Attachment 14

Options Analysis Report

AtkinsRéalis

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- ☐ **01 – REVIEWED AND ACCEPTED – NO COMMENTS**
- ☐ **02 – REVIEWED – INCORPORATE COMMENTS, REVISE AND RESUBMIT**
- ☐ **03 – REVIEWED - NOT ACCEPTED**
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Bay d'Espoir Unit 8 FEED

Newfoundland & Labrador Hydro

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OPTIONS ANALYSIS

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Contents

INTRODUCTION

APPENDICES

INTRODUCTION

This report contains a high-level improvement study with respect to potential enhancements as compared to the existing Unit 7 for inclusion in the design of Unit 8 for Powerhouse No. 2 of the Bay d'Espoir Generating Station. Descriptions of options considered are provided, including their advantages and disadvantages with respect to safety, reliability, economics, ease of maintenance and ergonomics. An order of magnitude cost estimate has been provided for several options in the report.

1. Executive Summary

Conceptual evaluation with respect to the options listed in Section 3 was carried out to ascertain the advantages and disadvantages of each option. Quantities for major items of work were requested through Request for Information (RFIs) to potential suppliers in addition to request for budgetary quotations, where required. Response to these requests were low despite multiple follow-ups. Section 4 highlights the information and quotations received for some of the recommended options.

A cost analysis will be considered for the following items at a high-level after budgetary quotes have been received from Turbine Generator OEMs (Original Equipment Manufacturers).

- Runner model testing versus Computational Fluid Dynamic Analysis (CFD).
- Equipping the new unit with synchronous condenser capabilities.

At the time of issuance of this report, runner model test cost has not been received from OEM, and therefore cannot be provided within this Bay D'Espoir Unit 8 Front End Engineering & Design (FEED) phase. .

The following table outline summarizes the given recommendation of each option.

	Options	Recommendation	Comments
1	Eliminate the Use of Heat Stretch Fasteners	Recommended as per modern Industry practice	Supply cost from Nordlock ~ [redacted] for three couplings.
2	Removal of the Draft Tube Cone and the Runner for Maintenance Without Unit Disassembly	Not Recommended	Not feasible due to powerhouse layout limitations
3	Addition of Main Inlet Valve to Support Maintenance Without Penstock Dewatering	Spherical Valve is not recommended due to high supply cost as well as additional cost for infrastructure. Additionally, non-availability of space in powerhouse is another constraint.	Supply cost from Voith ~ [redacted] (This cost does not include infrastructure and O&M costs)
4	Addition of Penstock Filling Valve	Recommended	Filling valve is recommended as well as an upstream sealing gate design

5	Greaseless Wicket Gate Bushings	Recommended as per modern Industry standard.	Supply cost from Thordon for Thermoplastic material ~ [redacted] (Operating ring bushing cost is included)
6	Oil Free Lower Guide Bearings	Recommended	Supply cost from Thordon for water lubricated bearings ~ [redacted]
7	Dust Collection System for Collector Rings and Brakes	Recommended	Supply cost from Mersen ~ [redacted] for Collector ring Supply cost from Voith [redacted] for Brakes
8	Cooling Water Pumps Versus Pressure Reducing Valves (PRV)	PRV system is Preferred	Cooling water pump cannot be completely ruled out. PRV system is the preferred option if rupture discs will be replaced with safety valves.
9	Service Elevator	Recommended	An estimated cost for supply of a similar elevator from another project in 2022 ~ [redacted]. Plus approx [redacted] for excavation.
10	Pressure Relief Method	Elimination of Pressure Relief Valve is recommended	To be further discussed with Turbine Generator Suppliers in detail design phase

11	CFD and Turbine Model Tests	Physical Model Test in conjunction with CFD is recommended	Cost of the model test provided in [redacted] New cost is requested from OEMs.
12	Synchronous Condenser	N/A	The benefit cannot be accurately quantified by AtkinsRéalis. Cost is requested from OEMs. Cost of Depression system for Synchronous Condenser operation [redacted]

2. Unit Capacity Improvement

Documentation provided by NL Hydro for Unit 7 of Bay d'Espoir Generating Station was reviewed to obtain the design parameters such as head loss and net head. These were used to develop potential improvement of the new Unit 8.

The improvement study to assess the possibility of increasing the unit capacity was initiated based on the same assumptions from the *Report on Hydrology and Feasibility Study for Potential Bay D'Espoir Hydroelectric Generating Unit No. 8* (Hatch, 2020) and the *1974 Report on the Extension of the Power Generation Facility at Bay D'Espoir (ShawMont, 1974)*

From 2022 Hatch report, Unit capacity of 154.4 MW was assumed and feasibility of it was confirmed by AtkinsRéalis. From the *Hydraulic Analysis of the Conveyance System Report* (SNC-Lavalin, 2018), the discharge of 102 cubic meters per second was considered for Unit 8 and accordingly, in this report, the feasibility of increasing the capacity to 155.25 MW was obtained and assessed for different net heads and head losses by simulation methods.

The review of the existing draft tube size and setting for Unit 8 in Powerhouse 2 led to the conclusion that the discharge equivalent to the installed Unit 7 could be accommodated safely without risk of cavitation in this hydraulic passage. Therefore, the discharge of 102 cubic meter per second was considered for Unit 8.

It was concluded that the installed capacity can be increased to 155.25 MW for the given runner setting of 1.22 m with respect to the minimum tailwater level of 1.22 m, estimated based on empirical formulae (JL Gordon, 1990), taking into consideration the restriction of the existing draft tube outlet. The table below summarizes the results of the runner setting calculation for Unit 8 for capacities of 154.4MW and 155.25MW.

BayD Espoir Unit 8 — **Summary - Runner setting calculation**

Description	Symbols	Units	Installed capacity 154.4 MW			Installed capacity 155.25 MW		
			Max net head	Average net head	Minimum net head	Max net head	Average net head	Minimum net head
FSL	FSL	m.	184.2	184.2	184.2	184.2	184.2	184.2
MOL	MOL	m.	178.3	178.3	178.3	178.3	178.3	178.3
Operating FSL		m.	184.2	182.23	178.3	184.2	182.23	178.3
Operating TWL Low/high tide	TWL_{op}	m.	1.22	1.5	3.5	1.22	1.5	3.5
Gross head	H_G	m	183.0	180.7	174.8	183.0	180.7	174.8
Head losses	H_{loss}	m.	5.35	5.49	5.92	5.41	5.56	5.99
Net head	Hn	m	177.63	175.24	168.88	177.57	175.17	168.81
Installed capacity		MW	154.4	154.4	154.4	155.25	155.25	155.25
Rated discharge	Qr	m3/s	96.7	98.0	101.7	97.3	98.6	102.3
Evaluation of output								
T-G Combined efficiency		%	91.6%	91.6%	91.6%	91.6%	91.6%	91.6%
Expected output	P_G	MW	154.40	154.40	154.40	155.25	155.25	155.25
Runner setting								
Speed	N	rpm	225	225	225	225	225	225
Runner outlet diameter	D3	m.	3.45	3.45	3.45	3.45	3.45	3.45
Operating TWL	TWL_{op}	m.	1.22	1.5	3.5	1.22	1.5	3.5
Calculated Suction head (-ve means Runner C/L is below TWL)	Hs	m.	0.15	-0.15	-1.01	0.02	-0.28	-1.15
Calculated Runner centreline	$T_{CL} = Hs+TWL_{op}$	m.	1.37	1.35	2.49	1.24	1.22	2.35
Desired Runner centreline	R_{EL}	m.	1.22	1.22	1.22	1.22	1.22	1.22
Conclusion on runner setting, Suitable if $T_{CL} > R_{EL}$			Suitable	Suitable	Suitable	Suitable	Suitable	Suitable

3. Options Review

The feasibility of the options listed below has been assessed along with advantages and disadvantages of such options. The associated high-level costs of the preferred/recommended options will be further evaluated in coordination with OEMs.

3.1 Eliminate the Use of Heat Stretch Fasteners

Heat stretch fasteners are used in the following couplings for Unit 7:

- Between generator rotor to generator shaft
- Between generator shaft to turbine shaft
- Between turbine shaft to runner

For Unit 8, heat stretch fasteners can be replaced by mechanical tensioners such as Nord-Lock Superbolt Multi-Jackbolt Tensioners (refer to Appendix A).

The mechanical tensioning is provided with the multi-Jackbolt tensioner which divides the load among multiple small jackbolts.

The advantages of using mechanical tensioners are as follows:

- Tightening in pure tension allows higher pre-loads with greater accuracy than the heating method.
- Improved bolted joints as they generate pre-loads above the separating forces. Preloads that exceed separating forces prevent bolts from vibrating loose.
- Easy to work with as they divide the load among multiple small Jackbolts.
- Can be installed or removed by a single worker with ordinary hand tools. Two or more technicians can work side-by-side, reducing installation time.
- Quick installation and disassembly reduce the expense of extended shutdown time.
- Eliminate dangerous pinch points, heavy-equipment lifts and tool-shattering stresses.
- Superbolt tensioners are reusable. Pre-load can be restored anywhere with a simple hand tool.
- Using the mechanical tensioner is modern industry practice.

There is no major disadvantage in using Superbolts although they are more costly than heat stretch fasteners. They have been used in the hydropower industry since the 1980s.

Use of Nordlock Superbolt or approved equivalent mechanical tensioners are recommended due to the above advantages.

An RFI (Request for Information) was sent to Nord Lock group for a budgetary quotation and a response was received. Refer to Section 4.1 and Appendix A for the budgetary quotation and all correspondence.

3.2 Removal of the Draft Tube Cone and the Runner for Maintenance Without Unit Disassembly

Bottom removal of draft tube cone and runner is not feasible due to large size of the runner, draft tube cone and the bottom cover. This was reviewed with reference to the proposed layout for the Powerhouse, as discussed below.

Runner and draft tube cone removal requires a hatch opening of 4.1m x 4.1m at every floor, which can be available between Bayline C-D & 9-10 on the General Arrangement drawings for Unit 8 (refer to Appendix B, Sketch 1, Figure 1, 2 and 3). However, the bottom cover needs to be removed prior to removal of the runner for which an opening of 7 m diameter is required in the concrete. There is no space for such a large opening in the powerhouse. Although the bottom cover can be fabricated in pieces, its assembly, disassembly, and alignment would be time consuming and very difficult.

Minimum gallery size of 4.1 m (W) x 2.2 m (H) is required at Elevation 0.305 m to transfer the runner or the split draft tube cone in the powerhouse. The gallery no.3 in the powerhouse is smaller than the minimum space requirement.

The estimated weight of the runner is approximately 24 tonnes which requires a high-capacity lifting device for its removal at the location. The lifting device cannot be installed inside the turbine generator unit.

