BSSA Conference 2000

The Water Industry's Balancing Act: Maximising Process Availability at Minimum Cost

Demands on the Water Industry come from several directions:

- **The Water Industry's regulator (OFWAT)** - demands a Capital Investment programme that not only ensures infrastructure replacement keeps place with wear and tear but also makes up for the deficiencies resulting from the times when this investment was part of the Public Sector Borrowing Requirement.

- **Legislation** - EU and UK Government Legislation require capital investment to meet ever tighter standards. The Drinking Water Inspectorate oversees the programme for improved drinking water quality with the Environment Agency responsible for river quality and other environmental improvements generally brought about by reduced abstraction from rivers and groundwater.

- **OFWAT and Customers** - wish to see operating efficiency improvements result in reduced consumer bills.

- **Shareholders** - want a continually improving return on their investment.

These pressures can be resolved by individual Water Companies as:

- **Minimising the capital investment required to achieve an outcome** – traditionally the water industry adopted a conservative approach to design so that plant could be operated at less than full rated load. Extra plant items would be installed to cover operating units in case of breakdown or maintenance requirements. Nowadays much effort is put into risk assessment so that design and operating standards are more akin to other process industries.

- **Reducing operating costs** – the widespread use of advanced control and monitoring techniques have been used to minimise the requirement for plant operators and maintenance staff. Unfortunately, the majority of modern treatment processes require a greater energy input than the more traditional ones.

- **Maximising the reliability of installed plant** – at the design and procurement stages the use of "duty" specifications is now almost universal. Where plant is required to operate continuously, the specification is likely to include the requirement for, say, "96% availability". This tends to focus design teams on the simplification or removal of maintenance operations. In this way the risk of environmental damage from equipment failure or downtime for maintenance is minimised. No Water Company wishes to incur fines or, worse still, the adverse publicity surrounding a failure to comply with a regulatory standard.

The “Balance” between Capital and Operating costs is well understood and can be calculated with relative ease. The inclusion in that calculation of a companies reputation, affecting, as it does, it’s perceived worth to investors and the publics confidence in it’s ability to provide them with life sustaining services is beyond normal calculation. It is however the “Balancing act” that water Companies have to perform on a daily basis.

This paper seeks to encourage both water companies and their suppliers to re-look at plant design as a way of reducing the costs and risks of ownership of equipment essential to the industry. It does it by way of an example which demonstrates the magnitude of benefits available to, I believe, anyone who makes the effort to take this approach.

The Huddersfield Waste Water Treatment Works (WWTW) is one of the most heavily loaded in the UK. The actual population served by the works is 170,000 whereas the “equivalent” population, taking into account the industrial load, is 790,000. The topography of the Colne valley imposed severe limitations on the amount of land available for a WWTW and resulted in the process being split between three sites over a distance of 3km.

The works inlet, screening and primary settlement are at Deighton. At Heaton Lodge, the first stage of biological treatment takes place on some 25,000m^2 of percolating filters. Secondary filtration, also on percolating filters, and final discharge takes place on the Cooper Bridge site.

Like many other works of this type, it was built in stages as more capacity was required. Refurbishment has also been an ongoing activity.

In 1996 the decision was made to refurbish the Heaton Lodge site. This work was to involve replacement and upgrading of the filter effluent pumps and a major overhaul of the 30 year old gantry type filter distributors. YW Research & Process Development, where I worked at the time, became involved as part of the project team that would determine the extent of the work required. Initial thoughts were that complete dismantling of the distributors followed by grit blasting, repainting and replacement of all mechanical parts and the rail system would extend the life of the installation by 20 years.

As part of the justification procedure for the work a comparison between the Heaton Lodge maintenance costs and those at Cooper Bridge, a works of the same capacity equipped with a later version of the same machines that were refurbished some 3 years ago, was made. This comparison revealed that all was not well and that not only were maintenance costs escalating towards those experienced before refurbishment, but that failures similar to those being experienced at Heaton Lodge were the basis of those costs.

