DIGESTER 8 – LESSONS LEARNT CONSTRUCTING NEW ZEALAND’S LARGEST MESOPHILIC WASTEWATER DIGESTER

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ABSTRACT

To meet the needs of Auckland’s strong regional growth, the digestion facility at Auckland’s Mangere Wastewater Treatment Plant required expansion, and quickly. Effecting this by means of the addition of an eighth mesophilic digester, Watercare Services (Watercare), CH2M Beca and Brian Perry Civil united to design and construct Digester 8, New Zealand’s largest mesophilic wastewater digester.

With its brownfield site, wholly contained within the existing operational plant, the Digest 8 project was challenging. Key issues to be addressed were: the pressing need for augmented digestion capacity; a short construction timeframe; the need for outstanding quality; and the requirement for a unique blend of heavy civil, process, electrical and control, mechanical and commissioning disciplines. This challenge was met through a mix of both traditional and innovative approaches, and a persistent team of engineers from all parties who worked to bring the project to its successful conclusion.

This paper outlines some of the unique problems faced on Digester 8 through the design, procurement, construction and commissioning phases and the lessons learnt by the collective team in resolving these issues.

KEYWORDS

Wastewater, Digester, Mangere WWTP, Civil Construction, Mechanical Construction, Lessons Learnt

1 INTRODUCTION

To meet the needs of Auckland’s strong regional growth, the Digestion facility at Auckland’s Mangere Wastewater Treatment Plant required expansion, and quickly. Watercare elected to meet this need through the addition of an eighth mesophilic digester that augments the capacity of the seven existing digesters. Through a traditional design-tender-build approach, Watercare employed the skills of CH2M Beca and Brian Perry Civil to respectively design and construct Digester 8, New Zealand’s largest mesophilic wastewater digester.

Figure 1 – Digester 8

The Mangere Wastewater Treatment Plant is New Zealand's largest wastewater treatment plant. First commissioned in 1962, this facility has grown to provide wastewater services to 70 per cent of Auckland's population. By the very nature of being a well-established plant, the Mangere Wastewater Treatment Plant is an extensive brownfield site, densely built with services and treatment processes. Digester 8, being wholly contained within the existing operational plant limits, would need to be able to be constructed within and integrate into the plant.

As a result of strong regional growth, there was a pressing need to augment digestion capacity at the facility. Digestion capacity of the existing plant was near capacity, and the ability of operations staff to remove digesters from service for long-term overhaul was hampered. A new facility would not only assist in meeting periods of peak demand but also relieve capacity constraints and ensure the plant continued to meet consent requirements, including during maintenance overhauls of existing digesters. The urgency of implementing this project meant there was only a short construction timeframe within which to build the new digester.

However, while it was necessary to undertake construction promptly, retaining outstanding quality was a key project objective. By its very nature, digestion is a hazardous and often corrosive process that is unforgiving on civil and mechanical equipment. High sand and grit content product, H_2S, methane gas and struvite issues mean that quality could not be compromised in achieving the project's timeframe objective. Digesters also demand a unique blend of heavy civil, process, electrical and control, mechanical and commissioning disciplines that challenge both designer and constructer to produce a seamless result across all areas. For Digester 8, this challenge was met through a mix of both traditional and innovative approaches, and a persistent team of engineers from all parties who worked to bring the project to its successful conclusion.

A number of significant setbacks were encountered during the construction phase, and an outline of these issues, as well as the lessons learnt by the collective team in resolving them, is worth sharing with the water and wastewater industries.

2 DESIGN CONSTRAINTS

When faced with the challenge of designing Digester 8 a spectrum of suitable solutions existed to meet this need. However, while at the outset many of these options appeared feasible, the designers found that a number of constraints inherent to brownfield wastewater treatment plant sites meant that only a limited amount of feasible solutions was possible.

2.1 LOCATION

At the time of the last Digester upgrade, in which three new digesters were added to the existing four, provisions were made for an eighth digester. Land was left vacant within the digestion facility area and piping and services were adequately sized with an eighth digester in mind. This made it an obvious site on which to locate the new digester.

What was not evident, however, was that the location of the digester proved to be the key determinate in defining the overall digester design. The proposed location had the effect of:

- Constraining the overall digester size in terms of height and width
- Restricting the digester hydraulics due to the need to use the existing connections available
- Constraining the digester's height, as a result of it being within the site's building consent height limitations
- Confining the range of feasible geotechnical foundation types due to the soft, peaty soil beneath the tank

The conceptual options eliminated by this choice of location are summarised in Table 1 below.