For all the above reasons, removal of the runner and the draft tube cone from the bottom are not feasible and not recommended. (Refer to Appendix B, Sketch 1, Figure 1, 2, 3A, 3B, 3C, 3D, 3E for schematics).

3.3 Addition of Main Inlet Valve to Support Maintenance Without Penstock Dewatering

The turbine main inlet valve (MIV) has an internal diameter of 4.2 m and weighs approximately 150 tonnes. The overall space required for the MIV including the layout of its associated components and the overhead crane lifting requirement for first installation or future removal, is about 8 m wide by 10 m long by 10 m high (Refer to Appendix B, Sketch 2, Figure 4, 5A & 5B). This minimum required space is not available inside the existing powerhouse. Therefore, due to space constraints and lack of the existing crane hook approach, the MIV cannot be installed inside or close to the powerhouse. It can be installed at a location approximately 132 m upstream of Powerhouse 2 (refer to Appendix B, Sketch 2, Figure 6).

This will require a separate MIV house consisting of an overhead crane and a hydraulic power unit (HPU). Since the operating head (including water hammer) at this location will be less than 200 m, a butterfly valve can be installed instead of a spherical valve as a cost saving measure.

The advantages of using the MIV are as follow:

- Maintenance of the unit will be performed without dewatering the full penstock. This will reduce the unit outage duration and consequently the loss of power generation.
- The MIV can be closed in an emergency event to stop the flow of water to the turbine in the event guide vanes are not capable of being closed under runaway speed.
- During unit shutdown, the guide vanes will be closed, however leakage through the wicket gates is inevitable. The MIV will provide an isolation device upstream of the unit and will minimize the leakage.

The disadvantages of using the MIV are as follow:

- Because the MIV cannot be accommodated within the powerhouse, a large building of approximately 10m wide x 12m long x 14m high is assumed to accommodate for an overhead crane and the associated MIV components.
- MIV house is required to be enclosed and continuously heated in a cold climate.
- Access road would need to be provided to the MIV house for operation and maintenance purposes.
- Addition of the MIV into the penstock will introduce hydraulic losses and slightly reduce the efficiency of the generating unit.
- Space within the powerhouse and overhead crane hook approaches is not available for MIV. Even if space is created for MIV by relocating step-up transformers, bus duct, other electrical items, and Unit 8 footings, the assembly and disassembly of MIV by overhead crane would be difficult and time consuming. (an alternate location of MIV is proposed in a location upstream of powerhouse, however the location of the MIV and the access road to the MIV building is not further investigated. Refer to Appendix B, Sketch 2, Figure 6 for schematic location of MIV).
- There will be a significant capital cost (cost of valve building and the access road) in addition to the [redacted], as well as a significant and continuous O&M cost to maintain the valve ,its auxiliary and control systems, its dedicated building and dedicated access road.

So, addition of a MIV is not recommended as per the above dis-advantages.

RFIs were sent to valve suppliers for a budgetary quotation for supply and installation of the MIV for Unit 8. Only one quotation was received from Voith Hydro. Refer to Section 4.3 and Appendix C for the email correspondence.

3.4 Penstock Filling Method

Addition of a penstock filling valve is feasible in terms of space, accessibility, ease of operation and maintenance. A penstock filling valve can be installed on a bypass pipe to the intake gate at the intake structure. The valve can be operated by a long stem actuator. The long stem actuator would be installed in a heated pit.

The advantages of using the penstock filling valve are as follow:

- Allows filling of the penstock without opening of the gate.
- Filling rate of the penstock can be controlled by the penstock filling valve.

The disadvantages of using the penstock filling valves are as follows.

- For maintenance of filling valve, an upstream isolation valve is also required.
- Requires a pit to accommodate the filling valve as well as isolation valve.
- Heating system is required during winter conditions.
- Filling with a valve will be slower that cracking a gate because rapid filling would require a very large valve which would not be economical.

An alternative scheme was reviewed for the Unit 8 intake gate using an upstream sealing gate during this FEED phase (refer to Appendix D for a concept sketch). The intake gate for Unit 7 is a downstream sealing type. The upstream sealing gate will allow for filling of the penstock via cracking the intake gate, hence potentially eliminating the need for inclusion of a penstock filling valve.

The advantages of using an upstream sealing gate and crack opening of the intake gate are as follows:

- Faster filling of the penstock when required.
- Lighter intake gate structure for an upstream sealing gate, resulting in lower supply cost of the gate.
- Upstream sealing gate requires lower lifting loads and lower capacity for the hoisting system, hence lower supply cost of the hoist.
- Upstream sealing gate design would be more reliable than a downstream sealing gate with respect to emergency closure of the gate against flow.
- Redundant limit switches will be included to ensure the gate will not move beyond the cracking open position.

The disadvantages of using an upstream sealing gate are as follows:

- Requires a heated hoist house with a large maintenance area in the gate shaft under the deck.
- The hoist house will require a ventilation system design with many louvers and dampers to prevent catapulting effect (forceful rush of air during gate emergency closure in the direction perpendicular to the flow).
- Different operational and control requirement from the other existing units (All seven existing units are downstream sealing type).

Addition of a penstock filling valve is feasible and recommended. However for back-up, it is also recommended to design and use the Intake gate as an upstream sealing gate to facilitate filling the penstock with crack opening of the Intake gate.

Refer to Section 4.4 and Appendix D for preliminary drawing and details.

3.5 Greaseless Wicket Gate Bushings

The greaseless wicket gate bushings can be installed in the new turbine for Unit 8.

The advantages of greaseless wicket gate bushings are as follows:

- Serviceable without the need for lubrication and maintenance free;
- Submerged application;
- High performance under high load and low speed operations;
- Wear resistance, corrosion resistance and chemical attack resistance;
- Environmentally friendly;
- Lower operating and maintenance cost; and
- No grease, therefore, reduced slipping hazards in the turbine pit.

There are no major disadvantages of greaseless wicket gate bushings. However, Thordon plastic bushings has increased susceptibility to thermal expansion. OILES provides the lead-free solid lubricant brass material bushing to address thermal expansion. Refer OILES catalogue in appendix E. Other minor disadvantage might be that high initial friction resistance can create a less refined movement. Precision is slightly lower than the grease type wicket gate bushings, but appropriate performance can be achieved on the bearing applications.

Greaseless wicket gate bushings are widely used in the industry and are recommended for Unit 8. Greaseless wicket gate bushings were successfully implemented in three 50 MW Francis turbines in the John Hart Replacement Project in British Columbia, which was successfully commissioned in year 2019.

An RFI was sent to bearing suppliers for a budgetary quotation. A quotation was received from Avalon Bearings for supply of Thordon material. Refer to Section 4.5 and Appendix E for the specification and budgetary quotation. Although OILES brass lead-free lubricating bushings is recommended, no reply to the cost inquiry were received from the OILES.

3.6 Oil Free Lower Guide Bearings

The oil free lower guide bearings can be designed and installed for new turbine for Unit 8.

The advantages of oil free lower guide bearings are as follows:

- No oil lubrication, therefore, no oil leakage, and oil top up and dirty oil cleaning are not required, resulting in reduced maintenance and operating cost.
- Environmentally friendly with no oil spill into the river; eliminating water pollution.
- Water lubricated bearings allow the shaft seal assembly and turbine guide bearings to be arranged in a simple and compact way streamlining the maintenance of the unit.
- With water lubricated bearings, the shaft seal assembly is easily accessible and the bearings themselves can be quickly inspected and replaced. If the bearings are damaged and required to be replaced, only the non-metallic bearing inserts are needed to be replaced in a couple of hours.
- No oil is being used, no oil contamination for the filtered cooling water. Filtered cooling water system will be supplied by either dedicated filters or from the cooling water system.

The disadvantages of oil free lower guide bearings are as follows:

- The oil free lower guide bearing requires continuous filtered cooling water system. This can be mitigated by providing the dedicated filter for guide bearing or by supplying clean water from cooling water system with desired filtration rating.
- If there are particles and abrasive materials in the water supply, the bearing life can be significantly reduced. The filtering system however can be supplied by the bearing supplier such as Thordon. (Refer to Appendix E for more details).
- Given the low viscosity of water, water lubricated bearings tend to operate in a boundary or mixed lubricated regime for relatively longer periods especially when considering low sliding speeds and/or stop/start cycles. This can significantly increase friction while shortening the effective wear life of bearing components.
- The number of hydroelectric fleets considering changing from oil lubricated to water lubricated bearings is increasing, to be aligned with climate change initiatives. Oil-free hydropower units could have positive impacts on the ecological status of rivers, supporting the clean and renewable energy targets sets by authorities.

  Based on the above, use of the oil free lower guide bearings is recommended for Unit 8.

  Note at present, open loop filtered water system is considered however closed loop filtered water for lower guide bearing will be envisaged during discussion with TG supplier in the next design phase.

An RFI was sent to a bearing supplier for a budgetary quotation for supply of water lubricated bearings. A detailed cost benefit analysis of grease versus water lubricated bearings together with bearing specifications and drawings were received from Avalon Bearings for supply of Thordon bearings. Refer to Section 4.6 and Appendix E for details.

3.7 Dust Collection System for Collector Rings and Brakes

Installing a carbon dust collection system for collector rings and brakes is feasible. Suppliers have extensive experience in the design, installation, and maintenance of dust collection system for hydro generators.

Debris or dust can accumulate on the surface of the collector rings, leading to irregular contact and wear of the brushes. Cleaning at appropriate intervals can dramatically increase the lifespan of the collector ring.

For Unit 8, the Mersen dust collector system or equivalent can be installed.

The advantages of the dust collection system are as follows:

- Reduces the environmental impact caused by generator brake dust and collector ring.
- The system can clean the dust online and will minimize the number of flash-over occurrences in the generator, maximizing performance and eliminating repair cost.
- It also reduces the risk of premature aging of generator rotor and stator windings due to contamination of carbon dust.
- Increases the safety and health for the Operator as over 90% of carbon dust is suctioned at its source and avoids dispersion all over the machine and reduces inhalation by the Operator.
- The dust collection system is easy to operate and requires minimal maintenance.

There are no significant disadvantages of the system. If the system does not perform at its maximum efficiency, there may be problems associated with inefficient filtering and dust collection. Another disadvantage would be the need for frequent maintenance of the dust collector system.

Use of dust collection system for collector rings and brake is recommended as per the above advantages.

