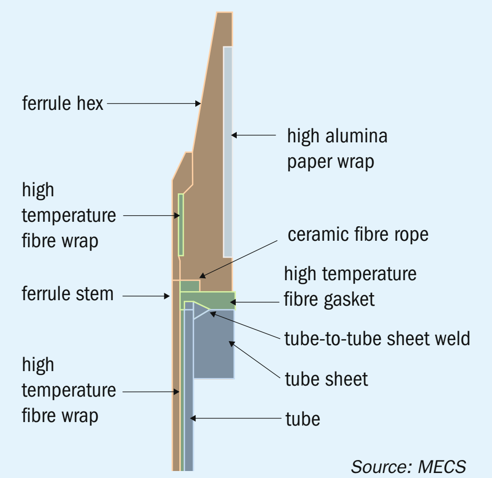
Rapid WHB retubing at IPL Mount Isa site

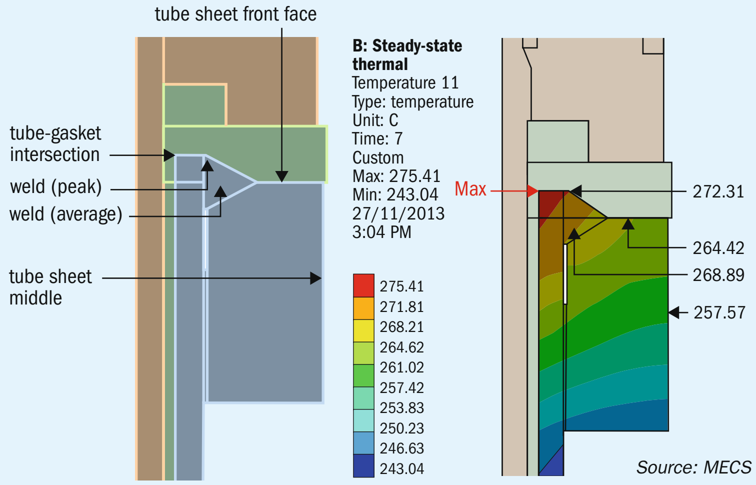
Energy recovery is a critical driver of sulphuric acid plant economics and the ability to properly design, operate, and maintain energy recovery equipment is critical to the successful operation of a sulphuric acid plant. Properly maintaining an acid plant waste heat boiler involves the right skill, expertise, and at times, creative solutions to balance the various needs of a plant. The IPL Mount Isa boiler retubing project, described here by **B. Lamb** of MECS, **M. Donaghue** and **R. Gosling** of RCR Energy and **L. Leonforte** of Incitec Pivot, provides a great example of this.

Fig 1: **Finite element model configuration**



Source: MECS

Fig 2: **Finite element model temperature results**



Source: MECS

Effective energy recovery in sulphuric acid plants can drive the economics of the plant every bit as much as the actual production of sulphuric acid. As such, many technologies have been used over the years to effectively recover energy. Examples include:

- waste heat boilers (WHBs) for recovering heat from the oxidation of sulphur into sulphur dioxide in the furnace;
- economisers, superheaters, and gas to gas heat exchangers for recovering heat from the catalytic conversion of sulphur dioxide to sulphur trioxide in the converter;
- boiler feedwater preheaters to cool strong acid by heating treated water that is fed to the deaerator;
- recovery of the heat generated from the absorption of SO_3 into sulphuric acid, such as MECS® HRS™
- latest generation, integrated technologies for optimising energy conversion across an entire plant, such as MECS® MAX3™

As energy recovery plays such a crucial role in overall plant economics, the reliable operation of energy recovery systems and the associated equipment is critical to the successful operation of a sulphuric acid plant. In the case of acid plant WHBs, ensuring reliable operation includes aspects such as proper design, operation, and maintenance.

Challenges for IPL Mount Isa

In the case of the IPL Mount Isa sulphuric acid plant, 2014 presented some very serious challenges associated with maintaining the site's 16 year old No. 1 waste heat boiler (WHB1).

