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RIVER PUMP ROOM ISOLATION FROM STATE LIBRARY

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Abstract

The Millennium Arts Project on the Brisbane River in Brisbane City is one of the largest State Government building projects undertaken in Queensland Australia for many years. Air-conditioning for the site is provided by the Central Energy Plant located in a dedicated building. This system receives its cooling water from a large river pump room located underground near the State Library of Queensland (Library) and Gallery of Modern Art (Gallery). The River Pump Room comprises 900kW of pumping capacity combining 3 submersible pumps and 3 plant room pumps. The initial design situated the pump room with a common wall to the Library which raised serious concerns regarding structure-borne noise and vibration.

This paper discusses some of the design process and selection of a suitable system to minimise the structure-borne noise and vibration transmission. The design solution included structural separation of the Pump Room from the Library and Gallery, and vibration isolation of the elements of the River Pump Room system. Vibration isolation of the submerged pump sets presented various design challenges including: buoyancy effects of the tidal river channel system, potential bridging of the vibration isolation system by foreign objects (under base), provision of accurate horizontal positioning, and allowance for maintenance of pumps and motors. The buildings opened in December 2006, and the results of testing undertaken with the River Pump Room operating are described in the paper. The designed systems have achieved a successful outcome, and will allow staff and the public to quietly enjoy their new Library and Gallery for generations to come.

1. INTRODUCTION

In 2002 design work commenced on the Millennium Arts Project located on the South bank of the Brisbane River in Brisbane City. The project was one of the largest State Government building projects undertaken in Queensland Australia for many years. The works included: doubling the size of the State Library of Queensland, construction of the Gallery of Modern Art, development of additional underground car parking with plaza entry area at ground level, upgrading of the Central Energy Plant, and construction of new entry points to the existing

Queensland Art Gallery and Queensland Museum.

Cooling water for the Central Energy Plant was to be provided by water from the Brisbane River rather than conventional cooling towers. The cooling system comprised: an underground culvert from the Brisbane River into the River Pump Room (Pump Room) well, three submersible pumps to provide river water to the heat exchangers in the Pump Room, and three pumps to circulate the cooling water between the heat exchangers and the chillers in the Central Energy Plant building over 100m distant. Figure 1 shows the location of the Pump Room system. The Pump Room well was designed to have river water from 2m to 4m deep at low and high tide respectively. The Pump Room was located adjacent the Library due to its proximity to the Brisbane River.