An RFI was sent to a supplier for a budgetary quotation for supply of a dust collection system for the generator collector rings and the brakes of Unit 8. A quotation was received from Mersen for collector ring and requested detail of generator brake to quote for same. Refer to Section 4.7 and Appendix F for quotation and details. Also, the budgetary estimate received form Voith for generator brake duct and oil mist collector. Please refer to section 4.7 Appendix F

3.8 Cooling Water Pumps Versus Pressure Reducing Valves

For Unit 7, the water source for the cooling water system is from the penstock through multistage pressure reducing valves (PRV). For Unit 8, the possibility of using water source from tailrace or draft tube thorough cooling water pumps was investigated.

The selection of PRV versus cooling water pumps is dependent on several factors such as submergence of pumps, maintenance and operational costs, frequency of maintenance, and functional and operational requirements.

The advantages of using cooling water pumps over PRVs are as follows:

- Cooling water pump system meets the functional and operational requirements.
- Cooling water pump system supplies relatively constant flow and pressure, while in case of PRVs the pressure may vary if the system malfunctions. However, this issue can be addressed with addition of a redundant PRV in the system so that the system switches over to redundant PRV allowing the repair of the primary PRV.
- U7 pressure reducing system uses rupture disc bypasses which frequently rupture due to pressure fluctuations. They are costly to replace and keep plant resources occupied.
- Cooling water pumps provide a reliable system for such net head in penstock compared to PRV with penstock tapping.
- Cooling water pumps can be installed in same pit as firefighting pumps therefore minimizing the excavation cost.

The disadvantages of using cooling water pumps over PRVs are as follows:

- Maintenance cost is higher for the cooling water system since the system contains rotating equipment (pumps and motors). Maintenance frequency is also higher compared to pressure reducing valves.
- Since the pump-motor requires continuous power consumption, the operational cost is higher compared to pressure reducing valves.
- Maintenance of pumps submerged or installed in pit is more difficult in terms of personnel access. Pumps may have to be disassembled from their skid and brought up to the main floor for repair or service.
- Since pumps are to be located below the tail water level, they would either be installed in a dry pit inside the powerhouse or wet well inside powerhouse.
- If a redundant PRV is included in the Unit 8 design, it could also be used as a backup for Unit 7 (Which doesn't have a redundant PRV).

Considering the above, the PRV option is preferred over the cooling water pump option for Unit 8. However, cooling water pumps cannot be completely ruled out at this stage and should be further investigated in the next design phase.

The new PRV system will have redundant bypass system for the pressure reducing control valves as well as pressure relief valves in parallel. The new PRV system shall consider using safety pins over the rupture discs for the pressure relief safety valves. Safety pins can be easily replaced within a short period of time (around 15 minutes) without requirement to remove piping, therefore the integrity of piping system will remain intact. Rupture pins can save loss of valves, disc replacement cost, and labour to replace the disc. This is to be further investigated in the next design phase.

An RFI was sent to valve suppliers for a budgetary quotation for the supply of PRVs. No response was received from suppliers. Refer to Section 4.8 for more detail.

3.9 Service Elevator

A service elevator could be located upstream of Bayline A, between Baylines 9 and 10 (refer to Appendix B, Sketch 3, Figure 7, 8 and 9).

A minimum overall space requirement of 2.2 m wide by 3.1 m long is required for the service elevator. The lowest elevator stop would be on the spiral case access floor at El. 0.305 m. The proposed location is outside existing excavation area adjacent to the existing concrete walls and generators requiring mechanical excavation for rock removal to prevent any damages to the facilities and the equipment. The vibration criteria should be considered for selecting the mechanical excavator.

At landing locations of each floor, determined equipment placement should allow for safe access for personnel or equipment transfer. The currently planned layout will need to be reassessed to determine if any equipment has to be relocated.

The proposed area is outside of current excavation zone. Blasting or rock removal options adjacent to an existing and operational powerhouse may present issues for the existing facility and will be further studied to reduce potential high cost associated with the construction difficulties, ensuring as well that there is no damage to the adjacent structures.

Refer to Section 4.9 for more detail.

3.10 Pressure Relief Method

For Unit 7, the wicket gate closing time is calculated 13 seconds for less than 30% pressure rise along with 10% discharge from the pressure relief valve.

For Unit 8, the 30% pressure rise can be maintained with increasing the wicket gate closing time to approximately 16 seconds (calculated) and eliminating the pressure relief valve. This will increase the speed rise to approximately 65% (calculated) above rated speed which is acceptable. With the current technology, speed rise of up to 80% is considered acceptable. OEMs will be consulted to confirm the allowable level of speed rise.

Increase in closing time and elimination of pressure relief valve will have the following advantages:

- Unit dependency on pressure relief valve and unit shutdown, either sudden or planned due to maintenance of the pressure relief valve will be eliminated.
- Any malfunction caused by pressure relief valve system may increase the pressure rise in the penstock. Such risk will be eliminated if the pressure rise is only controlled by the wicket gate closing time.
- Maintenance and overhaul cost will be reduced due to elimination of pressure relief valve.
- Generation loss will be reduced due to elimination of the risks mentioned above.

The only disadvantage is as follow:

- There would be a slight increase in the speed rise of unit which will be handled nowadays with robust design of the units.

Based on the above, eliminating the use of the pressure relief valve for Unit 8 is recommended. The pressure relief method for Unit 8 will be discussed with the turbine generator suppliers during the Detailed Design phase.

Refer to Section 4.10 for more detail.

3.11 CFD and Turbine Model Testing

The Computational Fluid Dynamics (CFD) simulation advantages are listed below:

- CFD simulation saves time and cost compared to the model test, as it can be performed on a computer without the need for physical prototypes. The model test, at a minimum, will require 10-12 months to complete whereas CFD simulation can be completed in a few weeks. Also, the cost of CFD simulation is about 20%-30% of the cost of a model test.

- CFD simulations can be used to explore a wide range of runner design options in less time, allowing engineers to optimize designs for specific objectives such as maximizing efficiency and minimizing the head loss.
- CFD simulations allow for virtual prototyping, which enables engineers to test and optimize the design before building the physical prototypes.
- CFD simulations provides a visual representation of flow patterns, allowing engineers to understand complex flow distributions in a way that is not possible with physical experiments.
- CFD simulations can provide more detailed information than physical experiments, especially in complex flow systems like between the runner blades.
- CFD simulations provide a deeper understanding of the flow behaviour and physical phenomena within a system, allowing engineers to make informed design decisions.

The Physical Turbine Model test advantages are listed below:

- Model test starts with the CFD and once the physical model is built, cavitation will be measured, and trial and error method will be performed between physical model and CFD. Therefore, model test includes all the advantages of the CFD method plus advantages of a physical test.
- For a large size unit (typically above 50 MW) with high capital cost, model test ensures a better performance of the generating unit and is considered a good investment.
- Physical model test will minimize losses and achieve zero cavitation and consequently helps reducing the long-term maintenance costs.
- Model test can determine turbine flow, or the flow can be measured within about 2% accuracy to facilitates achieving the turbine efficiency and the performance guarantees.

The disadvantages of a Physical Turbine Model test include expenses and time constraints. Nonetheless, relying solely on Computational Fluid Dynamics (CFD) might compromise reliability. The investment of both cost and time is justified by the assurance that the prototype's performance will achieve unit performance guarantees. Therefore, it is recommended to proceed with the physical model test in conjunction with CFD.

Refer to Section 4.11 for more detail.

3.12 Synchronous Condenser

The synchronous condenser has the following advantages:

- Reactive power shortage is one of the issues that endanger the stability of power grid systems. The unbalance of reactive power can cause grid instability. One solution to provide the necessary reactive power to the grid is to operate generators as motors and supply or absorb reactive power when needed. Hydraulic turbines suitable machines to perform this task since they can be easily and quickly dewatered to work as motors (Synchronous Condenser operation) without the need to consume water or other fuels.
- Synchronous condensers can be used to provide inertia to improve the stability of grid.
- The injection of high reactive currents during and after grid faults is also fundamental to avoid voltage collapse. Synchronous condensers are designed to deliver such a response and can also provide an extended time-limited overload capability.

Synchronous condensers have the following disadvantages:

- The high pressure compressed air system required for synchronous condenser operation will have additional cost and is expensive.
- Additional space is required for high pressure compressed air system.
- Continuous cooling water system is required during condenser mode operation. However, in the case of penstock tapping for cooling water system, as recommended for Unit 8, this requirement is easily met.

Recommendations concerning the use of synchronous condensers for Unit 8 cannot be made at this point. This option will be discussed further with OEMs and the cost will be provided to NL Hydro. Please note financial analyses such as internal rate of return (IRR) or return on investment (ROI) of synchronous condenser option is beyond the scope of this report. The cost will be provided, but the benefit cannot be accurately quantified. The final decision will lie with NL Hydro.

Refer to Section 4.12 for more detail.

4. Conclusions

The following sections summarize the key points and the budgetary cost estimates received from OEMs.

4.1 Eliminate the Use of Heat Stretch Fasteners

- The supply cost of thirty-six (36) pieces M130 EZFit Super bolt mechanical tensioning solution for Unit 8 from Nord-Lock Group is [redacted].
- Current lead time of [redacted].
- 2019 cost estimate provided by Andritz for Unit 7 fasteners was [redacted] for 34 bolts. There has been a price jump since 2019.
- Use of Superbolt or equivalent mechanical tensioning solution is recommended.

4.2 Removal of the Draft Tube Cone and the Runner for Maintenance Without Unit Disassembly

- No cost estimate is provided for this option.
- Removal of the runner and the draft tube cone from the bottom is not feasible and not recommended.

4.3 Addition of Main Inlet Valve to Support Maintenance Without Penstock Dewatering

- Quotation was received via an email from Voith Hydro.
- Voith's budgetary and non-binding price for a class 3, 4.2 m diameter Spherical valve (complete system including Bypass and controls) is [redacted] which includes design, supply, and delivery to site.
- Voith's budgetary and non-binding price for a class 3, 4.2 m diameter Butterfly valve (complete system including Bypass and controls) is [redacted] which includes design, supply, and delivery to site.
- Current lead time for supply of each type of valve would be [redacted] delivered from Voith Hydro factories in [redacted].
- The cost of Butterfly valve is slightly lower than the cost of the Spherical valve but has higher hydraulic losses. This would impact the efficiency of the system and likely offset these cost savings.
- The cost of the building to house the spherical valve including the overhead hoist are to be considered as additional cost.
- Addition of the MIV into the penstock is not recommended due its high supply cost as well as significant and continuous O&M cost, to maintain the valve and associated equipment. Also, the cost required to build the valve house and access road is significant.

4.4 Addition of Penstock Filling Valve

- No cost estimate is provided for this option.
- Addition of a penstock filling valve is feasible and recommended. It is also recommended to design the intake gate as an upstream sealing gate to facilitate filling the penstock with crack opening of the Intake gate.