WHB1 is a horizontal tube sheet boiler with 859 tubes, 70 mm diameter x 9,000 mm long. The boiler shell is 3,410 mm ID and 45 mm thick. Process gas from the sulphur burner directly upstream, enters a refractory-lined plenum and enters the tubes at 951°C, producing 2,400 kPa(g) steam in the boiler shell. The hot end tube sheet had circular ceramic ferrules consolidated with 100 mm of high alumina refractory held on with "cowhorn" anchors.

IPL had recent experience with tube to tube sheet failures in their No.2 waste heat boiler (WHB2), which was re-tubed under priority conditions by RCR Energy, including a redesigned tube to tube sheet joint. The original tube to tube sheet joint had a large root gap and a large "V" at the back

Fig 3: **Cutting WHB cold end vestibule (left) and tube sheet (right)**

Fig 4: **Hot end tube cutting**

Fig 5: **Insertion (left) and cutting (right) of new tubes**

Fig 6: **Marking out hand holes prior to complete removal**

PHOTOS: MECS

of the tube hole, which seemed intended to wash the crevice and cool the tube welds. However, IPL preferred a conventional hole with face welding followed by expansion, although this configuration had the potential to increase the tube tip temperature. Whilst there was no refractory in WHB2, the methodology formed a basis for retubing WHB1.

Ultimately, it was the pitting corrosion found in the tubes of WHB2, attributed to water chemistry that led to the decision to re-tube WHB1.

With WHB1, there was concern that the tube tips may be experiencing high temperatures under the hot face refractory. Excessive tip temperatures can lead to sulphidising and hence weld failure. IPL identified that a new hot face design, incorporating HexPro™ ferrules manufactured by Blasch Precision Ceramics (Fig. 1), provided time savings during re-tubing and afforded better inspection and repair options in the future. RCR Energy performed thermal calculations on the boiler and had Aurecon carry out thermal finite element analysis (FEA) of the redesigned tube to tube sheet joint, inclusive of the HexPro™ ferrules (see Fig. 2). Comparative analysis was carried out up to 1,200°C and it was found that the HexPro™ ferrules provided excellent protection of the tube ends with slight improvement in temperatures at the tube sheet.

In addition to the capital cost of a new boiler; the likelihood of removing and replacing a new boiler and its infrastructure during a three week shutdown is remote. With tubing unlikely to last another four year campaign, the decision was made to re-tube WHB1, including new tube sheets and hot face refractory.

Retubing considerations

A major time constraint identified was gaining access to the hot end, where the plenum has three layers of interlocking refractory brick. As personnel and tools could access the hot end through the sulphur burner openings, it was decided that the three layer system would not be disturbed, and the hot end tube sheet would be brought through the boiler shell from the cold end. The tube supports would be sectioned to allow the tube sheet to pass through from the cold to the hot end. This necessitated pre-determining a tube sheet diameter that was accessible from the hot end and compatible with the refractory design. RCR Energy designed a rail system that could support the tube sheet in its optimal orientation during insertion.

Note: It was not possible to simply cut the tube sheet and "pull" the bundle as steam risers and down comers projected inside the shell. Further, impingement plates and tube support plates (baffles) were welded to the shell and support plates were not connected to either tube sheet with tie rods.

To commence repairs, access was gained from the cold end plenum by cold cutting the dished end from the plenum cylinder, as shown in Fig. 3.

After removal of the hot face refractory, tubes were released from behind the hot end tube sheet and the hot end tube sheet removed in sections, as shown in Fig. 4. This allowed the tubes to be withdrawn from the cold end.

After the new tube sheet was installed in the hot end, openings in the tube support plates were restored. As there were no manways in the boiler shell, RCR Energy removed hand holes (in their entirety) to provide the access necessary to reinstate and inspect tube supports and guide tubes during insertion. The cold end tube sheet was installed and tubes were loaded, tacked, trimmed and welded, as shown in Fig. 5.