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At this stage a more thorough analysis of maintenance records was combined with a critique of the design to try to determine the root causes of the problem. In broad terms the report determined that
some of the problems were caused by wear and tear but the majority were the result of design deficiencies. In a recent 12 month period maintenance costs of £80,000 had been incurred. This was associated with a 78% plant (process) availability and a 12% works compliance failure.

Filter outages were, in the main, caused by the following:

+ **Wheel, Wheel bearing and rail track failures** – the difficulty in achieving and maintaining accurate wheel alignment over such large track gauges resulted in wheel flange wear and excess wheel bearing loads.

+ **Haulage rope breakages** – several kilometres of wire rope were used in the haulage systems. Because the distributors had to be attached to the haulage ropes at both ends, the rope and pulley arrangement was complex. Despite rope failure sensors, it was possible for a rope breakage to result in machine derailment and serious damage to the cast iron and steel components of the distributors. The Company maintenance engineers were divided on the best way of minimising the "collateral" damage resulting from rope failure – one school of thought kept the ropes under high tension which helped machine and wheel alignment but resulted in pulley bearing failures. The other school kept the ropes slacker which minimised pulley bearing failure but increased wheel problems.

+ **Drive failures, principally gearboxes, but some electrical control problems** – included in the drive train was a worm reduction gearbox. This had to reverse each time the distributors reached the end of their travel. The lubrication problems associated with reversing a worm gear are well documented and caused some failures in as little as 18 months. Even with star delta starting the inefficiency of the drive imposed a high load on motor control gear as acceleration takes place under full load conditions. Combined with the age of the starters, this caused it's share of machine stoppages.

+ **Blockage of the holes in the distribution sparge pipes** – the perennial problem with most distributors. Caused principally by debris that avoids the works inlet screens.

It was also evident that the riveted steel supporting frames were corroded to the point where replacement of some frame members (generally at bottom of the structure) was required. The frames, which were almost 15m long, had to support their own weight plus that of the distribution pipe assemblies - a total of approximately 1.8 tonnes. Had the frames been of a welded construction, repair followed by shot blasting and the application of an epoxy paint system would have extended their life. Unfortunately the riveted construction employed had allowed corrosion to develop within the joints where shot blasting would have no effect.

The bottom line was that no amount of refurbishment would increase the reliability of the plant sufficiently to meet it's operational obligations. Either the process would have to be changed, almost certainly involving the demolition of the filters or a different approach to distribution of the effluent over the filters was needed.

An outline specification and design using Structural Hollow Section (SHS) as the basic construction medium was evolved. Each pair of the existing gantry machines would be replaced by a single cantilever type running on rails at the base of the channel walls. The design addressed all the deficiencies of the existing machines and was estimated to be capable of saving at least 50% of maintenance costs over it's predicted life and increase process availability to in excess of 97%.

At that time Yorkshire Water was involved in what was proving to be a very successful R&D project with Adams Hydraulics of York. They were asked to appraise the proposed design and provide budget costs for carrying out the works.

Discussions with Adams proved extremely fruitful. A plan emerged for a two stage project where, because of tight timescales involving the Environment Agency's requirement for an improved effluent quality, the design of replacement distributors was to evolve over the four sets of equipment required.

Sets 1 to 3 would be constructed with conventional tubular steel distribution arms and set 4 with a set of high-tech channel arms. This modification, which would be an extension of some existing research work, would be suitable for retro-fitting to sets 1 to 3 at some point in the future. In view of the environment in which the plant was to work (chloride, measured at the inlet works, in the region of 300mg/l) , the design life of 20 years, the difficulty of not damaging protective coatings during maintenance and the impossibility of maintaining a 97% plant availability if replacement of the protective coating became necessary, Adams proposed that the main chassis be fabricated from S31600 stainless steel SHS.