4.5 Greaseless Wicket Gate Bushings

- Total budgetary supply cost for thermoplastic ThorPlas-Blue Upper, intermediate, and lower Wicket Gate Bearings, upper lip seals, top seals, ThorPlas-Blue servomotor bearings, operating mechanism bearings, operating rings upper wear pad bearings and operating rings thrust wear pad bearings is [redacted].
- Price accuracy is within ± 20%.
- Thordon Bearings to be designed and installed in accordance with the requirements of the Thordon Engineering Manual E2006.1.
- Refer to Appendix E for detailed Thordon proposal.

4.6 Oil Free Lower Guide Bearing

- Initial cost comparison of water versus oil lubrication is shown in the table below.
- A conceptual proposal for a 1050 diameter shaft design was requested by AtkinsRéalis in a RFI. Thordon has a standard 1065 mm diameter design in hand and budgetary pricing was already provided to NL Hydro with respect to Unit 7 for a 1065 mm design.
- Refer to the budgetary pricing below for a typical 1065 mm diameter Main Guide Bearing and Segmented Seal Assembly for water lubricated and oil lubricated bearings.
- Water Lubricated bearing option as found below was [redacted] vs. Oil Lubricated Bearing at [redacted].
- Refer to Appendix E for the detailed Thordon proposal including specification and budgetary pricing.

Initial Cost Comparision of Water vs Oil lubrication
Dollars Estimated

Item	Water Lubricated Bearing	Oil Lubricated Bearing	Comments
Bearing with housing and mounting hardware	$ [redacted]	$ [redacted]	Water Bearing housing smaller less complicated, 50" oil 39" for water
Oil Seals	$	$	
Shaft Sleeve	$	$	Water Bearing has larger shaft sleeve
Shaft Seal	$	$	Shaft Seal is simplified and reduced mass with water bearing, acces to runner bolts not requred shinking bottom seal ring
Head Cover Extension	$	$	Water Bearing Headcover extension shorter and no access holes
Shaft	$	$	Water Bearing allows for smaller shaft with no step out
Opperating Ring	$	$	Shorter with water bearing
Oil Pump / filter	$	$	
Oil Cooler	$	$	
Oil to water Seperator	$	$	Not required as no oil on headcover
Water Filtration and supply	$	$	Much larger for water bearing with redudancy
Oil	$	$	
Head cover Pumps	$	$	
Headcover	$	$	No features to allow access to shaft seal or caprture seal leakage water
Total	$	$	

Note: For water lubricated bearing in the above table, oil pump, filter and oil is not required.

4.7 Dust Collection System for Collector Rings and Brakes

- The estimated budgetary price is [redacted] for 1 Mersen dust collection system unit for collector rings, excluding taxes.
- The estimated budgetary price for brake dust collector system is [redacted], quoted by VOITH for supply of the system, excluding taxes.
- This price does not include shipping, installation, spare parts, slip rings, commutator, and bus bar.
- A full inspection of the equipment will be required by Mersen personnel to determine the final pricing.
- The system will include approximately 20 carbon brush holders equipped with collection shrouds, a vacuum unit, control panel, tubing, and hardware.
- Refer to Appendix F for detailed Mersen proposal including specification and budgetary pricing.

4.8 Cooling Water Pumps Versus Pressure Reducing Valves

- No quotation was received from OEMs for cost of PRV system.
- Voith Hydro does not provide pressure relief valves but can discuss alternatives such as a cooling water system.
- PRV system is the preferred system over the cooling water pumps however, cooling water pumps cannot be completely ruled out at this stage and should be further investigated in the next design phase.
- To address the existing issue of disc rupture in Unit 7, Unit 8 PRV system design will consider using safety pin valves instead of rupture discs.
- Redundant PRV in the Unit 8 design could be used as a backup for Unit 7 (in which Unit 7 does not have a redundant PRV).

4.9 Service Elevator

- A service elevator can be added in the powerhouse. Refer to Appendix B, Sketch 3, Figure 7, 8 and 9 for approximate location.
- Installation and supply of a new underslung OTIS elevator 2000lb capacity 350 fpm top speed (3 levels) was quoted at approximately [redacted] for another project in 2022. This would exclude any excavation, shaft work, electrical etc.
- Future excavation and associated cost estimate will consider the risk of blasting and rock removal adjacent to the existing powerhouse.

4.10 Pressure Relief Method

- For Unit 8 Increase in closing time and elimination of pressure relief valve is recommended.
- Allowable level of pressure speed rise for Unit 8 will be discussed with the turbine generator suppliers during the detailed design phase.

4.11 CFD and Turbine Model Test

- The physical turbine model test will benefit from the CFD analysis and includes the advantages of the CFD method.
- The project schedule can accommodate the time to perform the model test program.
- A Physical model test is recommended to achieve the best unit efficiencies and the performance guarantees.
- The turbine model test will help to optimize the geometry of the intake and the discharge to minimize losses.
- A cost for the model test provided in SNC Report 2018 by GE was estimated [redacted].
- A budgetary quote has been requested for the model test from the Turbine generator suppliers in the specifications (6999257-0000-45E5-0001, section 1.3). At the time of issuing this report, quotes have not been received.

4.12 Synchronous Condenser

- A budgetary quote has been requested for the Synchronous Condenser from the Turbine generator suppliers in the specifications (6999257-0000-45E5-0001, section 1.3). At the time of issuing this report, quotes have not been received.
- Recommendations concerning the use of synchronous condensers for Unit 8 cannot be made at this point. Cost will be provided once received, but the benefit cannot be accurately quantified. The final decision will lie with NL Hydro.

APPENDICES

APPENDIX A: Mechanical Bolt Tensioner

[redacted]

[redacted]

NORD-LOCK GROUP

SUPERBOLT EZFIT

THE EASY WAY TO INSTALL COUPLING BOLTS

Latest technology and innovation

Simple, accurate, and easy

Significant time and labor savings

Safe and durable

SUPERBOLT®

AN ACCURATE, EASIER WAY OF BOLTING

Traditional, 'fitted' bolts reduce in diameter when tightened, leaving clearance and the possibility of coupling slippage under shock loading. This can lead to difficulty in removal, resulting in coupling hole and bolt damage and causing outage delays and expensive repair work.

Hole and bolt damage as shown in these images can lead to days of unplanned work, meaning loss of availability and additional high-cost critical downtime.

Superbolt EzFit expansion bolts prevent all of these issues because they are installed and removed in clearance conditions, ensuring coupling make-up and break-up schedules are easily maintained.

SUPERBOLT EZFIT

EzFit mechanical expansion bolts offer tremendous radial expansion and joint clamping power in one bolting system.

They are specially designed for rotating couplings or alignment systems that require the bolts to transfer forces in shear.

This innovative product replaces large fitted or interference fit bolts, no modifications required. The key to this solution is the split expansion sleeve that mates with the customers' machined holes.

The split sleeve requires less tolerance on mating parts than is traditionally required with interference fit, saving critical machining time.

REPLACEMENT WITHOUT MODIFICATION

The innovative EzFit expansion sleeve coupling bolt from Superbolt lets you replace large fitted or interference-fit bolts without modifying your equipment, optimizing drive and preventing coupling slippage.

HIGH PRELOADS WITH HAND TOOLS ALONE

Integral Superbolt multi-jackbolt tensioners (MJTs) enable EzFit to attain extremely high preloads with simple hand tools alone.

ACCURATE RADIAL FORCE

EzFit's split, tapered bore sleeve also provides a true radial force that translates to greater flange connection rigidity and eliminates harmful micro-movements at the split line. Because the sleeve can compensate for a wider range of bore tolerances, it simplifies machining and installation.

SUPERBOLT EZFIT

Superbolt EzFit is ideal for turbines (hydro, wind, gas, steam), engines, generators, compressors, motors, and marine propulsion drives.

SECURE
Elimination of internally connected thread puller.

EFFICIENT
Design that removes the need for oil injection removal methods, preventing a known mode of failure.

COST SAVING
Hole preparation costs are reduced as less demanding hole tolerances are required.

SAFE
Use only simple, low-risk hand tools for installation and disassembly.

COST EFFICIENT
Fully reusable, only requires sleeve replacement for rotor changes.

ACCURATE
Radial fit which allows for better coupling alignment and concentricity.

PRACTICAL
Superbolt Ezfit split sleeves allow greater expansion to achieve hole tolerances more easily.

WITH DECADES OF SUCCESS IN EVERY MAJOR INDUSTRY WORLDWIDE

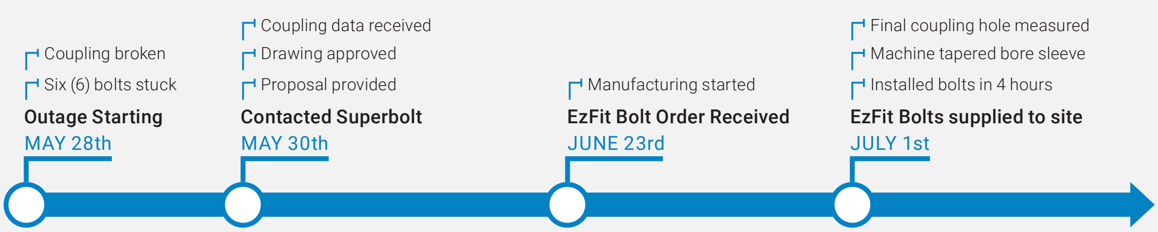
The outcome for OEM and MRO teams who partner with Nord-Lock Group is secure critical bolted connections that are easy to install/remove, safe and reusable. Or in other words, more flexible and cost-effective maintenance with a reduction in downtime.

Our solutions are available worldwide, and you can speak to a local sales engineer right away. Nord-Lock Group services focus on life cycle profitability, design, production, training, and installation support. We'll work closely with you to understand your needs, solve your problems and design an optimal long-term solution.

SUCCESS IN GAS & STEAM TURBINES

With fast-rotating machinery and limited maintenance windows, these turbines have unique challenges that are easily addressed with Superbolt expansion bolts. This on-demand application replaces existing bolting connections, reducing downtime.

Don't wait until the bolts are stuck to replace them with an EzFit solution – plan for replacement during scheduled maintenance!



TIMELINE FROM A CUSTOMER OUTAGE

SUPERIOR PERFORMANCE MADE EASY

HOW IT WORKS

The mechanical tensioner at the small end of the taper stud **(side A)** pulls the stud into the expanding split sleeve for radial preloading.

The split sleeve expands and exerts a large radial force into the bores of the coupling bolt holes to give a truly fitted bolt.

The mechanical tensioner at the large end of the taper stud **(side B)** provides the axial clamping forces.