Table 1 – Conceptual Constraints and Conceptual Options Eliminated

Conceptual Constraint	Restriction	Conceptual Options Eliminated
Tank location	Located in space designated for the eighth digester. No suitable space elsewhere nearby within the plant. Lack of trunk infrastructure outside of digester area	Locating the digester on the fringes of the plant. Sitting it in locations with less interference with wastewater treatment plant operations. Locating it in places other than the designated reserved space
Hydraulic design	Location dictates use of existing common trunk infrastructure (e.g. sludge feed pumps, sludge discharge pump station). Must meet the hydraulic criteria of these services	Water level significantly higher or lower than existing digesters – eliminating options like multiple ground-level tanks. Overall size exceeds the service capacity of trunk infrastructure
Height restrictions	Site wide height restriction	Roofs with high overall height: diameter ratio (e.g. Glass Reinforced Plastic, ellipsoid)
Geometry/Size	Hydraulic retention times must be similar to existing. Must be able to be taken off-line without severely impacting on the plant's operation. Long-span roof structural limitations. Near circular for mixing efficiency	Tanks larger than space allows. Tanks significantly bigger than existing digesters (capacity issues when taken off-line). Square or other space-efficient types
Geotechnical	Peaty, soft underlying soils with high water table	Bedrock foundation types. Out of ground solutions (consolidation issues)

Considering all of the constraints involved, the natural best-fit conceptual solution for the eighth digester at the Mangere Wastewater Treatment Plant was a pre-cast concrete tank with a half-in-ground construction type similar to the existing tanks on site. During the concept design phase, the solution was further refined and benefits over the existing designs realised while remaining within the required parameters:

1. Maximising the digester size from 6500 cubic metres to 8500 cubic metres
2. Utilising a fixed cover to maximise sludge capacity (the existing digesters are floating cover types)

2.2 EXISTING SERVICE CAPACITY

Determining the capacity of existing facilities was an unforeseen challenge to the Digester 8 project. As with all operational plants, overhauls, upgrades, process modifications and operational methodologies all evolve over time, meaning original design parameters are often incorrect. Even with services deliberately sized for an eighth digester during the last upgrade works, there was a high degree of uncertainty as to the capacity of existing common service infrastructure.

The primary approach to resolving this issue was to apply modern analysis techniques to existing equipment. Telemetry data was collected, reviewed and cross-checked against hydraulic models and pump operating curves. Complex systems such as hot-water loops required significant design investigations to determine their capacity. Despite this analysis, in many of the systems a degree of uncertainty remained. For example, in the hot-water loop, maximum demands are rarely achieved in practice and no telemetry data was available. Further, although a theoretical maximum exists, modern biogas engines and heat exchange systems have been installed since the commissioning of the loop; combined with many years of general wear and tear on the system, this meant that determining this maximum with certainty is difficult in practice.

In many respects, conservative assumptions had to be implemented to ensure service capacity for the new digester. Where conservative assumptions could not be used to determine the capacity, Watercare acknowledged these items as a project-wide risk and carried forward this risk into the construction and commissioning phases.

Mitigating against risks in this way allowed Watercare to save capital costs of expensive service infrastructure upgrades, while also limiting project risk by, where possible, checking assumptions during construction activities such as process tie-ins and implementing commissioning testing to simulate full-load demands. For example, in the heat loop system, a new full-duty heat exchanger was installed and a known risk of hot-water flow and heat availability was identified and carried forward into the construction and commissioning phases. During the commissioning phases, a full-load heat demand was simulated on the heat exchanger and telemetry data was monitored to determine whether sufficient heat capacity existed in the system.

2.3 FAMILIARITY VS MODERNITY

An inevitable challenge with upgrades to legacy systems is the balance between familiarity and modernity – do you keep with the status quo or do you adopt modern best practice? Often the answer lies in between – cherry-picking the best bits of the existing designs and combining them with modern best-practice elements. The choices faced in resolving this quandary on Digester 8 are summarised in Table 2 below.

Table 2 - Familarity vs Modernity Choices on Digester 8

Familiarity	Modernity
• Same discrete systems present on site (recirculation, mixing, heat exchanger, services) • Similar discrete system layout • Use of valves of a similar make and model to existing • Concrete tank design • ‘Fill and spill’ operating mode • Replication of existing automation sequences e.g. pumped unloading of digester contents	• Volumetric feeding • Simplified valving • Full-load heat exchanger • Fixed roof design • Increased telemetry equipment and generally improved quality • Better access to tank, roof and valving

Overall, an incremental improvement mentality simplified the overall design of the digester. Wastewater treatment plant operators could easily understand how the digester works as the design replicated much of the functionality of the existing digesters, with only small changes and improvements – for example, the change from timing-based to volumetric-based feeding.

2.4 LESSONS LEARNT

Key lessons learnt during the design phases:

1. Understand the project’s design constraints early on.
2. Be aware of the consequences of key decisions at the initial stages of the project.
3. Determining existing service capacity can be difficult; a risk-management approach is an effective way for the owner to manage these risks and minimise any associated costs.

3 MANAGING RISK IN IMPLEMENTING INNOVATION

3.1 BACKGROUND

An innovation implemented by the constructor of Digester 8 was the casting of full-height stitch joints between pre-cast wall panels. By virtue of the design methodology selected, the pre-cast, post-tensioned tank design required 40 concrete stitch joints to be cast between each of the 40 panels and the wall of the tank. Each stitch required the 29 post-tensioning tendon ducts to be cast integrally into the stitch.

The natural sequencing of Digester 8’s construction (Figure 2 below) meant that completion of the concrete tank structure involved critical path works. Any time savings that could be achieved from this construction phase would, therefore, directly impact on the overall construction programme.

Figure 2 - Key Construction Sequence

3.2 DESIGN

The design of the Digester 8 tank structure was commensurate with a standard pre-cast panel, post-tensioned concrete tank. The height and geometry of the tank was dictated by process requirements (see Section 1 above). The panels themselves were designed to meet the capacity of local pre-cast panel manufacturing facilities in Auckland.

