about 20 feet (6m). In current practice, the exhaust from the HP cylinder is about atmospheric, from the IP it is about 22 inches of vacuum (0.75 atmosphere), the best that can be raised. The designed timing of the closure of the LP exhaust valve was set far enough before dead centre to build up a compression pressure approximating to that in the IP receiver so that when the inlet valve opened, there was a smooth flow of steam into the cylinder. At the very low steam flow required for museum operation, the whole balance has been upset, resulting in the inlet valves being pushed off their seats by internal pressure and closing with a loud bang as the pressure escaped. The solution has been to gag open the inlet valves on the LP cylinder

The result of this is that 21 tonnes of piston, crosshead, connecting rod, pump rods and the ram is being driven up and down by the crankshaft. All the designer's careful balance of forces has been lost and the loads on the bearings have been increased by a factor of three or four.

These bearings are substantial. The journals are steel, the bearings themselves phosphor bronze. Lubrication is of the hydrodynamic type. The bearings should take the load but the slightest disturbance of the oil film results in severe problems which have led to cancelled steamings, much hard work and considerable expense.

The first to suffer was the main crankshaft bearing supporting the over-hung LP crank. Smoke appeared and friction slowed the engine. It was relatively straightforward to inspect the top half but the load carrying lower half could not be so easily accessed. Maintainability was not a factor in the engine designer's mind in the 1920s!

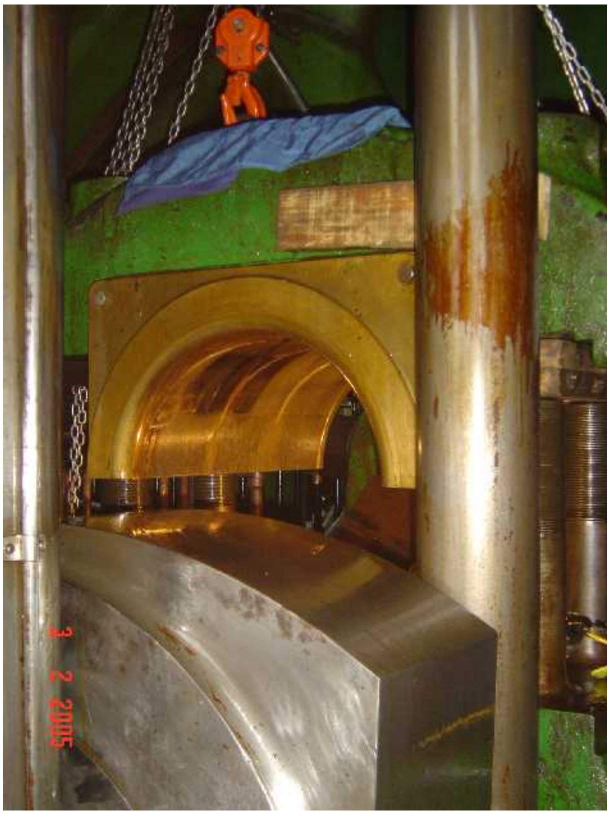

Figure 9. *Kempton engine main bearing.*

Eventually it was accepted that the lower half of the bearing would have to come out. This meant bringing in a contractor who built a frame with rolled steel joists so that the crankshaft, the LP cylinder running gear, and the flywheel could be lifted with hydraulic jacks just sufficient to take the load off the bearing. After lifting the shaft, it took a complete day to turn the bottom half of the bearing out of the bed plate. No serious damage was found and the journal and bearings could be cleaned up by hand stoning and scraping. A long and tedious job, One interesting aspect of all this was that the drawings showed that all the load carrying halves of the crankshaft bearings had oil grooves cut in them. When the bearing was finally removed, it was found to be plain. Written evidence in Worthington-Simpson's archives shows a request from their erection engineer for a new bearing and crankshaft lifting gear during commissioning. Conventional wisdom is that the load carrying capacity of hydrodynamic bearings of this type is reduced by the presence of oil grooves and this would account for the replacement bearing being plain. There is no record of further problems with this bearing during the engine's working life.

To minimise the risk of dry pick up after the winter lay-up, and reduce the time required to build up the hydrodynamic film during the frequent starts that the engine is now subject to, a horizontal drilling was put through the bearing shell at the six o'clock position with an outlet in the middle of the bearing. Prior to each start, oil is pumped in with a hand pump.

This has worked so far and there has been no further problem with the main bearing. It has simply shifted to the crank pin bearing!

During a test run in March 2009 prior to the start of the season, this bearing showed signs of distress; smoke and rapidly rising temperature. It was necessary to get another jacking system in to lift the weight of the piston, crosshead, connecting rod, pump rams and rods off the pin to allow both half bearings to be inspected.