In removal, the large end tensioner **(side B)** is used to pull the stud out of the sleeve, which then collapses for easy withdrawal from the hole.

EZFIT COMPONENTS

1 Tapered stud
2 Split tapered bore sleeve
3 Positioning spacer
4 MJT and hardened washer

STANDARD RANGE

EzFit mechanical expansion bolts can be designed using the latest FEA technology for any type of coupling with bolts of diameter 20mm (3/4") or upwards.

Unique features and advantages of both hydraulic and mechanical expansion sleeve coupling bolts can be combined to best suit your specific requirements.

A TYPE

- Mechanical expansion bolt for threadless bore
- Access and operation from one side
- Dimension on request

B TYPE

- Mechanical expansion bolt for blind holes
- Access and operation from one side
- Ø 28 – 165 mm

C TYPE

- Mechanical expansion bolt for through-holes
- Access and operation from both sides
- Ø 28 – 165 mm

WE WORK THERE WITH YOU With production sites in Switzerland, the UK, and the USA, worldwide material specification, certifications and shipping are all easily provided. As part of the Nord-Lock Group, we have sales offices and representation around the world. Installation, maintenance training and supervision are offered to ensure client satisfaction.

Nord-Lock Group
Tel: +1 412 279 1149
Email: bolting@nord-lock.com
www.nord-lock.com

NORD-LOCK GROUP

[redacted]

[redacted]

APPENDIX B: Powerhouse Layout

Sketch 1

Space for removal of the Draft tube cone and Runner for Maintenance Without Unit Disassembly.

Drawings found herein are extracted from the 2018 proposed Bay d'Espoir Generating Unit 8 study by SNC Lavalin.

1. Runner and DT cone Bottom removal

1.1 Runner overall size : Dia. 3.75m x 1.4m (H)
Gallery space required for transfer of the runner: 4.1m (W) x 2.1m (H)- Figure 1

1.2. Draft tube cone size : Dia 3.5 m x Dia 3.6 m x 3.2 m (H)

Gallery space required for transfer of draft tube cone: 4.1m (W) x 4.0m (H)
Height of 4 meters seems not feasible for DT cone, So DT cone can be of Split type.

Split draft tube cone size for bottom removal: Dia 3.5m x Dia 3.6m x 1.6m (H)
Gallery space required after split: 4.1m (W) x 2.2m (H) - Figure 1 (similar to space required for runner removal)

1.3. Bottom cover outside Dia. 5.7 m (estimated)
Can not be removed in single piece. If split, installation and dismantling will take a long time. Figure 2.

1.4 Runner removal hatch - Space required is 4.1 m x 4.1 - Figure 3

Gallery size 4.1 m (W) x 2.2 m (H) is required for transfer of the Runner or the split draft tube cone underneath the hatch at EL: 0.305m to facilitate lifting of the components to the main floor.

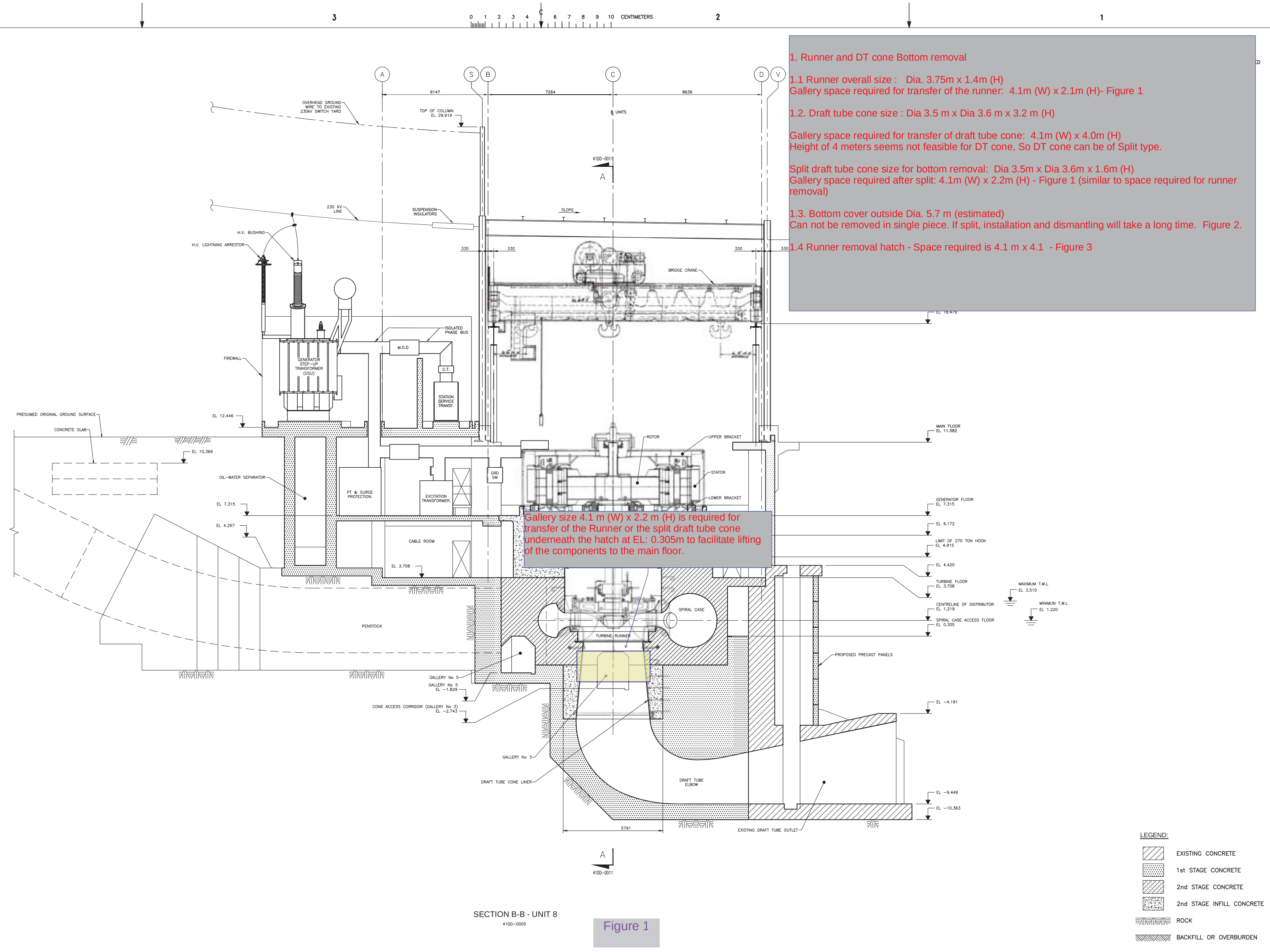


Figure 1

ISSUE No	REV.	DATE (Y/M/D)	PURPOSE OF ISSUE
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2	PB	2017/08/25	ISSUED FOR CLIENT REVIEW.
1	PA	2017/08/16	ISSUED FOR SLI INTERNAL REVIEW.

ISSUE REGISTER | ISSUE REGISTER | REVISION REGISTER | REVISION REGISTER | REFERENCE DRAWINGS NUMBER

PROFESSIONAL SEAL

SNC-LAVALIN Hydro & Power Delivery, 1801 McGill College Avenue, Montreal Quebec Canada H3A 2N4

PREPARATION	APPROVAL
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DRAWN: Y. TREGUER	PROJECT ENGINEER: R. GRAVEL
CHECKED: D. KASSIS/S. MOUSSEAU	PROJECT MANAGER: S. PERRON
DATE: 2017-07-17	CLIENT: A. FORHAD
SCALE: 1:75	

