Water hammer

When a drainage study at the Conwy tunnel in north Wales revealed unexplained pump activity, a failed fire main was to blame. Brian Tinham reports

Right: entrance to the Conwy tunnel
Above: the pipeline and valves, post remediation

The destructive potential of water hammer and entrained air were demonstrated recently at the Conwy tunnel, where a leaking fire main had been discharging at 300m^3 per day for well over a year – costing some £3,500 in electricity alone for extra pumping.

It's an interesting story, which came to a head in April, but has its roots back in February 2007 when replacement isolation valves and a non-return valve were installed on 200mm diameter pipework forming the Conwy tunnel fire main. New valves were installed to deal with problems on the exiting plant; new chambers were provided to improve maintenance access; and the non-return valve was added to reduce the chance of back flow into the Welsh Water Authority water main.

Process of elimination

Almost immediately, pump operations at two roadside drainage sumps had surged – by 800% and 350%. However, this change went undetected for more than a year – until a regulatory compliance drainage study in April 2008.

Wyn Roberts, of Atkins Traffic-Wales, senior engineer for the ensuing investigation, points out that hydrant outlet flows and static pressure tests had all been recorded as normal throughout 2007. He also says that, although the increase in pump running events was easily discernible from the SCADA (supervisory control and data acquisition) system history, it was imperceptible to operators.

However, inspection of the isolation valves in April, using listening sticks, confirmed substantial flow, despite the pipework being a dead fire main. Engineers on the team decided that the most likely cause was a displaced Viking Johnson coupling – where the piping installed in 2007 meets the existing fire main – probably caused by water hammer. That was confirmed by excavation. However, with the flanged joint repaired and the pipework re-pressurised, the valve bonnet cover gasket on the main isolating valve also failed – probably due to air entrapment.

Roberts says that, at this stage, the non-return valve was removed, since it seemed to be compounding the problem – reflecting water hammer pulses and preventing trapped air from migrating upstream to an existing air valve. So the installation contractor provided a bobbin piece with a welded boss to which an air valve could be fitted.

Roberts points out that water hammer in the mains was likely to be pushing pressure pulses of 22.5bar at flow velocity changes of 1.5m/sec, rising to a full 37.5bar and 2.5m/sec, which was certainly capable of causing a serious breach of integrity in the pipework and valves, which had been sized for a maximum 20bar static pressure. He also asserts that the probable cause was rapid shutting of the hydrant valves, sending shock waves up the pipework, in turn reflected by the non-return valve.

As for the air, he suggests the source as being ingress during maintenance back in 2007, together with air in suspension in the water. Adding the air vent valve solved that problem, but recommendations from the Conwy tunnel also point to a need for some new procedures. Specifically, slower closing of the hydrant valves during routine testing and also operation are recommended to reduce the risk of water hammer. Further improvements to this installation now include a pressure reduction facility on the fire main.

Roberts notes that for newer pipework meeting the BD78/99 standard, which goes some way to reducing the effects of air and water hammer, no action may be required. However, he warns tunnel operators and plant engineers working with pipework that precedes that standard to be aware of the potential for catastrophic failure, and suggests amendments to meet BD78/99. PE

Pointers

- Maintenance and renewal operations can solve some problems, but cause others
- Water leakage can be substantial, even if it goes unnoticed on SCADA screens
- Water hammer and air entrapment create pressures and forces that are frequently underestimated
- In this case, pressure pulses rose to 37.5bar, with flow velocity changes of 2.5m/sec – well above the pipework rating
- Tunnel operators and plant engineers need to be aware of the potential for catastrophic failure