Pump retrofit for new mode of operation

Commissioned in 1968, Radcliffe-on-Soar power station has a prominent position in the Trent valley. The plant has 4 coal-fired boilers and generates more than 2000 MW.

The generation of power stations built in the United Kingdom 40 years ago are now all operated by private companies. Originally designed for continuous operation, modern conditions require that the stations are routinely run at part load and brought on and off load in a 2-shift operation. This places heavy demands on the feed pump and may reduce its reliability. Sulzer Pumps undertook a major retrofit of the boiler feed pumps at the Radcliffe-on-Soar power station to upgrade them to a design suitable for this new mode of operation.

The original feed pumps, not manufactured by Sulzer, were designed for operation at their maximum continuous rating delivering 1660 m^3/h of water at 196 bar. However, privatisation and modern conditions led to operation between 180 and 520 MW with much higher stop start cycle rates. This new operating mode caused problems with the feed pumps, specifically:

- Low pump flow produced much higher pump bearing vibration levels, typically 12 mm/s.
- Low pump flow accentuated blade passing hydraulic pulsations generating undesirable vibration levels, sometimes >20 mm/s.
- Greater risk of bearing wear/failure and balance disk wear/failure.
- Greater risk of impeller failure.
- Failure at the back shroud/hub radius due to fatigue.

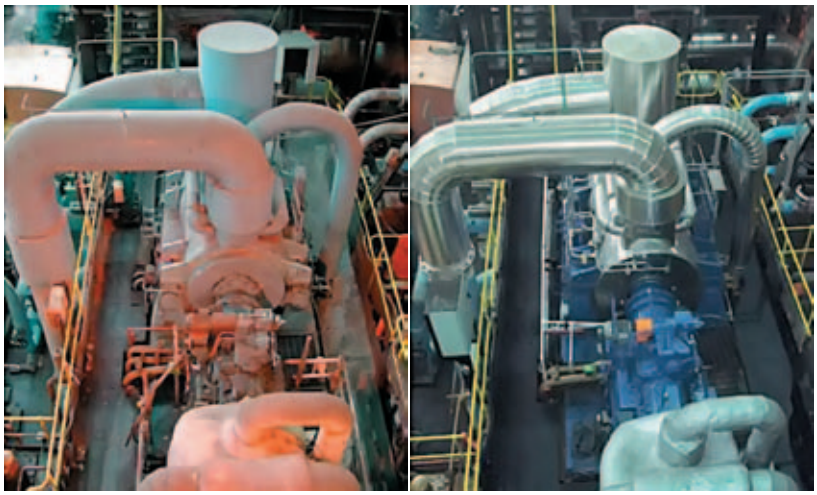
Low speed, and therefore low flow operation of large boiler feed pumps, can significantly increase the risk of failure of components such as bearings and the balance disc. Blade passing frequency effects have also proved to be particularly troublesome.

A state-of-the-art cartridge

Because the station is expected to be generating for at least the next twenty years, a complete replacement of the existing cartridge was proposed, while still retaining the pressure containing barrel. The new cartridge would be specifically designed to address the challenges of the new operating regime and featured:

- Retention of existing drivers
- Minimum impact on pipework and foundations (cost)
- Hydraulic sized for today's duty requirements
- Optimized inlet geometry for improved suction performance
- Minimize vibration reducing the blade pass excitation at low flow rates
- Increase in peak and off load efficiency

- Balance drum in place of the existing balance disc
- Mechanical seal in place of existing labyrinth seals
- Bearings suitable for a barring speed of 28 rpm and the introduction of a modern thrust bearing
- Cover the new elastic pressure bolting to interface with the existing barrel
- Service life approaching 60'000 hours



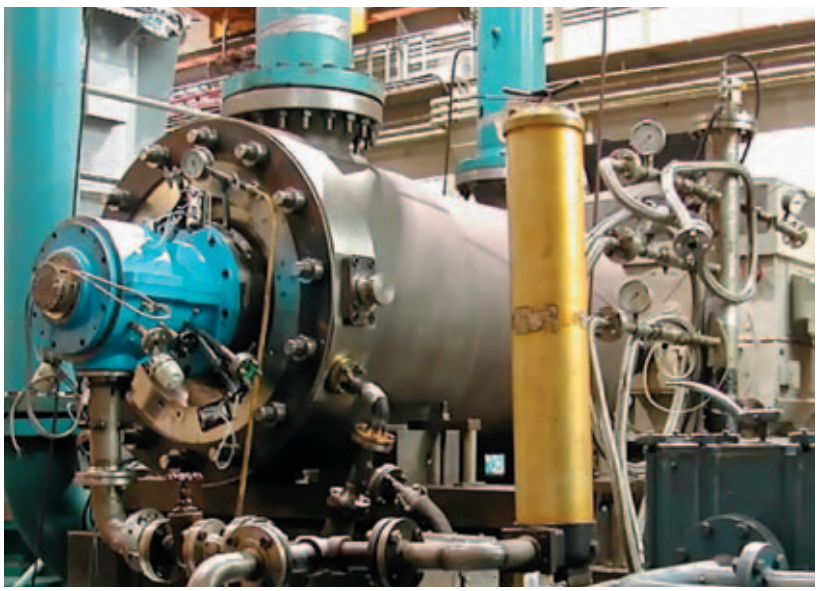
The original and retrofitted boiler feed pump.

Other train related modifications included a modern non-lubricated coupling between the pump and driver, a grounding device to help prevent shorting across the seal faces and an upgrade of the existing oil supply. The chosen solution was the cartridge of a Sulzer HPT 350-540 6-stage pump designed to operate at 1690 m^3/h at 200 bar, but with a preferred operating range covering 1345 to 1960 m^3/h. This design flexibility allows the pump to be reliably operated over a wide range of station output levels.

Building and testing

Essentially the cartridge manufacturing and assembly followed the same process as for a new pump. The key difference in this instance was the refurbishment of the existing barrel casing to accept new studs, and the refurbishment and resize of the sealing faces. Inspection of the casing indicated the existing faces were damaged and needed a full weld repair and re-machining. To ensure a high degree of accuracy, the casing was removed, welded and re-machined on a vertical borer. To allow testing without the original barrel, a low pressure test barrel was manufactured to allow the new cartridge to be tested at reduced speed. The test would however allow accurate calculation of full speed performance as well as assessing the cartridges mechanical performance including axial thrust loads. Extensive testing confirmed that the new design covered the required duty envelope with better performance than initially predicted, including a power saving of 2.5% at the 100% load condition compared to the proposed performance. After testing, the cartridge was assembled into the refurbished barrel and installed on site ready for re-commissioning. Performance after commissioning reflected the test data and the pump continues to deliver the flexibility the operator initially specified.

Cartridge on test installed in the temporary low pressure barrel.



Conclusion

The constraints of designing a modern day, state-of-the-art, cartridge to fit an existing ageing barrel are the biggest challenges that face pump manufacturers when designing retrofit cartridges. Items such as the existing site Net Positive Suction Head (NPSH) and essential services such as lube oil and cooling water can, in some cases, limit the design scope or solution. The real challenge for the Radcliffe Project, was not just designing a cartridge that included modern mechanical features, but rather providing a hydraulic solution that allowed the pump to operate efficiently over a wide operating envelope. An effective design solution was demonstrated during the slave tests and the pump has gone on to perform as predicted, reducing the operator's costs through improved efficiency, extended time between maintenance and much improved reliability. After the benefits were proven to the customer's satisfaction they proceeded to upgrade the remaining boiler feed pumps in a similar manner.

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