CLIENT: hydro

PROJECT: BAY D'ESPOIR

TITLE: HYDRO GENERATING UNIT 8 GENERAL ARRANGEMENT TRANSVERSE SECTION

PROJECT No	SUBDIVISION	SUBJECT	SERIAL	REV.
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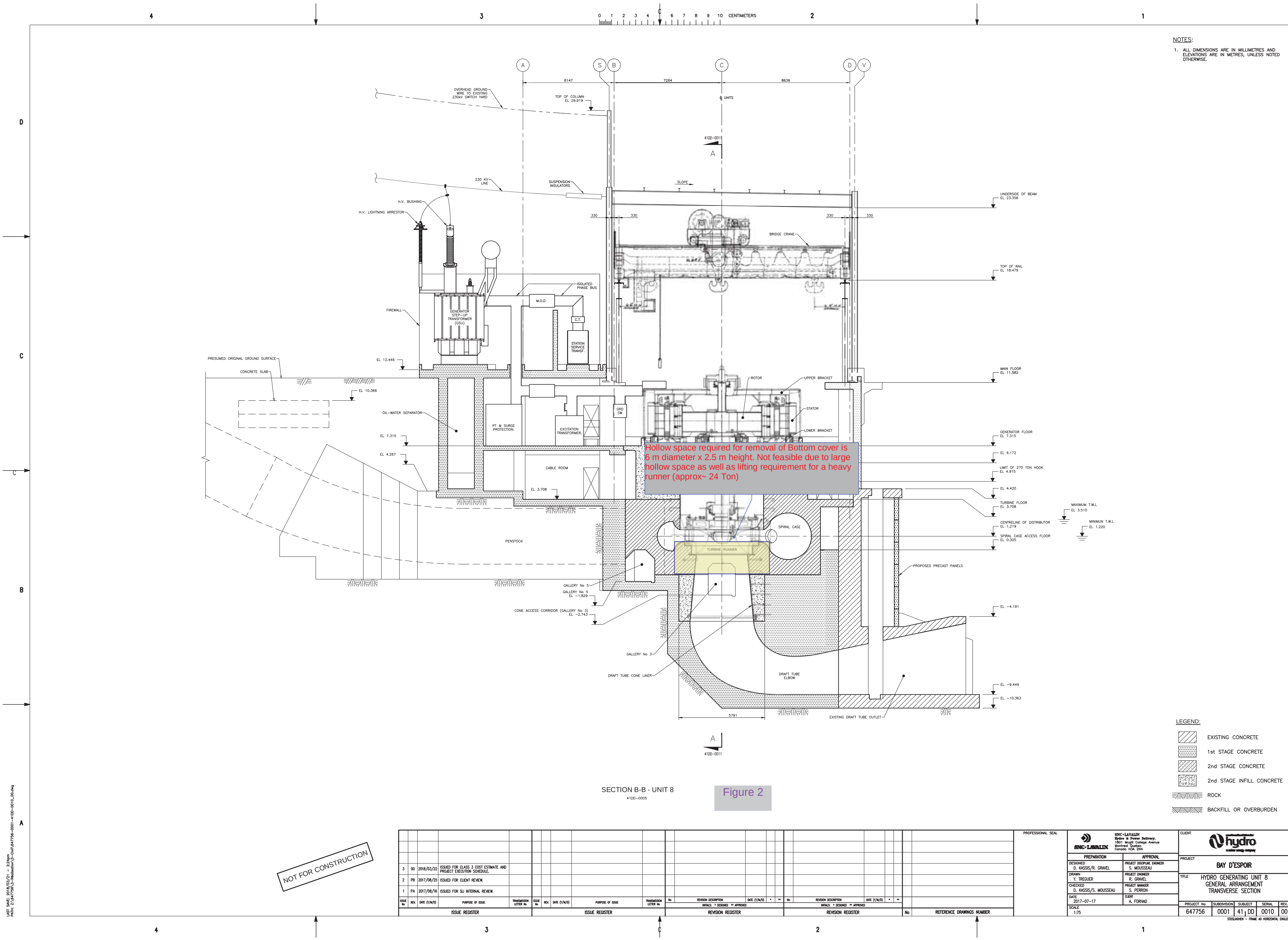
NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
Hollow space required for removal of Bottom cover is 6 m diameter x 2.5 m height. Not feasible due to large hollow space as well as lifting requirement for a heavy runner (approx~ 24 Ton)
OVERHEAD GROUND WIRE TO EXISTING 230kV SWITCH YARD
TOP OF COLUMN EL 29.919
230 KV LINE
SUSPENSION INSULATORS
H.V. BUSHING
H.V. LIGHTNING ARRESTOR
BRIDGE CRANE
UNDERSIDE OF BEAM EL 23.356
TOP OF RAIL EL 18.479
ISOLATED PHASE BUS
M.O.D
C.T.
STATION SERVICE TRANSF.
GENERATOR STEP-UP TRANSFORMER (GSU)
FIREWALL
PRESUMED ORIGINAL GROUND SURFACE
CONCRETE SLAB
EL 12.446
EL 10.366
OIL-WATER SEPARATOR
PT & SURGE PROTECTION
EXCITATION TRANSFORMER
GRD SW
ROTOR
UPPER BRACKET
STATOR
LOWER BRACKET
MAIN FLOOR EL 11.582
GENERATOR FLOOR EL 7.315
EL 6.172
LIMIT OF 270 TON HOOK EL 4.915
EL 4.420
TURBINE FLOOR EL 3.708
CENTRELINE OF DISTRIBUTOR EL 1.219
SPIRAL CASE ACCESS FLOOR EL 0.305
MAXIMUM T.W.L. EL 3.510
MINIMUM T.W.L. EL 1.220
EL 7.315
EL 4.267
CABLE ROOM
EL 3.708
PENSTOCK
SPIRAL CASE
TURBINE RUNNER