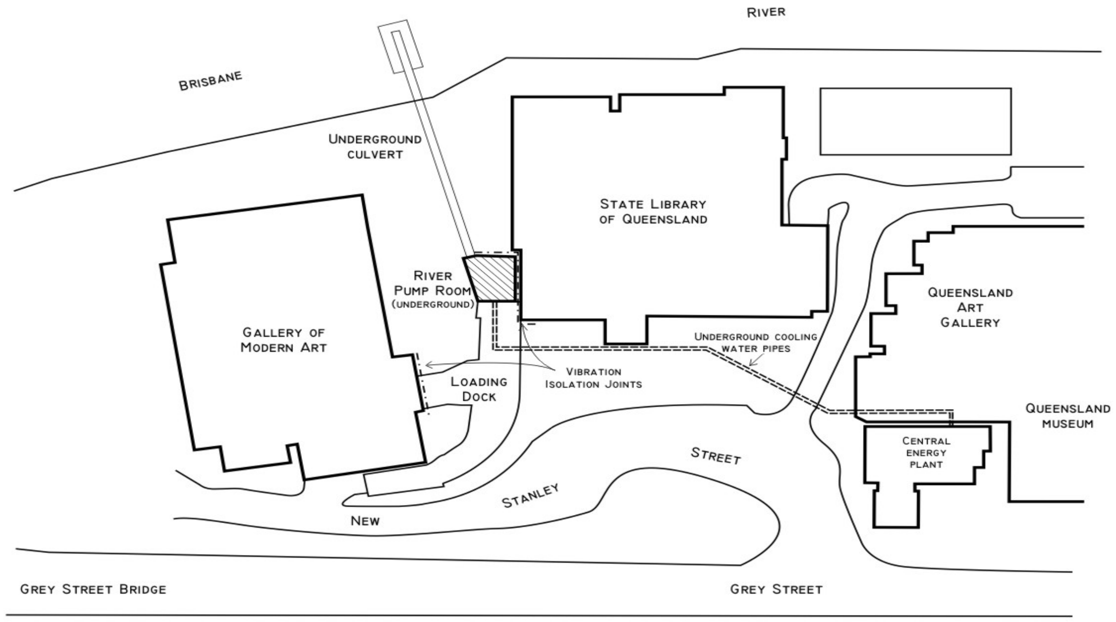

Figure 1. Site layout showing river water culvert, River Pump Room, Library, Gallery, and pipes to the Central Energy Plant.

2. CONFIGURATION OF RIVER PUMP ROOM

The initial site layout showed the Pump Room with a common wall to the Library. This wall passed through several noise sensitive spaces within the Library including the Indemnified Gallery – a space for display of special collections from Australia and overseas. This raised serious concerns regarding structure-borne noise and vibration travelling though the structure into the Library, particularly as the Pump Room contained 6 x 150kW pumps, which were to be rigidly bolted to the concrete floor, as this was the standard industry approach for these larger types of pumps. It was found that limited noise or vibration data was available for the pumps, as they were typically used in industrial installations where structure-borne noise and vibration was not an issue. Consideration was given to measuring noise and vibration levels from similar pumps used at a sewage pumping station by the Gold Coast City Council. However the pump wells presented difficulties from a Workplace Health and Safety view point, as they were underground wells with access restricted to staff with “confined space” training and experience. Gas inside the wells also posed a potential safety problem. Hence it was determined that measurement was not practical. To achieve a high level of isolation for the Library and Gallery it was recommended that the Pump Room be built as a separate structure to the Library and Gallery, with the pumps and equipment isolated from the structure of the Pump Room.

The initial approach was to relocate the Pump Room some distance away from the Library and Gallery structures; however this was constrained by the need to provide access to the underground pump room via the proposed loading dock that connected the basements of the two buildings. Several options were considered, however it was ultimately agreed that the Pump Room would need to be located within 1m of the Library. This achieved the primary aim of having no direct connection between the Pump Room, Library and Gallery structures. Figure 2 shows the location of the Pump Room relative to the Library, and the isolation joints. The space between the Library and Pump Room was used as an access corridor and provided a sound lock between the Pump Room and the Library. Pump Room access stairs were located in this corridor and were designed to be cantilevered from the Pump Room wall with no contact to the Library wall, to maintain the isolation break between the buildings.