Figure 10. *Kempton engine crankpin bearing.*

In spite of repeated scraping, adjustments, and opening up of clearances, this bearing is still overheating. It may have been damaged by rather complex factors, including too much adjustment by scraping. The engine is still being demonstrated with care, and slowly, with the bearing being monitored continually with thermocouples, but much more work, and thought, is required for this coming winter.

It is clear, from this experience, that restoring large stationary steam engines to run in museum conditions requires a great deal of understanding of the engine design. It is not just a matter for the cleaners and fitters!

5. OPERATION AND MAINTENANCE

It is comparatively easy to get a team together to restore an engine. Projects will go through the usual phases, starting with enthusiasm, descending to weariness, despair, the falling away of all but a hard core and eventually, for most projects, of reaching a triumphant conclusion. Assuming all is well and the project reaches its triumphant conclusion, what then?

Most teams, in their euphoria, look for the next engine to tackle. In the meantime, there's the recent project to run, to clean, to maintain, to cherish.

At Kew Bridge it was decided from the beginning that the museum should be open and in steam every weekend. As time went on, and more engines added, the burden on the volunteer drivers became greater. A significant number of today's drivers started over 25 years ago and it is a tribute to them that the place is still open. Many are now in their mid-seventies and older. The museum is not fighting off candidate drivers nor are there enough resources to clean and maintain the engines to the standard the old engine drivers kept in working days. The training and time commitment is a turn-off for all but a few. Perhaps a system of giving certificates to drivers setting out what engines they are passed out on and whether they are qualified to take on trainees would give some structure and reward. I have long advocated this, but it remains a good idea that might be adopted - one day. Evidence from aircraft restoration groups suggests that volunteers welcome having a log-book setting out what they can and can not do and what they have achieved. Similarly the steam locomotive support groups, so essential to the main-line operation of steam in the UK, are trained and documented. The stationary engine movement is a long way behind but it may be that some such recognition will provide an incentive to train and stay.

Insufficient training can lead to damage. There is a case for a pre-start routine and checklist being insisted upon.

Figure 11 shows the results of a careless, or inadequate, warm-up procedure on a 1910 rotative engine. And the rate at which an engine without any remaining pumpwork will accelerate requires sensitivity and anticipation in handling the throttle.

Figure 11. *Cracked LP cylinder cover*

The non-rotative engine requires close control in starting and throughout the run. There are no flying balls to keep it within bounds and clear of the blocks. Yet the driver has also to be the face of the museum, the one person that the visitor can relate to. Having the charm and patience to master this aspect is essential. Usually, it is a very rewarding experience, but occasionally the really dumb question, the Smart Alec or the nice but boring old boy with his reminiscences, can try the patience. And throughout, the driver must be aware of the length of stroke, any change in the vacuum, the boiler pressure and the whereabouts of any over-adventurous visitor. It can be demanding and requires more skills than simply an ability to start and stop the machine.

These are some of the manning problems now being encountered. Any organisation running elderly steam machinery before the paying public must be prepared to demonstrate that there is a robust training, passing out, and re-inspection system for those in charge of operating the plant and driving it.

Similarly with maintenance. It is not a surprise that the breakdown philosophy is the norm. Operations continue till some thing has to be dealt with. This has worked well – Kew Bridge has had no major catastrophes as a result of moving parts letting go, engines going out of control, or pressure parts failing. But have they been lucky?

Should there not be a regular inspection of the engines on a planned time basis on the lines of the routine surveys carried out on ships by Classification Societies and State administrations? It is not a dangerous environment, as it is at sea, but there is a degree of risk attached to the machine that could have consequences for those near to it if it fails. At Kew Bridge there is no such procedure – indeed, it would not be possible to carry it out with the resources available. Most other steam sites are in a similar situation, I believe. There may be no case for a full survey, but at least there should be a formal condition assessment at regular intervals. Kew Bridge has now been running one engine for 34 years; another has accumulated 12,000 hours. Better to have a firm understanding, before restoration has started, as to how the engine is to be maintained and inspected. At most sites, I suspect, the only target was to get the engine running with little thought to the future.

It might be said that steam sites should get together and work out some Code of Operation, perhaps through a body who could speak on their behalf to government authority. The very successful railway preservation groups in the UK have such a body, as do those who operate steam engines on the highway and at fairs. Apart from an attempt in the 80s there has been little appetite for stationary steam sites to work together in the UK. Yet, if one has a serious accident, all are in trouble. Sir Neil Cossons and his STIR initiative may well provide an answer to many of the problems. A corpus of knowledgeable advice available to groups is attractive, provided those that need it recognise their need.

