Pumping challenge

Engineers can't bury their mistakes, as surgeons can. Brian Tinham talks to the chief mechanical engineer for the Margate and Broadstairs water treatment project about how his team has been getting it right

Engineering invariably involves a balancing act – mostly between, on the one hand, keeping within budget, while, on the other, developing robust, dependable solutions that meet parameters, such as design life and risk mitigation.

That's certainly the case with the £66 million Margate and Broadstairs water treatment project, currently being commissioned by Black & Veatch and Costain. The scheme aims to improve the quality of sewage discharged from the Kent coastal towns by Southern Water – and, given its scale, the critical nature of the service and the need to re-use existing infrastructure, it presented challenges.

The original plant comprises two preliminary treatment works – one at Foreness Point in Margate, the other at North Foreland, Broadstairs – treating flows from the individual catchments and discharging through outfalls to the English Channel.

The new scheme would reconfigure the Broadstairs headworks to transfer raw sewage to Margate, which would, in turn, be refurbished and upgraded to provide preliminary screening and transfer pumping to Weatherlees Hill, where a new secondary treatment works would be constructed. There would also be an 11km 800mm diameter flow and return mains to transfer the screened effluent flow from Margate to Weatherlees and fully treated flow back to Margate for discharge down the existing long sea outfall. And there would be a new storm storage and return system at Margate, as well as new controls and instrumentation for all sites.

Key to ensuring the robustness of the whole scheme was designing and building reliable transfer pumping stations at all three sites, with particular attention to specifying and testing pumping plant and equipment. As the project's chief mechanical engineer Paul Booth explains: "The whole system relies on being able to pump predictably to Weatherlees for treatment and, just as important, back for outfall. If the pumping stations fail, you can deal with the effluent at Margate, but it would only be screened, not treated, before discharge and then you're in breach of the legislation."

That said, the duties at each pumping station were quite different. At Broadstairs, the pumps would need to handle raw sewage – thus including insoluble material such as rags, sanitary materials and grit – and be capable of 132 l/sec, with a duty/assist/standby configuration. For the Margate to Weatherlees transfer, the duty had to be similar, but with detritus bigger than 6mm removed: specification was 278l/sec at 75m head, again as duty/assist/standby. As for final effluent from Weatherlees back to Margate, the duty required was 297l/sec at 79m, again as duty/assist/standby.

So far so good; but, with the requirements assessed, it was time for supplier selection. “The Broadstairs pump duty was well within the normal operating range of submersible pumps, and hence there was no particular concern there,” says Booth. But it wasn’t going to be so easy at Margate and Weatherlees: pressure heads in excess of 50m are uncommon in sewage treatment, but here they were 75m and 79m respectively.

The joint venture team considered a dry well arrangement, with pumps operating in the well and motors at machine floor level. But, with the additional shafting costs and the footprint required, it rejected that approach. That meant specifying two sets of four, near identical, submersible pumps – those for Margate to be constructed using enhanced durability, abrasion and salinity resistant (Duplex impeller and suction cover and Belzona-coated volute) wetted parts, while those for Weatherlees could be fabricated from standard materials (all Belzona-coated). “Given the heads and flowrates involved, that limited us to just two possible pump suppliers,” says Booth.

Duties and models

“We chose Grundfos variable speed pumps, partly because of their wide range – they go up to 120m head as standard – and partly because of their track record. They have carved themselves quite a niche in high-head submersible pumping. For example, there can be issues of vibration and bearing wear with this kind of head, but their pumps included sensors to monitor pump and motor vibration and bearing temperatures, as well as pump protection features such as seal leak and motor stator temperature trip switches.”

Following modelling (see panel), and the usual supplier witness and sign-off (the result of which was a slight elevation of minimum level to reduce the risk of cavitation), the project moved on to the plant factory testing stage. “Pumps of the size required for the three sites normally undertake an individual factory test, and this scheme was no different,” says Booth. “So testing was carried out to BS EN ISO 9906:2000, with the Broadstairs pumps tested to Grade 2 [±8% on flow, 5% on head], and the Margate and Weatherlees pumps tested to the tougher Grade 1 [±4.5% on flow, 3% on head] tolerance to meet our concerns over the critical nature of these pumps.”

Beyond that, the Margate and Weatherlees pumps were given vibration and bearing temperature limits (8.7mm/sec maximum and 130°C respectively – the latter to avoid premature grease degradation), which were also measured during the factory test.

The final point of interest concerns the variable speed drives, for which ABB had been selected, because the motors integral to the Grundfos submersible pump design are also ABB. Given the size of the transfer pump motors at Margate and Weatherlees, Black & Veatch wanted to ensure that the chosen regenerative drive unit would have no compatibility issues with the motors.

“To verify compatibility, we carried out a string test using a drive compartment from the MCC [motor control centre], a representative length and type of cable, and one of the transfer pumps,” explains Booth. “We ran the pump under a variety of load and speed conditions, monitoring vibration and bearing temperatures throughout, and testing for stray current building up in windings. We also used it to test the cable, since we intended to run the earth through the cable armour. And we also took the opportunity to perform an extended full load test to determine peak bearing temperatures, and establish the VSD settings and measurements as reference settings to be used in subsequent plant commissioning.”

Booth agrees that the approach taken throughout the design, test and build of the Margate and Broadstairs scheme carries a cost. “It’s a tangible cost and it needs to be weighed against the risk reduction to the contract and the confidence in the reliability of the final plant. Commissioning of the scheme is ongoing and, to date, the pumping stations have been completely reliable.” PE

Modelling for success

“Physical sump modelling is a proven method for de-risking pumping station designs, particularly where high heads and flows are present, or unusual configurations are required,” comments Paul Booth, project chief mechanical engineer. “It’s expensive, but computer simulations, which are good for mixing tanks and flows in channels, just aren’t a reliable enough alternative. They can’t get down to low enough levels where you’re looking at the detail of swirl and pump suctions.” So scale models were built of the sumps and pumps for Weatherlees, Margate and Broadstairs, and water run through them to prove the sump configuration, determine minimum operating levels and eliminate undesirable effects, such as vortices and pre-swirl, which could lead to vibration of the pump and premature failure. They were also used to model solids deposition in the sumps in order to minimise the problem.

“This part of the project was doubly important for us, because each of the pumping stations had unusual configurations,” adds Booth. “For example, at Margate we modified existing structures with a split sump arrangement – two pumps and sumps linked by a balance pipe, one being fed by straight-through channel and the other by a dog-leg channel. So we had to model from upstream of the dog-leg to understand the flow split between two sumps. In an arrangement like that, you invariably get different levels and you need to establish which to use to control pump operating speed. In this case, the system looks at both level instruments and compares the two.”

Each Perspex model cost around £20,000 to build, and one was required for each of the transfer stations. But as Booth says: “Once those pumps are in and running, they can’t be taken offline. You only have one chance to get something like this right.”