3.3 CONSTRUCTION

The constructor's methodology detailed pouring the stitch joints in a single lift to complete these wall panels. A traditional approach is to construct these stitches in two lifts, though this is inefficient with multiple formwork and concrete-placing operations required. A single lift not only meant a reduced overall construction period but it also simplified much of the detail involved, such as eliminating the construction joints between separate lifts.

Figure 3 - Wall Stitch Joint Formwork and Concrete Placement. Note: Concrete Enters Near the Stitch Bottom

To undertake the single lift, reinforcement and post-tensioning tendon ducting would be installed, along with Hydrophilic sealing material within the stitch detail, as well as formwork consisting of two large I-beams with a timber facing clamped over the stitch between each panel. Self-compacting concrete would then be pumped to a valved inlet at the bottom of the I-beam clamp and concrete would be placed bottom-up into each stitching.

After a successful trial on the first stitch between panels, this methodology was then replicated for the next 40 stitches. The ducts were checked after each pour by passing water through the duct, in order to ensure grout intrusion was not creating blockages that would require remedial works.

3.4 PROBLEM IDENTIFICATION AND RESOLUTION

Once two-thirds of the panels were stitched together, installation of post-tensioning strand was trialled. It was found that a number of ducts had deformed or crushed completely, resulting in it being impossible to install post-tensioning tendons.

Extensive CCTV investigations were then undertaken to determine the scale of the problem. As far as practicable (where ducts had crushed it was not possible to CCTV beyond these points), all of the internal ducting was CCTV surveyed to determine the condition. It was estimated that 15 to 20 per cent of the ducting had been severely deformed or crushed. The first eight stitches poured had no duct failures.

In consultation with post-tensioning experts, it was determined that there was no permissible tolerance for duct deformities, because the post-tensioning strand is tensioned considerably (approximately 80 per cent of the yield stress of the tendon material) and non-smooth ducting had the potential to cause a localised stress point in the cable and cause the cable to fail. Cable failure would be significantly hazardous for those working on site, and could potentially cause the structure to implode.

After trialling of various experimental remedial methods, it was decided that saw-cutting and removing the affected stitch joints (Figures 4A and 4B below) and recasting them was the best-for-project remedial solution.

Figures 4A and 4B - Saw Cut Removed Stitch Showing Duct Deformities

3.5 ROOT-CAUSE ANALYSIS

Through further investigation it was determined that a change to the tendon ducting installation methodology during construction resulted in failure of the ducts due to hydrostatic pressure during placement of the concrete. Ducts were meant to be installed as a solid tube; however, it was found that splitting these tubes lengthways and 'clamping' these over the tendon ducting spigots installed in the wall panels enabled significantly more straightforward construction. Splitting of the tubes also could have the detrimental effect of substantially reducing structural strength.

While a risk review was completed as part of the stitch-pour work planning, it assumed a solid tube installation and focused on grout intrusion into the duct. The specified duct type proved difficult to install as it entailed working within the confined space available; this would ultimately lead to an uncontrolled change to the installation method (splitting the duct), without appropriate risk review. Alternative duct types that may have eased installation were available; however, these were previously not considered appropriate.

3.6 LESSONS LEARNT

1. The innovation itself was successful – pumping of self-compacting concrete bottom up in a single lift resulted in competent, void-free concrete and gained programme advantages for the project. Inspection of all of the stitch joints removed by cutting showed excellent, well-distributed concrete with no obvious flaws.
2. The difficulties experienced by the site team in constructing the detail as intended led to the change. Constructability of critical details should be considered by the designer and contractor during the design and work planning phases. For items not specified in detail at the design phase, proven proprietary systems should be used, where possible. Constructability, as well as technical suitability, should be considered by all parties in the final preparation of the work planning. IPENZ Practice Note 13 provides good guidance in this area.
3. On-site changes to planned work methods should be encouraged but require full risk review prior to implementation. The parties should agree to the scale and scope of work plan reviews prior to commencement in order to balance risk mitigation for the project while enabling the benefits of innovation to be realised.
4. Adequate inspection and testing regimes must be in place and updated to address specific risks as they are identified. In this case the ducts were checked with water (for grout intrusion), although this was not adequate to recognise the subsequent crushed ducts issue.

4 CHALLENGES INHERENT IN WATER-TIGHTNESS TESTING OF LARGE WATER-RETAINING STRUCTURES

4.1 BACKGROUND

Standard practice for water-retaining structures is for the unit to undergo water tightness testing during construction. Testing generally comes in the form of a drop test – where the tank is filled with water and the water level in the tank is monitored for a certain period of time. Should the level not drop further than prescribed limits over a prescribed period, then the tank is deemed to be watertight. For Digester 8, the NZS 3106:2009 limits of a maximum drop of 10 millimetres over five days was specified.

4.2 DESIGN

The drop-test limits were specified by the designer, based on Watercare’s requirements. Historically these drop tests have been successfully utilised for enclosed water-retaining structures such as reservoirs.

At the time of design, it was envisaged that this test would be carried out with the fixed roof installed, which would have minimised evaporation, rainfall and wind effects.