PROPOSED PRECAST PANELS
GALLERY No 5
GALLERY No 5 EL -1.829
CONE ACCESS CORRIDOR (GALLERY No 3) EL -2.743
EL -4.191
GALLERY No 3
DRAFT TUBE CONE LINER
DRAFT TUBE ELBOW
EL -9.449
EL -10.363
EXISTING DRAFT TUBE OUTLET
6147
7264
8636
5791
SECTION B-B - UNIT 8
Figure 2
LEGEND:
EXISTING CONCRETE
1st STAGE CONCRETE
2nd STAGE CONCRETE
2nd STAGE INFILL CONCRETE
ROCK
BACKFILL OR OVERBURDEN
NOT FOR CONSTRUCTION
3 | 00 | 2018/03/22 | ISSUED FOR CLASS 3 COST ESTIMATE AND PROJECT EXECUTION SCHEDULE.
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1 | PA | 2017/08/16 | ISSUED FOR SLI INTERNAL REVIEW
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REVISION REGISTER
REFERENCE DRAWINGS NUMBER
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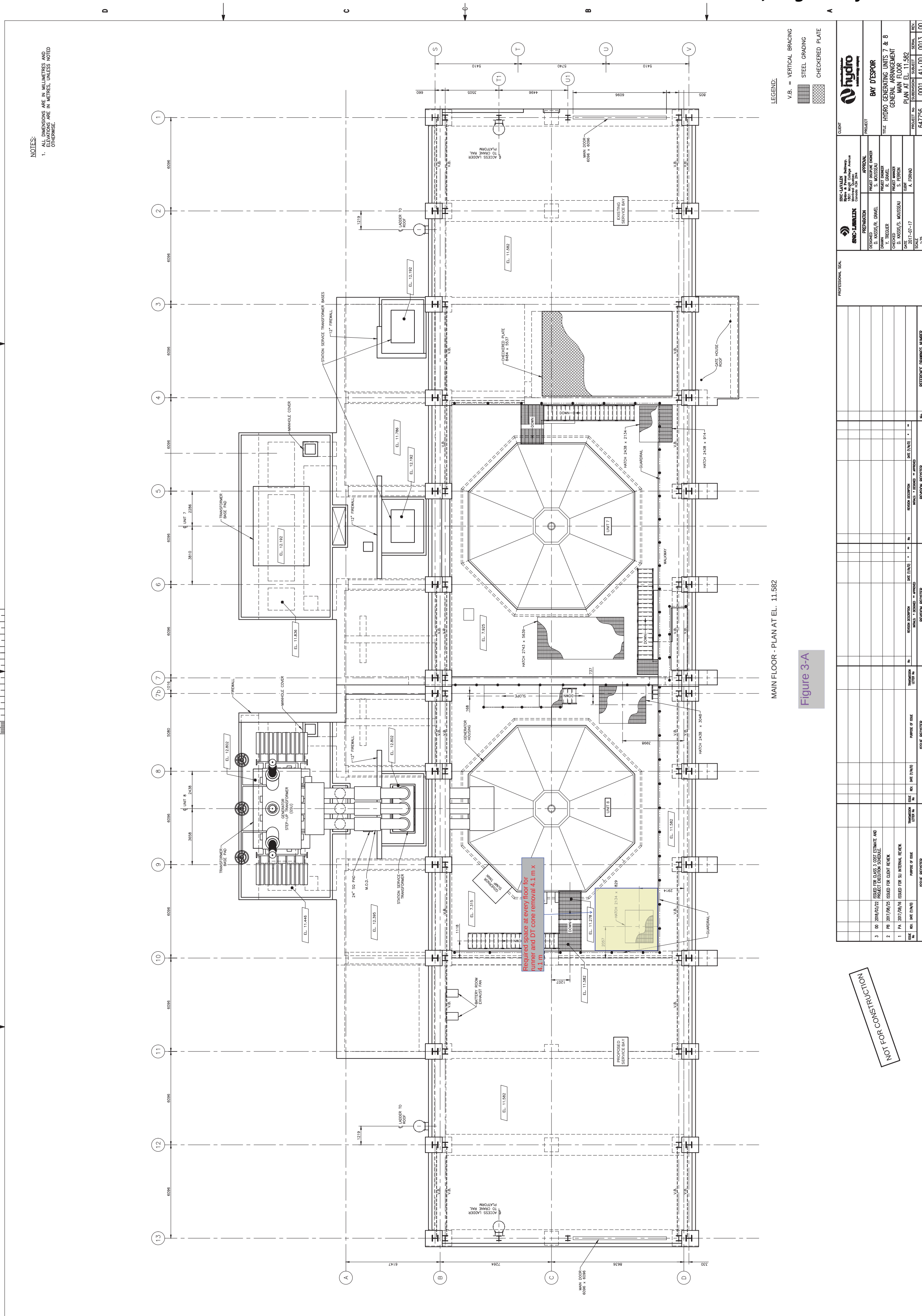
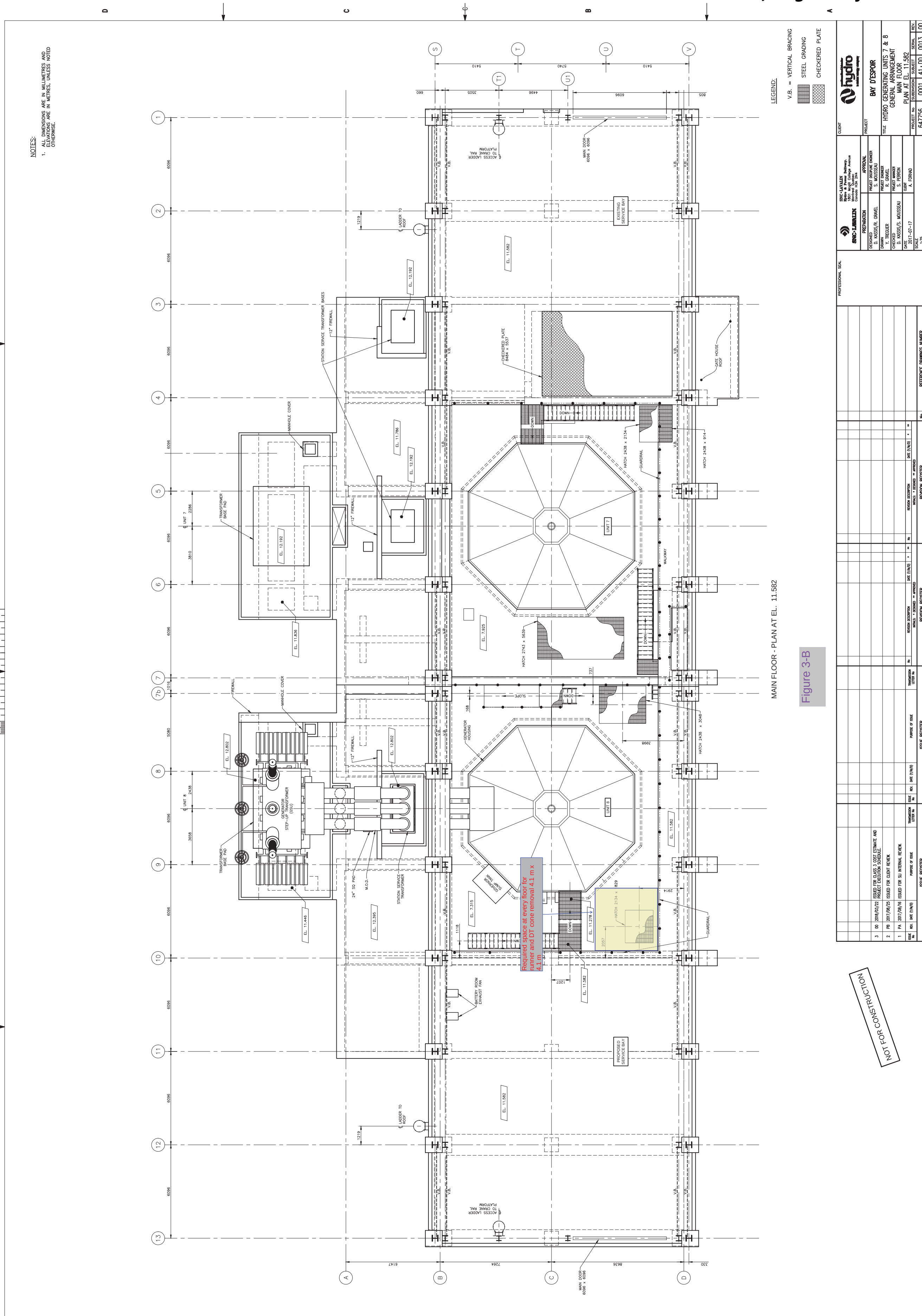
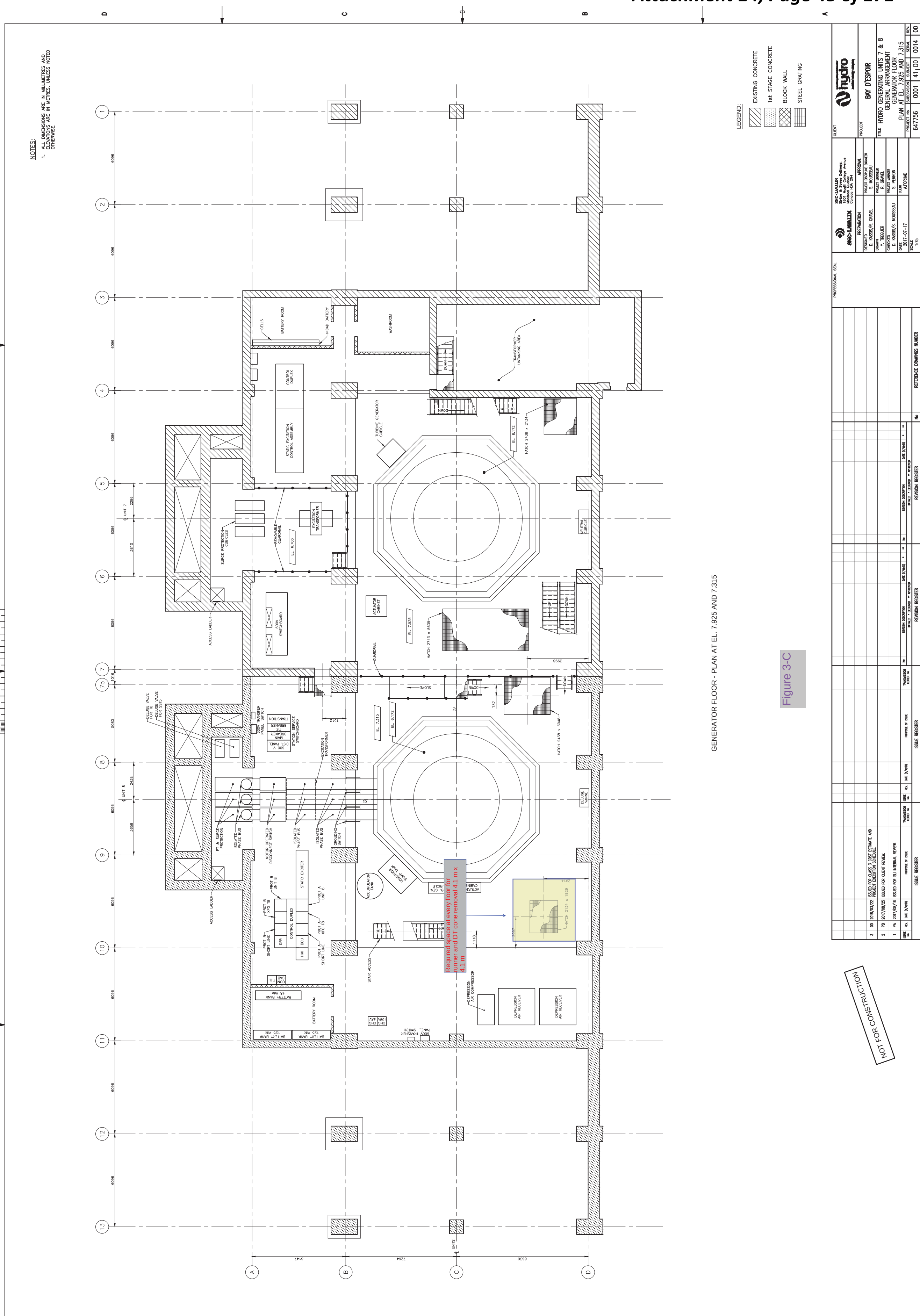
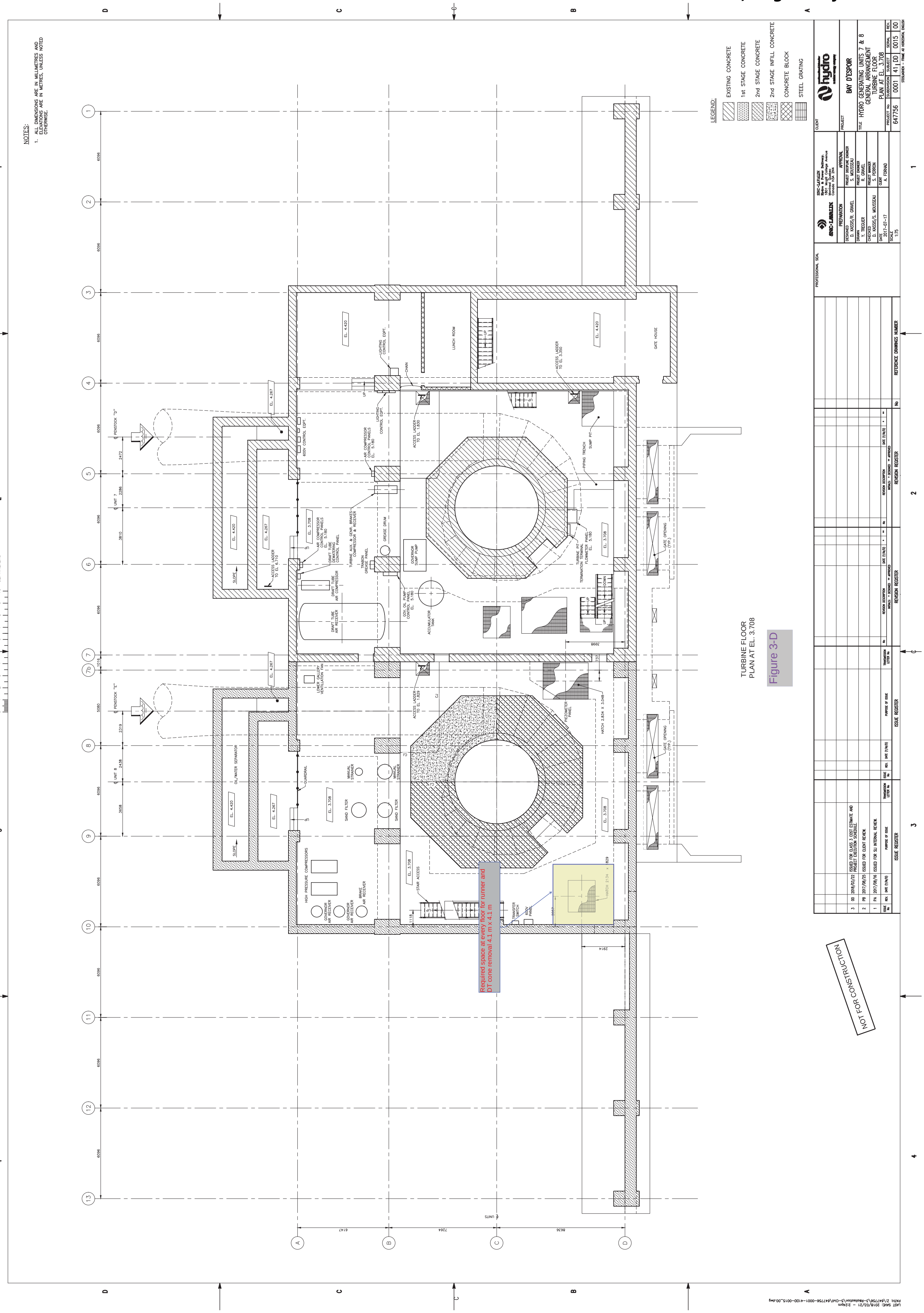
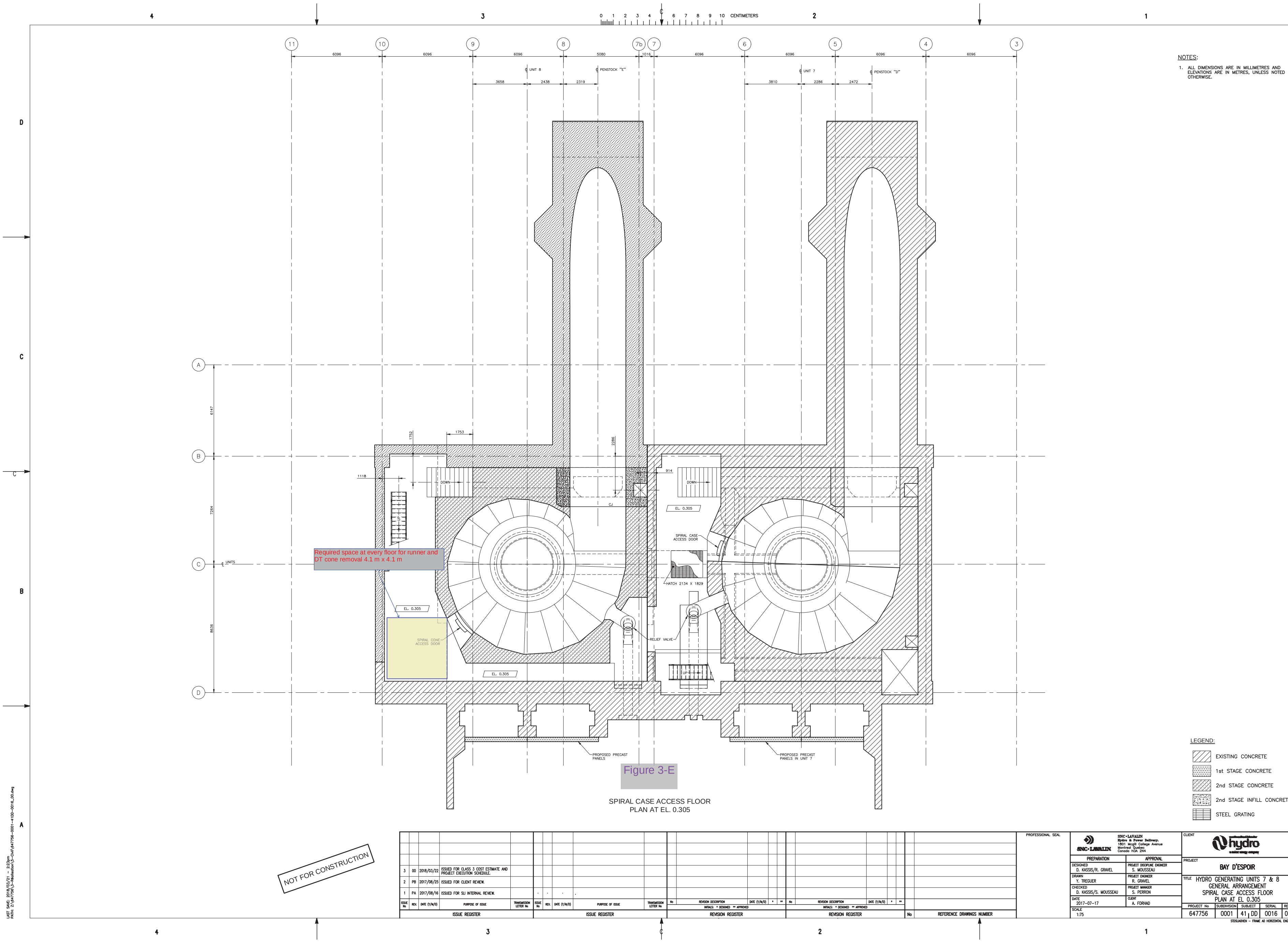
DESIGNED D. KASSIS/R. GRAVEL
DRAWN Y. TREGUER
CHECKED D. KASSIS/S. MOUSSEAU
DATE 2017-07-17
SCALE 1:75
APPROVAL
PROJECT DISCIPLINE ENGINEER S. MOUSSEAU
PROJECT ENGINEER R. GRAVEL
PROJECT MANAGER S. PERRON
CLIENT A. FORHAD
hydro
PROJECT BAY D'ESPOIR
TITLE HYDRO GENERATING UNIT 8 GENERAL ARRANGEMENT TRANSVERSE SECTION
647756 | 0001 | 41 DD | 0010 | 00