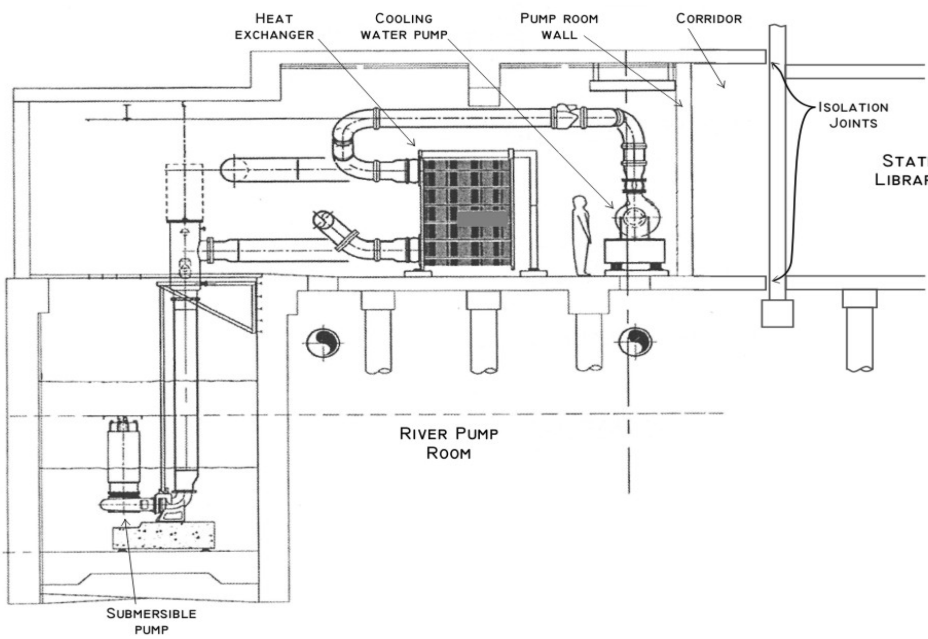

Figure 2. Section showing Pump Room wall, corridor and Library. Note the separate foundations and isolation joints.

The Pump Room structure was designed as part of the loading dock ramp, which was installed on separate piles to the building structures. Figure 1 shows the location of the loading dock and the isolation joints that separate it from the Library and Gallery. Through discussions with the structural engineers the distance between the Pump Room piles and building piles was maximised and set at 3m. The plan to combine the Pump Room with the loading dock increased the mass of the structure supporting the pump sets, therein theoretically reducing the likelihood of vibration excitation resulting from pump operation. It was also expected that some damping effect would occur from the soil pressure exerted on the walls of the structure (being underground), further reducing the anticipated vibration transfer between structures. Isolation joints were designed to resiliently connect the three structures while still meeting functional requirements. The joint between the Library and Pump Room had to be water proof, as it formed part of the paved Plaza at ground level, and hence would be open to the weather including rain. This was achieved using a sliding joint, with a gutter underneath to catch any penetrating moisture. The loading dock joint had to be designed to withstand forklifts passing over it, and this was achieved using embedded steel sections and a recessed resilient seal. The joints provided a nominal gap of 25mm between the concrete structures to allow for structural movement.

3. ISOLATION OF SUBMERSIBLE PUMPS

The submerged pumps proposed for the project were typically secured directly to the floor of the well as this type and capacity of pump is usually installed in industrial surroundings (eg. sewage pumping stations), and hence noise and vibration is usually not an issue. Direct fixing simplifies the installation by minimising effects from water flow turbulence, variation in submerged height, and any imposed turning moment or out-of-balance forces. As a result noise and vibration information was very limited and there was no “standard solution” to vibration isolation of the pumps, however this was seen as an important component in meeting the requirements for noise and vibration in the adjacent Library and Gallery. To further complicate the design process, the submersible pumps had a “duck foot” arrangement which enabled the pumps to be hoisted for maintenance, and then lowered back into position where they formed a watertight seal with the pipe work. The “duck foot” required good alignment of the pump in order to achieve the required seal, which conflicted with the desire to isolate the pumps using resilient isolators. Figure 3 shows a section of the River Pump Room well.