4.3 CONSTRUCTION

The contract documents dictated various hold points, including a drop test to prove water tightness as a significant milestone. The drop test was programmed immediately after completion of the concrete tank structure. Mechanical works could not be installed until the coffer dam in which the tank was being built had been backfilled; similarly, roof construction could only begin upon completion of the concrete tank structure. This rationale was based around backfilling of the tank, making the opportunity to identify and repair any leaks significantly more difficult. These programme constraints led to an open-air test of the tank being required.

A methodology to accurately measure the change in levels to determine drop-test criteria proved challenging. Physical access to the surface of any apparent free water was difficult because of the stage of construction at the time of the testing. Measurement errors, in particular wind on the water surface, also proved problematic in obtaining any accurate level measurements from the water’s surface.

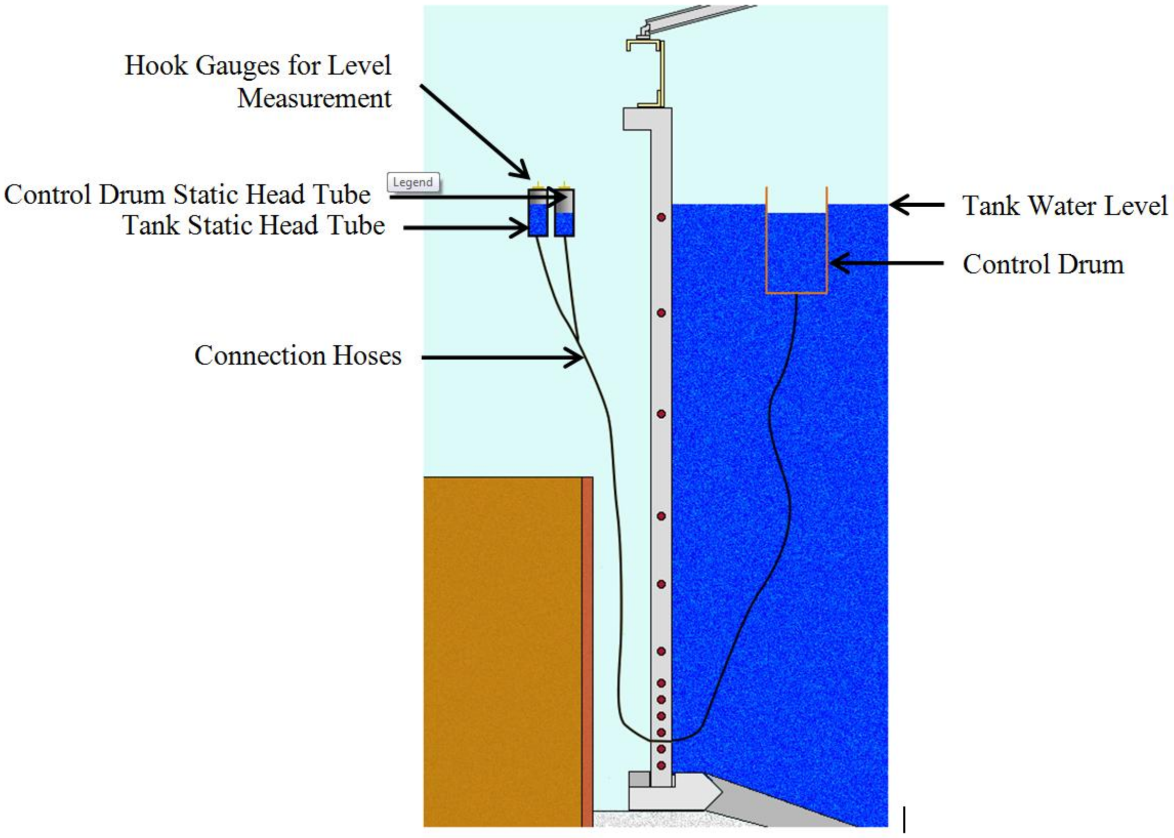

Figure 5 - Static Head Tube Measuring Equipment

To eliminate these sources of error, international best practice was researched and implemented. Static head tubes were attached to the tank and an evaporation control drum located with the tank (see Figure 5). This apparatus enabled levels to be accurately measured remotely by means of a hook gauge placed on the tank.

Although the test apparatus mitigated much of margin for test measurement error, the size of the tank, at a diameter of 32 metres, introduced a number of challenges during the water test period. These included:

1. Large fluctuations in water levels, and determining whether these could be attributed to evaporation from the open-air tank (see Figure 6)
2. Accounting for precipitation

A reliable and satisfactory method to determine these factors was unable to be realised during the testing period. NZS 3106:2009 is lacking in any stipulated method for accounting for items 1 and 2 above, though significant research and specifications were found to be available internationally. After approximately a month of testing, the specification limits for the drop test were reached, and testing subsequently ceased. The authors suggest that is an area where additional research would be valuable.