6. RISKS AND RESPONSIBILITY

In the UK we act under the umbrella of the Health and Safety at Work Act 1974 and its various amendments since then. This Act imposes a responsibility on all of us to have done our best to have taken care of ourselves, our fellow workers and anybody else who might be at risk. Recent years have seen a tightening of legislation in an endeavour to ensure that those at the top, with an ultimate responsibility for running an organisation, can be held personally accountable, with criminal sanctions, when loss of life occurs.

The risks of any museum using steam as an energy source to drive moving machinery are obvious. Yet that is the attraction and raison d'□tre of the museum. Is this risk managed well enough?

The answer appears to be yes. There have been no major accidents involving the death or serious injury of a volunteer or visitor at a UK steam site to my knowledge. Nothing on the scale of, for example, the failure of the boiler of a traction engine in Ohio in 2001. There have been minor problems of course.

Incidents at UK steam museums in the last few months came very close to injuring the volunteers involved but luck was on their side. Where some groups may be remiss, and thus vulnerable, is in not having an adequate paper trail of their work to control risk.

Although some outside bodies can, and do, inspect specific parts and aspects of museum premises and plant, there is no one single overall body monitoring the operation and, in practice, each operating group is its own final inspection authority. If nothing goes wrong, there are no problems; but if something does, operations, procedures, driver qualifications, stewarding practices, inspection records, and risk assessments will come under detailed scrutiny. This is the 21st century when today's standards of safety will apply and good, documented, reasoning and records must be available. This requires serious attention and application by those with some qualifications, and the whole-hearted support of everybody else from the Chairman down.

Engines built in the first half of the 19th century are being operated by volunteers surrounded by the public. Loads have been lightened, but how can we be sure that they are safe? Are we certain that cast iron does not slowly change its characteristics in two centuries? Is there a crack developing? How much wastage has occurred? Is low cycle fatigue playing a part? What is the effect of the frequent thermal cycling on engines which were designed to run for months on end and warmed up to resume load over days, not hours? These are serious questions, yet there is a strong body of opinion amongst volunteers that sees no problems in just continuing as before from the time the engine stopped working over 50 years ago without recognising the changed running conditions, the lack of general steam expertise amongst the operators and, above all, the current legislative climate.

In a volunteer run organisation, the voice of the fully qualified engineer is only one of many. It can be swamped. There needs to be someone in the organisation who is strong enough, and well supported enough, to say “STOP. Do not continue running this plant until such and such is done”. I repeat that, apart from the boiler, no outside body is likely to come in with enough understanding and authority to say just that. It is up to those involved in the project in general and the professional engineer in particular.

Usually the constraint is not technical, but financial. It requires a big personality to make the case that money must be spent to ward off a possibility, when the whole operation is on a shoe-string and the lack of money means that if the engine is not steamed, the certainty is that the income will not be there to pay for it!

Those of us with understanding of basic engineering, Strength of Materials, Thermodynamics, Metallurgy and current plant operating practices, can find it difficult to get our points across in an unstructured, democratic, environment. It can be very frustrating. It needs a strong character with an indifference to other’s opinion. If that is not forthcoming, better to be out of it or, at least only take a minor role.

As a result, I concluded that, after thirty years, I no longer wished to be a Trustee, or a driver of the magnificent engines we have at Kew Bridge Steam Museum.

7. CONCLUSION

Does all this seem to be too discouraging? Those of you who have seen the John Key engine in Auckland in its motorised form and as it is today in steam will have no doubt. If you have a dormant engine near you, Go Ahead! You’ll enjoy the work and the sense of achievement.

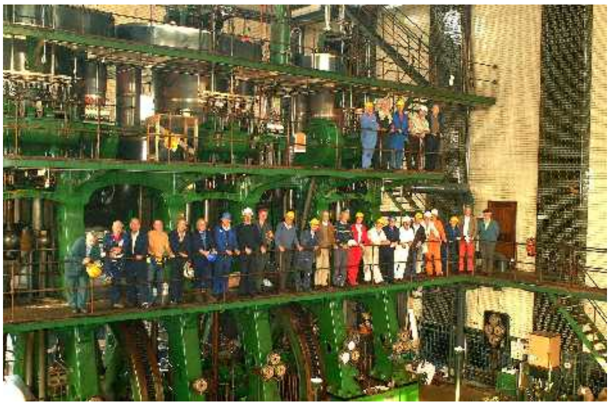

Figure 12. *Successful team at Kempton Park*

But remember that a 19th or early 20th century steam engine, however wonderful it was in its day, was worn out when it was finally stopped and must now be treated with a lot of understanding and to current legislative and safety standards if it is to be operated in public by enthusiastic volunteers under conditions well away from those it was designed for.

And be ready to answer this question after things have gone wrong.

Why did you, a qualified professional engineer, allow this to happen?