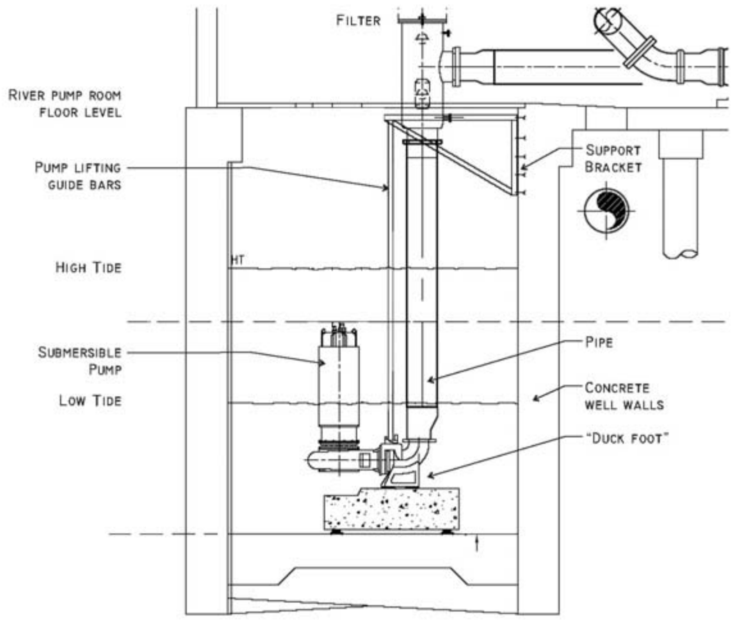

Figure 3. Section of River Pump Room well showing one of the three submersible pumps fixed to the inertia base mounted on rubber isolation mounts, “duckfoot”, pump lifting guide bars and bracket.

The solution adopted was to directly fix each submersible pump onto a large concrete inertia base (to provide the required alignment), and to install suitable vibration isolators between the inertia base and structural floor of the Pump Room well. A range of isolator types were evaluated for potential inclusion: X-Type and Lattice Type rubber isolators, galvanised and stainless steel coil spring isolators, and elastomeric isolators with various compounds and Shore A Hardness. The most suitable combination of isolation performance, stability and longevity was found to be rubber cup type isolators (made of a salt water resistant compound with stainless steel metal inserts and fasteners for corrosion resistance) with up to 12mm static deflection (at operating loads). The vibration isolation system was designed so that minimal height change (nominally 3mm) would occur with the removal of the pump or motor for maintenance to avoid issues such as pipe rupture or change in pipe position.

Calculations were undertaken to confirm the isolation efficiency achieved over the pump speed range (ie. 960rpm – 1440rpm), and taking into account the changing buoyancy effects from pump casing, motors, pipe work and inertia bases depending on the tidal river levels. The lower speed which is more difficult to isolate, combined with high tide (maximum buoyancy effect resulting in less weight on isolators), resulted in a minimum efficiency of around 70%. At low tide and high speed an efficiency of 91% would be achieved. While this was less than the 95% efficiency achieved for other spring mounted pumps in the Library, it was considered the "best available" solution given the constraints, and still represented a significant improvement over the pump being directly bolted to the floor of the well.

Allowance for variable imposed turning moments (for cantilevered sections attached to the inertia base) was required in order to complete the design selection and position of the isolators. Figure 4 shows the layout of the isolators on the inertia bases.

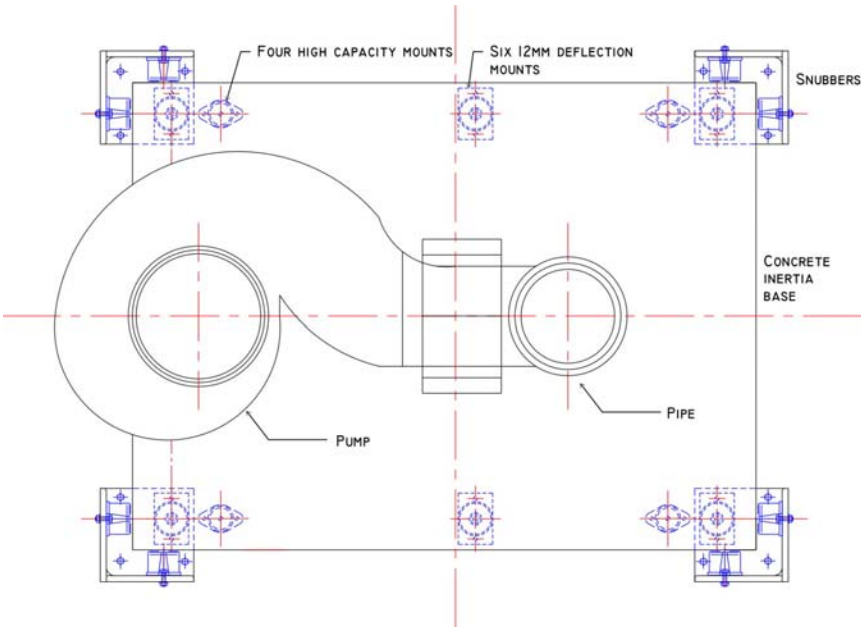

Figure 4. Plan showing location of isolators for the submersible pump inertia bases. Six isolators located to take account of the turning moment on the inertia base, and four higher Durometer isolators to carry the weight of the inertia block and pump when there was no buoyancy effect. Snubbers were located at each corner to resiliently locate the inertia base.