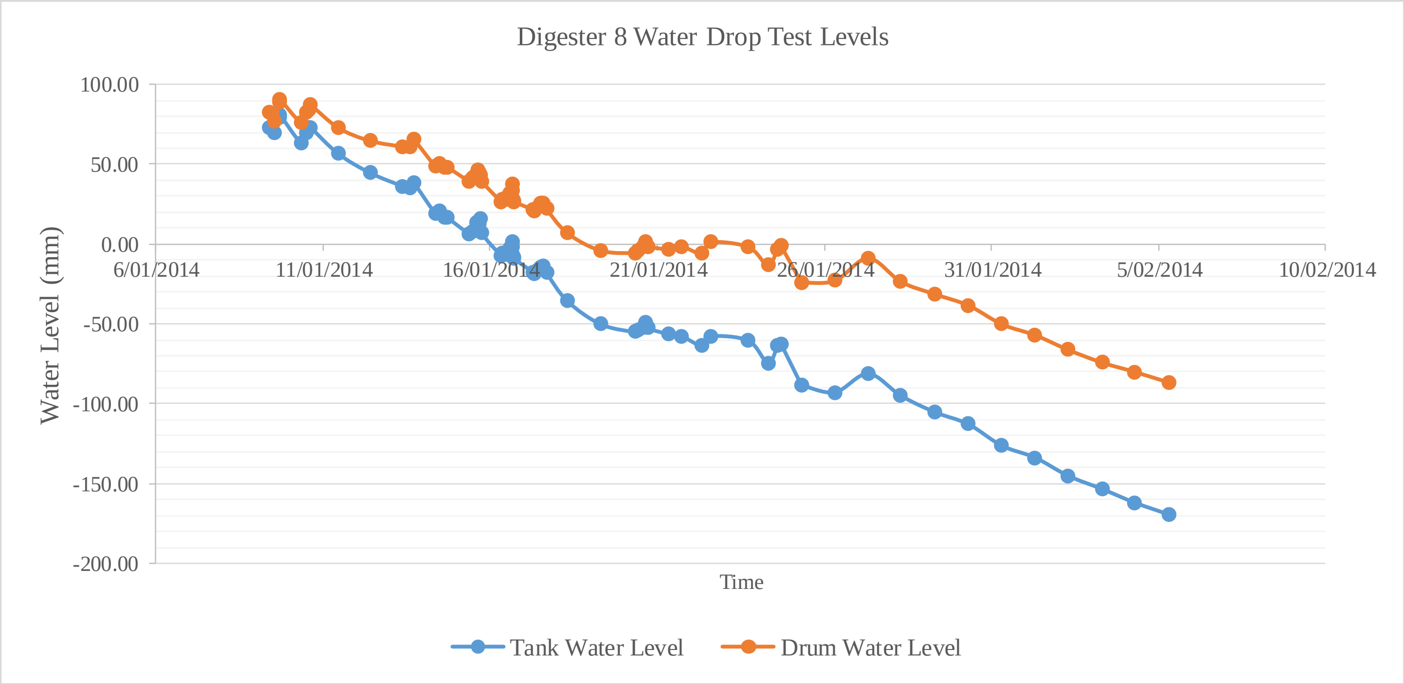

Figure 6 - Digester 8 Water Drop Test Levels

4.4 LESSONS LEARNT

1. Accurate water-tightness testing of water-retaining structures in open air to limits in accordance with NZS3106:2009 is difficult to achieve and sufficient time should be stipulated in the contract to ensure adequate allowance in the contract programme.
2. The limits specified by NZS3106:2009 are potentially difficult to achieve. It is suggested that, at the design stage, designers and clients come to an agreement for an appropriate leakage rate at which the process fluid is contained. For digesters, it was felt that the high solids content of the sludge would plug large cracks in operation, and that the 10mm water drop limit may not be appropriate in this instance. It is recommended that water test specifications be more clearly defined to supplement NZS3106:2009.

5 PROCUREMENT OF VALVES RIGHT FOR THE JOB, AND THAT MEET THE CLIENT’S REQUIREMENTS

5.1 DESIGN

During the design phase, valve makes and models were nominated by Watercare with the option for the constructor to propose alternatives. The underlying philosophy behind this was twofold: as far as practicable, match existing site valves for operator familiarity and maintenance synergy, and to select valves of known quality.

Flange types were specified by the client’s standard specification documents as being EN1092-1 Type 02 slip-on flanges.

5.2 CONSTRUCTION

For risk mitigation, the constructor elected to issue all valves for approval by the engineer before procurement. Many valves were selected in accordance with the nominated valve types, and these included the numerous knifegate valves.

During construction, it was found that the knifegate valves in question did not adequately seal when pressurised against a closed, seated gate. Diagnostic testing was undertaken in an attempt to determine the root cause, including yet to be delivered valves being hydrostatically tested at the manufacturing facility before being despatched. Despite this precaution, valves that passed the hydrostatic pressure test in the factory were found to not pass hydrostatic testing on site.

Figure 7 - Knifegate Integral Seal vs Slip-on Flange

Investigations concluded that the integral seal of the knifegate valve did not seal against the slip-on flange (see Figure 7), and the integral seal was designed for a weld neck-type flange. It was estimated that with the slip-on flanges, only two millimetres of the integral seal was mating with the slip-on flange and facilitating valve sealing. The weld neck-type flange has a smaller internal diameter, and therefore creates a better seal. This problem existed for valve sizes 250NB and smaller, as the pipe's outside diameter for these sizes was significantly larger than those of the nominal size of each pipe. This issue did not arise in valve sizes of 300NB and larger as the pipe's outside diameter was closer to the nominal size of the each valve.