Re-welding of the complete hand holes was carried out with temper bead welding to avoid stress relieving of the boiler shell, as shown in Fig. 6. This technique was a success with weld hardness limits met throughout.

Reinstatement of the cold end dished end, combined with progressive non-destructive testing of welds and final hydrostatic testing of the shell allowed WHB1 to be returned to service in the allotted time.

Refractory Considerations

Another consideration for minimising plant downtime was the refractory work to be done on the WHB tube sheet. Conventional boiler designs utilise cylindrical ceramic ferrules, as shown in Fig. 7. Although inexpensive, the installation of conventional round ferrules can be quite time consuming, requiring the packing of monolithic refractory between the ferrules themselves, as well as a careful, lengthy curing and subsequent dry out of the refractory in order to ensure that, first, a ceramic bond is formed, and second, that all free and chemically combined water is removed from the lining prior to start-up. Failure to do this can have catastrophic consequences for the refractory.

To make matters worse, this labour-intensive and time-consuming technique for protecting the WHB tube sheet often causes other adverse effects. The monolithic refractory structure that is created on the tube sheet is prone to cracking when the boiler is cycled from ambient temperature up to operating temperature, as shown in Fig. 8.

To better understand this concept of thermal cycling, it is convenient to picture concrete pavements. Pavements often have expansion gaps every one metre in order to allow the concrete to expand and contract when the temperature cycles between day time and night time temperature (perhaps a temperature difference of 20°C). Pavements without expansion gaps can develop cracks, as shown in Fig. 9. Thus it is no surprise that when a boiler cycles by thousands of degrees, the tube sheet refractory can crack if it is not engineered with the capability to expand and contract.

Fig 7: **Conventional waste heat boiler ferrules**

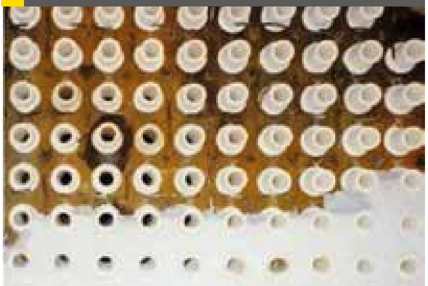


Fig 8: **Cracks in tube sheet refractory**

Fig 9: **Pavement with expansion gaps (left) vs pavement without expansion gaps (right)**

Fig 10: **IPL Mount Isa ferrule installation with HexPro™ ferrules**

Fig 11: **HexPro™ ferrules with tapered inlet for lower pressure drop**

PHOTOS: MECS

In order to provide adequate tube sheet protection for the long run, avoid refractory cracking due to thermal cycling, and provide a solution that could be installed as quickly as possible, IPL management employed the use of MECS® HexPro™ WHB ferrules manufactured by Blasch Precision Ceramics. In contrast to conventional ferrules, HexPro™ ferrules utilise hexagonal heads so that no mortar is required in between the ferrules. Thus the ferrules can simply be put into the tube sheet, as shown in Fig. 10. The result is a 67% reduction in ferrule installation time. In the case of the IPL Mount Isa boiler retube project, this time proved to be very valuable; thus the higher material cost for the ferrules was justified by the speed of installation.

Furthermore, the HexPro™ ferrules offered IPL the opportunity to face lower future maintenance costs. This is because the ferrules are engineered to expand when the boiler heats up and contract during cool down. Since there is no mortar in between the ferrules, the ferrules can grow and shrink without cracking.

As an added bonus, the ferrules selected by IPL Mount Isa also had a lower pressure drop compared to conventional cylindrical ferrules because the hexagonal ferrule heads allowed for the use of a tapered inlet, as shown in Fig. 11.

Putting it all together

Working with the right team of experts, the team at IPL Mount Isa were able to successfully retube their boiler before it failed, execute the work during a tight turnaround, and take advantage of modern technologies such as thermal modelling, finite element analysis, temper bead welding, and HexPro™ ferrules that will lead to improved operation, longer service life, and reduced maintenance costs down the road. ■