Consideration also had to be given to the longevity of the isolation system, and minimum clearances required under the pump sets to avoid bridging and loss of isolation efficiency. In addition to the 6 x 12mm deflection mounts, four high capacity mounts were included to allow for maintenance / emptying of the Pump Room well and initial construction when there would be no buoyancy effect. Low profile mounts were selected to ensure they cleared the floor of the well during normal operation of the pumps (ie. when submerged).

Consideration was given to various methods to periodically clean any mud/ debris under the inertia blocks. However data provided by the well designers indicated that the river water silt/ debris would remain in suspension in the well, as the culvert was designed to allow all of the heavier materials to precipitate prior to reaching the well.

In order to locate the inertia blocks and avoid them moving over a period of time, it was necessary to provide resilient restraints. Various options were considered, the most simple being to bolt through the base of the rubber isolation mounts, however this proved impractical as the mounts were located under the inertia base and hence the bolts could not readily be installed. The final installation used "snubbers" - stainless steel brackets with two rubber isolators positioned on the four corners of the inertia bases. The brackets were installed with the isolators just touching the inertia base, so that they would not limit vertical isolation, but would provide immediate lateral restraint if the inertia block started to move.

4. ISOLATION OF COOLING WATER PUMPS

Isolation of the Cooling Water Pumps used a more traditional approach, with the pumps mounted on concrete inertia bases on 25mm deflection open steel springs selected to provide 95% isolation efficiency. The base plate of the spring mounts included a rubber pad to control transmission of high frequency vibration to the structure, and the springs were bolted in position using rubber isolating sleeves and washers. Springs were mounted on brackets off the sides of the inertia bases to allow the centre of gravity of the inertia base plus pump to be lowered to improve stability. Figure 5 shows one of the installed cooling water pumps.

The pumps are usually installed vertically (when rigidly bolted to the floor as per industrial installations), however concerns were raised regarding the stability of the 1.5m high pumps if mounted on springs. To address this, the pumps were laid on their side (rather than standing vertically) to reduce vibration levels, and improve stability.

Figure 5. Photograph of installed cooling water pump, with inertia base on spring mounts and flexible connection to pipe work.

5. ISOLATION OF ANCILLARY EQUIPMENT

Resiliently sealing the 400mm diameter water pipe penetrations of the River Pump Room floor and walls presented a challenge, as they had to withstand the hydraulic pressure of the ground water. "Link seals" were installed to address this issue. The seals comprise a series of rubber elements linked together by bolts. The link seal is placed over the pipe and into the gap in the concrete, and as the bolts are tightened the rubber elements expand to form a watertight resilient seal between the pipe and concrete. In addition to isolating the pipes as they passed through the Pump Room structure, care was required when laying the underground pipes to ensure that they did not contact any piles or concrete slabs associated with the loading dock, Library or Gallery.

All pipe work and ventilation fans in the Pump Room were hung or supported on 25mm static deflection spring mounts, to minimise vibration radiated into the Pump Room structure. The heaviest of these elements was the filter located above the submersible pumps. These are backwashed with water and required selection of specific spring hangers. Care was taken during installation to ensure that the suspension rods did not contact the cage of the spring hangers. Isolation of ventilation ducts and cable trays was achieved by providing resilient elements prior to contacting the Library structure. Ventilation ducts incorporated flexible connections and electrical cable trays had a break between trays with slack in the cabling.