5.3 PROBLEM RESOLUTION

The problem was resolved by a three millimetre-thick stainless-steel plate being installed either side of the knifegate valve. This stainless-steel plate had an appropriate internal diameter for sealing against the valves' integral seal, and 'bridged' the gap to the slip-on flange type. Retrofitting of this solution caused approximately three weeks of delay, primarily in determining the root cause of the problem, in addition to only being able to resolve the issue once all of the pipework had been installed. This meant that reworking was required to allow for insertion of the plates.

5.4 ROOT-CAUSE ANALYSIS

There were a number of contributing factors identified that resulted in the procurement and installation of knifegate valves, which were not designed to seal against a slip-on flange. This issue was believed to be caused by a number of factors:

1. Incorrect supplier literature – the literature listed the valves as being compatible with the DIN 2501 PN16 flange, which is identical to the EN 1092-1 Type 02 slip-on flange. This was the case only for valve sizes of 300NB and larger.
2. Inadequate verification during the procurement process – best practice is to seek manufacturing or shop drawings for the valves being procured, and to verify these against the type of flange being used. This is not common practice in New Zealand. Had this process been followed, it may have identified an issue with the valves integral sealing and the slip-on flange type.
3. A number of these valves had been installed against slip-on flanges at this site previously and it was incorrectly assumed that this also made them suitable to use during this project. Testing of the newly installed valves identified a potential cause of poor performance of existing valves.

5.5 LESSONS LEARNT

1. Valve manufacturing or shop drawings should be requested for all valves being procured. At a minimum, these should be compared with flange types specified for the job. While this is an aspirational ideal, it may not be achievable in practice for various reasons including supplier intellectual property.
2. Utilisation of site experience in determining valve issues – it was revealed that the site had a history of valve sealing issues with this type of valve when used in conjunction with slip-on flanges.
3. Identification of key risks when procuring valves – this valve's design rested entirely on the integral seal sealing against the flange to provide a leak-tight finish. Other valve options considered were not of this type of design. Identification of key risk items and then management of those risks is invaluable in avoiding installation and performance issues.
4. Providing that the valves are rated for the test pressure employed, pressure testing against valves confirms their performance. Had bench testing been carried out against blanking plates, it is unlikely that the valve issues would have arisen unless the bench test recreated equivalent installation and operational conditions.

6 IMPLEMENTING INDUSTRIAL COATINGS ON PIPEWORK AND CONCRETE

6.1 DESIGN

The adoption of coated pipework throughout much of the design process was driven by process fluid issues. Epoxy-coated mild steel (ECMS) pipe is typically employed for sludge pipework due to the low-oxygen environment generated inside the pipe. ECMS was also seen as cheaper than stainless-steel pipework. Unless process conditions dictated, all pipework was specified as ECMS, including those of small-diameter configurations.

Because of H_2S generation during the digestion process, a typical detail is to protect the digester's internal concrete surfaces exposed to digester gas. For Digester 8, a polyurethane-based concrete coating system was specified as satisfactory results had been achieved with this system on previous projects. Specification of the product's application was the supplier provided literature.

6.2 CONSTRUCTION

6.2.1 PIPE COATINGS

It was identified early in construction that it is impractical to internally coat pipework of less than 150 millimetres in size. During the application of coatings, a rotary sprayer is dragged through the pipe; this set-up simply cannot fit through a narrow internal bore and/or produce acceptable finishes. Pipework material was changed to stainless steel for these smaller-sized bore pipes.

Application of these coatings was subcontracted to paint specialists. The paint system specified was a high-performance, multi-coat paint system from a nominated paint supplier. Being a high-performance coating system, tight tolerances were specified on many of the application parameters. These parameters were beyond what is typical for industrial coatings.

To verify that the specification was being met, an independent paint inspector was engaged. His role was to inspect paint application during the painting process and perform final inspection upon completion. This was achieved by means of random visits throughout the painting of the pipework. Work that did not meet supplier specifications was rejected and completion of any reworking required.

6.2.2 CONCRETE COATINGS

During procurement of the concrete coatings the suitability of specified materials for Digester 8's internal environment was revisited. As a result, an alternative epoxy coating system was proposed and accepted. The internal conditions of the digester are highly corrosive to concrete; therefore, providing a suitable protective barrier over the concrete was a critical element in achieving the specified design life of the structure.

Multiple attempts were needed to meet the required standard of coating. The issues encountered arose from three broad areas:

- Resources – the availability of suitably experienced professional applicators and suppliers.
- Specification – lack of detail in the manufacturer's specifications on which the contract details were based
- Environment – extremely difficult conditions for the application of specialist coating products within a humid, confined environment, under low light and at height.

Work to repeatedly identify and remediate flaws in the surface coating added significant challenge, delay and cost to the project.