As soon as contractual matters were agreed (which took rather longer than it should and impinged heavily on Adams design and manufacturing time) some of the less obvious advantages of Stainless fabrication became evident:

+ The main chassis needed to be very stiff laterally to maintain wheel alignment but less so longitudinally so that flexure could accommodate uneven wheel loadings resulting from the inevitable inaccuracies that arise from the fabrication and rail laying processes. The availability of a wide size range of SHS simplified this design.

+ The "A" frame that supports the arms was to be in galvanised mild steel but as the design evolved it became clear that it would be more economic to manufacture it in S30400 stainless.

+ The time consuming process of preparation and surface coating was avoided.

+ The use of Stainless Steel required no corrosion allowance. This combined with rigorous structural design methods allowed a much lighter design than would have otherwise been achieved. In turn this reduced transport and craneage costs and got around many of the problems of a very restricted site access.

+ Site assembly time was minimised because there was no need for any precautions to avoid surface damage and no repair of damaged surfaces before wet commissioning. As the plant was running with only 75% process availability while each set was being “swapped” anything that reduced the time “at risk” was welcomed by Yorkshire’s operational staff.

The other design issues were tackled in an equally competent manner by Adams staff. A new haulage configuration utilising a multistage spur reduction gearbox, a soft start and stop combined with electronic variable speed and the location of all control and safety sensors either on the drive unit or immediately outside the drive house, overcame the problems of the existing drive arrangement. The new distributors ran on rails adjacent to the bottom of the effluent feed channel walls. Although this means that only half of the rails previously used were needed, it did mean that rail alignment, both gauge and height were more critical. Once an accurate technique was developed for rail alignment a tolerance of ±2mm on gauge and ±1mm on height were achieved. To minimise corrosion problems in this very vulnerable area, the rail mounting chairs had elastomer inserts so as to avoid crevice corrosion. The chairs were fixed with S31600 resin anchors. During the running in period it was evident that the wheels were not as accurately aligned as was required despite the careful use of an assembly fixture by the fabricator. Again Adams designers produced a simple but elegant fix for the problem that was fitted on site with minimal disruption.

Adams sub-contracted the Stainless Steel fabrication to Minster Engineering Ltd. of York. Their efforts in accurate cutting and fitting of Rectangular Hollow Section and good welding procedures combined with the use of pickling paste for the effective removal of weld tint produced a fabrication that emphasises the elegance and efficiency of the Adams structural design.

Two years on with all the teething problems that are inherent in a new design behind us, how is the system performing?

The latest figures from Yorkshire Water suggest that, so far at least, maintenance has been cut not by the 50% expected but by in excess of 90%. Some minor components failures have occurred but generally operational staff are very happy with the outcome. The 97% process availability target is a little more difficult to measure accurately but best estimates are nearer 98% availability.

What of Adams then?

Before the Huddersfield contract was complete Yorkshire Water were sufficiently confident of the outcome that they awarded them a further major contract for the supply of similar machines at the nearby Dewsbury works. Since then a further set of machines has been installed at Mexborough. Amongst the other Water Companies, one major installation has taken place with several others in the pipeline.

And what about the “Water Industry’s Balancing Act”?

This is essentially about realistic whole life costing. It is probably true to say that all process problems are soluble if sufficient money is spent on the right capital solution. The real difficulty arises when the true operating costs of the plant are revealed. In this case the extra capital expenditure required to replace the plant rather than refurbishing it is more than off-set if the assumptions that we made about maintenance costs and process availability (i.e. plant reliability) prove correct, and I'm coming around to the view that they were somewhat pessimistic, then the balance tips firmly in the Water Companies favour! Without counting the benefits of increased process availability a payback period of under three years looks likely.

This paper was originally presented at the BSSA Conference 'Make it in Stainless' on 9th November 2000 at the National Motorcycle Museum, Birmingham

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