The brackets designed to support both the River Water Pump pipes and pump lifting guide bars had to be isolated from the well wall, as the submersible pumps did not have rubber bellows due to the “duck foot”. Discussions with the pump suppliers indicated that due to alignment requirements it was not practical to install higher deflection mounts on these brackets. Pad mounts were selected to avoid resonance and meet the alignment requirements. The brackets were bolted to the wall using ribbed rubber pads under the brackets, with isolating rubber sleeves complete with stainless steel fixing sleeves inside and rubber washers with stainless steel spreader washers over to allow the brackets to be secured in place. The hollow pump lifting bars were core filled with a suitable grout to reduce radiated vibration and noise.

The heat exchangers were over 2m high and were supported on three steel legs, usually bolted to the floor for stability. To avoid resonance and maintain stability of the units (eliminating higher deflection mounts), pad mounts similar to those for the brackets were used. Pipes were connected to the heat exchangers using rubber bellows, to minimise transfer of vibration. This was particularly relevant for the submersible pumps as the duck foot arrangement did not allow for flexible bellows between the pipe and the pump.

The six variable speed drive units (to control the pump speeds depending on the demand for cooling water) were resiliently mounted on the Pump Room walls.

6. NOISE CONTROL

Noise control treatments were required to achieve suitable noise levels of 55dB(A) for Library and Gallery staff working in the loading dock and nearby sorting areas. Treatments were designed to contain the Pump Room noise including: insulation and perforated metal linings to ceiling and wall areas; 45mm solid core timber doors to the sound lock corridor; Rw40 steel acoustic rated doors between the Pump Room and loading dock; and acoustic linings to ducts penetrating the Pump Room walls to control breakout noise. Penetrations of the walls by cable trays and ducts were resiliently sealed. The walls to the Pump Room provided adequate noise isolation being 200-300mm thick in-situ concrete for structural requirements.

The noise control materials were corrosion protected as per all other elements in the Pump Room (eg. colour bond steel, aluminium, galvanised steel, or stainless steel) due to the high moisture content from the river water in the well. The wall linings were stopped nominally 300mm above floor level to allow for spillages/ wash down in the plant room.

7. MEASURED OPERATIONAL LEVELS

Following installation of the pumps and ancillary equipment, noise and vibration monitoring was undertaken to confirm that the treatments had successfully contained the Pump Room sources. Noise levels were measured inside the Indemnified Gallery of the Library, and several other spaces including the Gallery of Modern Art. Pump noise with all 6 pumps operating in the low speed range was just audible as a low frequency hum in the Indemnified Gallery. The measured pump level was 24dB(A), and peaked at 22dB 'A' weighted at 40Hz, with all 6 pumps operating. This met the design level of 25dB(A). This low speed measurement was considered to represent a "worst case" scenario for structure-borne noise and vibration as the pumps would be operating closer to resonance as previously discussed. Operational levels would typically be lower as the system is designed to operate with four pumps, leaving one pair of pumps on stand-by. Investigations revealed that the level reduced notably when the cooling water pumps were turned off, suggesting that these pumps or associated pipe work were the main source of the structure-borne noise, however as the criteria were met further treatment was not warranted. Vibration measurements were also taken at various locations, but due to the low vibration levels and limited time in the commissioning program these were less conclusive.

The noise level in the Pump Room was 81dB(A) with four pumps operating, which enabled the level in the loading dock to be met. One of the more noisy events in the River Pump Room was the periodic backwashing of the filters associated with the River Water Pumps.

8. CONCLUSIONS

Despite the lack of available noise and vibration data for the river pump room system, suitable structure-borne noise levels were achieved in the Library and Gallery with the use of a separate building construction, and vibration isolation of the pumps and other elements in the room. The submersible pumps were able to be isolated through the use of inertia bases mounted on suitably selected isolators. Investigation revealed that the low level of structure-borne noise was primarily associated with the cooling water pumps.