6.3 LESSONS LEARNT

1. Pipework of less than NB150 in size should not be specified as ECMS due to impracticality in coating.
2. Stainless steel offers superior site installation flexibility and site modifications compared with ECMS. Material cost savings of ECMS over stainless steel are offset by multiple handlings required for ECMS pipe (for example, site fit, shop fabrication, paint coating). This means the overall cost difference is marginal.
3. Requirements for the inspection of coatings must be clearly spelt out in the tender documentation. Watercare's standard specifications do not adequately identify extraordinary testing requirements.
4. A general low level of knowledge and skill of the requirements for applying industrial coatings is present in the local market, even amongst specialist applicators. Designers should try to minimise or eliminate industrial coating requirements in their design if possible – for example, through higher-strength concrete, greater cover or by means of admixtures.
5. In most situations, it is recommended as a requirement of the contract that an independent paint specialist be engaged by the constructor to advise the project team. The specialist's role should be to assist the project participants in specifying, procuring and achieving the required coating system.

7 INSTALLATION OF A LARGE-SPAN, FACTORY-FABRICATED, KITSET ROOF STRUCTURE

7.1 DESIGN

At the design stage, Watercare required that Digester 8 would have a gas-tight fixed roof as opposed to the floating roofs utilised on the existing digesters. This would provide additional operational flexibility, reduce gas leakage, improve the digester's capacity and lower the costs of maintenance compared with the existing floating-style roofs.

Because of site planning height restrictions and tank size, the digester required a 32 metre diameter free-span roof structure with a low overall height. There was limited local experience and capability to allow for such a large roof to be designed and fabricated. Therefore, it was decided at the design phase that a proprietary roof system would deliver a best-for-project outcome as it would:

1. Leverage the expertise of specialist digester roof designers and manufacturers to achieve a gas tight roof.
2. Influence the capability of international suppliers to fabricate and supply such a roof (only a small range of New Zealand-based fabricators could deliver such a requirement).
3. Utilise a high-quality, factory-applied coating, eliminating the need for hard-to-apply, on-site coatings.

The roof structure was included in the construction contract as a design-build item to be delivered by the constructor.

7.2 PROCUREMENT AND CONSTRUCTION

In procuring the roof, two international suppliers were identified that were able to meet the project requirements. Each of these suppliers offered a slightly different product, the key difference being that one was a fully welded roof with site-applied coatings and the other, a factory-coated roof, which was bolted together in situ. Recognising the importance of the coating system in the aggressive digester environment, the project team selected the bolted kitset option.

The design and fabrication of the roof was provided by an experienced USA-based company, with a local agent co-ordinating the design and installing the roof. Significant challenges were encountered when attempting to complete the detailed design:

- Level of expectation around the detailed design information required to be submitted by the specialist roof designer, who was reluctant to provide this. Such reticence was perceived as being on the grounds of intellectual property and customisation of a generic design into a small market.
- The difficulties arising from the offshore procurement of a complex design-and-build component of critical importance to the success of the project
- Resolution of ambiguities in the project's specification and the ability of a specialist supplier to meet the requirements with a product made up of standardised components.

Once the detailed design drawings were accepted, fabrication and factory coating were completed offshore. The roof was delivered in five shipping containers, and part-assembly of some components was able to be completed prior to erection.

To facilitate installation, the roof specialist’s local agent developed an innovative gantry structure. This gave a moving platform that could revolve within the digester to enable installation of roof components.

Figure 8 - Gantry Structure Used to Assist Roof Installation

Key difficulties experienced during installation of the roof were as follows:

1. Shipping damage – despite being well packaged, a number of items were damaged during transit from the USA.
2. Installation speed of the roof was affected by:
    a. Access restrictions limiting the amount of resource that could be assigned to roof construction. Assembly of the hundreds of roof components had to be mainly undertaken in situ, to meet the specified fabrication procedure.
    b. The complexity of the roof and the sheer number of components and site connections.
3. Roof to concrete tank interface – the requirements of the roof structure and the concrete on which it was to be situated was a key interface. Both the dimensional aspects and methods for achieving a reliable gas-tight seal proved difficult.

4. Mastic application – the effectiveness of the entire roof relied upon the correct application of mastic to all joints. In places this application needed to be undertaken at height and in confined work areas, making the proper control of this task problematic.
5. Testing – challenges in reaching agreement on the test regime for the roof. The method of testing was not clearly defined by either the supplier or the designer. An additional issue was subsequently locating the source of minor leaks, when the point of exit is often not reflective of the actual leak source within the roof.

7.3 LESSONS LEARNT

1. The procurement of critical items as design-and-build elements can pose challenges to complex multidisciplinary projects. Considerations include:
    a. Careful specification of requirements to ensure available options are not overlooked
    b. Clarity on the level of detail that likely suppliers will be willing to provide
    c. Elimination of ambiguity between client requirements, contract specifications and equipment providers
    d. Verification of information, such as programme durations, provided through experience on similar projects.
2. The innovative gantry structure was a good solution to the challenges of installing such a large roof at significant height without the need to erect a full scaffold within the digester.
3. Testing regimes should be prescribed and agreed during the design process.
4. Critical interfaces should receive detailed attention early in the design and construction processes, driven through the project risk processes.

8 TECHNIQUES USED TO ACHIEVE A CONSISTENTLY HIGH-QUALITY RESULT ACROSS A WIDE RANGE OF ENGINEERING DISCIPLINES

Being such a technically diverse project, co-ordination across disciplines, together with liaison with wastewater treatment plant operations staff, was essential in reaching a successful outcome. The challenging aspects of digester design and construction in general, and in particular of the Digester 8, were:

1. The number of engineering disciplines and stakeholders involved: process, mechanical, structural, geotechnical, electrical, instrumentation, software, architectural as well as client wastewater treatment plant operations, client projects staff, the contractor and many specialist subcontractors, a lead and sub-consultant designer. With so many parties involved, and each discipline essential to the project's success, all areas had multiple interfaces with multiple parties.
2. A strongly process-led design means that structural, mechanical and electrical disciplines have limited flexibility in their designs.
3. Design co-ordination between structural, mechanical and electrical disciplines required high levels of co-ordination between themselves and the existing systems.

8.1 CONSTRUCTION

During construction, the following approaches were utilised to ensure a consistently high-quality result was achieved:

1. Work plans were produced by the constructor for all areas of construction. These work plans were then reviewed and scrutinised by stakeholders.
2. Non-conformance reports – where works undertaken were not in accordance with the agreed work plan, or the resulting works did not meet the required contract or industry-standard result, the constructor completed a non-conformance report. Each report outlined the issue, the background, key causes, a proposed remedy, preventative and corrective actions, and then a close-out section. This enabled all parties to review the defective works and agree on suitable resolutions.
3. Independent inspection – for key quality areas, such as pipework painting, external expertise was brought on board by the client to independently inspect the execution of the works and check that the final result was within specification. This approach helped to ensure that sub-standard materials were not accepted into the final works.
4. Quality Assurance (QA) documentation – the constructor was not permitted to bring materials on site without first providing the appropriate QA documentation. This gave the advisory team time to review

the information and check for inconsistencies or non-compliant materials these were being included in the main contract works.

8.2 LESSONS LEARNT

1. Quality management systems greatly assist in achieving best-for-project solutions in often complex construction issues. The expectations of such systems should be clearly defined in the contract documents to enable them to be adequately resourced, provided that they are closely monitored and incorporated into plans and all programmes consistently followed.
2. Independent inspection should be implemented for all specialist areas for the benefit of all parties.
3. Regardless of value, on jobs with inherent complexity such as digesters a CM4 or CM5-level site presence is necessary.
4. Design co-ordination across structural, mechanical and electrical disciplines required high levels of co-ordination between themselves and the existing systems. The constructor’s ability to deliver on quality, time and cost can be affected by the degree to which design co-ordination and completeness is achieved.

9 DESIGNING AND CONSTRUCTING CONNECTIONS INTO LIVE PROCESS FACILITIES IN WELL-ESTABLISHED WASTEWATER TREATMENT PLANTS

9.1 DESIGN

Digester 8 required tie-ins into existing wastewater treatment plant services. A number of service connection points were provided for Digester 8 as part of previous upgrades. These were utilised in the design, with connections to, or minor modifications of, these service connection points specified in the design drawings. In development of these details, some planning and co-ordination with wastewater treatment plant operations staff had been undertaken. Limited effort was spent on the design and construction methodology for these connections. Considering the complexity inherent in some of the process tie-ins, design of a more comprehensive construction methodology may have been more appropriate.

9.2 PLANNING, CO-ORDINATION AND CONSTRUCTION

Planning and co-ordination for tie-ins coincided with the general mechanical pipework planning. Early on in the design phase, the key process tie-ins of sludge feed, sludge discharge and hot water were identified as high risk to the operating parts of the wastewater treatment plant. Each of these tie-ins would require a process shutdown to enable the tie-in to be executed. As a consequence of isolation locations, all of these key process tie-ins would result in operational digesters being removed from service for a short period of time. The principal tie-in risk was this removal from service – and the potential to cause process issues or eliminate the wastewater treatment plant operators' ability to intervene should process issues arise (for example, lowering the digester level as a result of foaming).

Another issue identified during tie-in planning was the period of time required to complete the tie-in works. To limit process risk, it was desired to minimise service outages. Because of the inherent uncertainties in existing pipework, tie-ins required a site fit element of typically flange connections. At a NB250 pipe size, each flange takes approximately three hours to weld, in addition to any painting, pickling or pressure testing required. Finding methodologies that minimised service outages but also optimised site installation to ensure a successful, water tight product was challenging.

To resolve this, where possible, outages were co-ordinated with general wastewater treatment plant maintenance activities (for example, sludge pipeline cleans). The contractor prefabricated as much of the tie-in pipework as possible, and in agreement with the client and consultant, stainless steel was selected over ECMS to enable a high-quality, site-fabricated result without the need for specialist coatings.

Through the concentrated focus of all parties and inclusion of stakeholders in the planning of key tie-ins, these were successfully completed on the project without unscheduled disruption to Watercare’s operations.

9.3 LESSONS LEARNT

1. At the design stage, tie-ins should be designed with at least one feasible way of being installed. This should include early input with wastewater treatment plant operators to ensure that process outages are

unlikely to affect the plant’s operations. Critical constraints and access restrictions should be clearly identified in the contract documents.

2. Planning and co-ordination are key – a significant number of meetings was held for all process tie-ins, beyond what was anticipated at the time of tender. This planning and coordination added value to the project and resulted in best-for-project outcomes. Consultants and contractors should resource adequately for this.