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
LEGEND:
V.B. = VERTICAL BRACING
STEEL GRADING
CHECKERED PLATE
MAIN FLOOR - PLAN AT EL. 11.582
Figure 3-A
Required space at every floor for runner and DT cone removal 4.1 m x 4.1 m
NOT FOR CONSTRUCTION
UNIT 7
UNIT 8
WALKWAY
GUARDRAIL
EXISTING SERVICE BAY
PROPOSED SERVICE BAY
GENERATOR STEP-UP TRANSFORMER (GSU)
STATION SERVICE TRANSFORMER
TRANSFORMER BASE PAD
MANHOLE COVER
FIREWALL
LADDER TO ROOF
BATTERY ROOM EXHAUST FAN
GATE HOUSE ROOF
REFERENCE DRAWINGS NUMBER
REVISION REGISTER
ISSUE REGISTER
PROFESSIONAL SEAL
BAY D'ESPOIR
HYDRO GENERATING UNITS 7 & 8
GENERAL ARRANGEMENT
MAIN FLOOR
PLAN AT EL. 11.582
647756


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
LEGEND:
V.B. = VERTICAL BRACING
STEEL GRADING
CHECKERED PLATE
MAIN FLOOR - PLAN AT EL. 11.582
Figure 3-B
Required space at every floor for runner and DT cone removal 4.1 m x 4.1 m
NOT FOR CONSTRUCTION
EXISTING SERVICE BAY
PROPOSED SERVICE BAY
UNIT 7
UNIT 8
GENERATOR STEP-UP TRANSFORMER
STATION SERVICE TRANSFORMER BASES
TRANSFORMER BASE PAD
MANHOLE COVER
FIREWALL
WALKWAY
GUARDRAIL
LADDER TO ROOF
MAIN DOOR 6096 x 6096
GATE HOUSE ROOF
BAY D'ESPOIR
HYDRO GENERATING UNITS 7 & 8
GENERAL ARRANGEMENT
MAIN FLOOR
PLAN AT EL. 11.582
647756


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
LEGEND:
EXISTING CONCRETE
1st STAGE CONCRETE
BLOCK WALL
STEEL GRATING
GENERATOR FLOOR - PLAN AT EL. 7.925 AND 7.315
Figure 3-C
Required space at every floor for runner and DT cone removal 4.1 m x 4.1 m
NOT FOR CONSTRUCTION
BATTERY ROOM
WASHROOM
TRANSFORMER UNLOADING AREA
STATIC EXCITATION CONTROL ASSEMBLY
CONTROL DUPLEX
SURGE PROTECTION CUBICLES
EXCITATION TRANSFORMER
600V SWITCHBOARD
ACTUATOR CABINET
ACCESS LADDER
STAIR ACCESS
STATIC EXCITER
DEPRESSION AIR RECEIVER
DEPRESSION AIR COMPRESSOR
hydro
BAY D'ESPOIR
HYDRO GENERATING UNITS 7 & 8
GENERAL ARRANGEMENT
GENERATOR FLOOR
PLAN AT EL. 7.925 AND 7.315
647756
ISSUE REGISTER
REVISION REGISTER
REFERENCE DRAWINGS NUMBER


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
LEGEND:
EXISTING CONCRETE
1st STAGE CONCRETE
2nd STAGE CONCRETE
2nd STAGE INFILL CONCRETE
CONCRETE BLOCK
STEEL GRATING
TURBINE FLOOR
PLAN AT EL. 3.708
Figure 3-D
Required space at every floor for runner and DT cone removal 4.1 m x 4.1 m
NOT FOR CONSTRUCTION
BAY D'ESPOIR
HYDRO GENERATING UNITS 7 & 8
GENERAL ARRANGEMENT
TURBINE FLOOR
PLAN AT EL. 3.708
647756


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
LEGEND:
EXISTING CONCRETE
1st STAGE CONCRETE
2nd STAGE CONCRETE
2nd STAGE INFILL CONCRETE
STEEL GRATING
Required space at every floor for runner and DT cone removal 4.1 m x 4.1 m
SPIRAL CASE ACCESS DOOR
HATCH 2134 X 1829
RELIEF VALVE
PROPOSED PRECAST PANELS
PROPOSED PRECAST PANELS IN UNIT 7
EL. 0.305
Figure 3-E
SPIRAL CASE ACCESS FLOOR
PLAN AT EL. 0.305
NOT FOR CONSTRUCTION
3 00 2018/03/22 ISSUED FOR CLASS 3 COST ESTIMATE AND PROJECT EXECUTION SCHEDULE.
2 PB 2017/08/25 ISSUED FOR CLIENT REVIEW.
1 PA 2017/08/16 ISSUED FOR SLI INTERNAL REVIEW.
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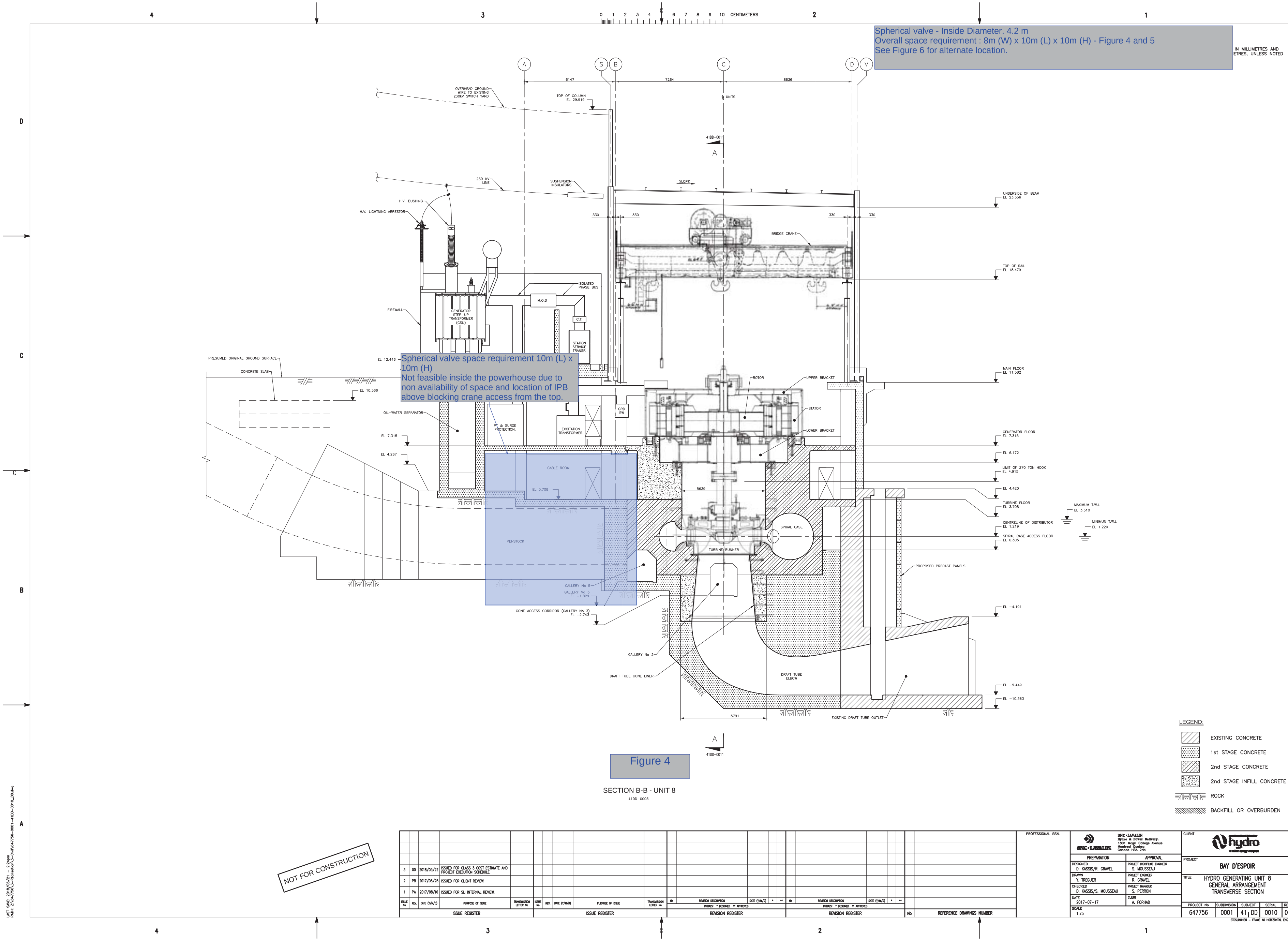
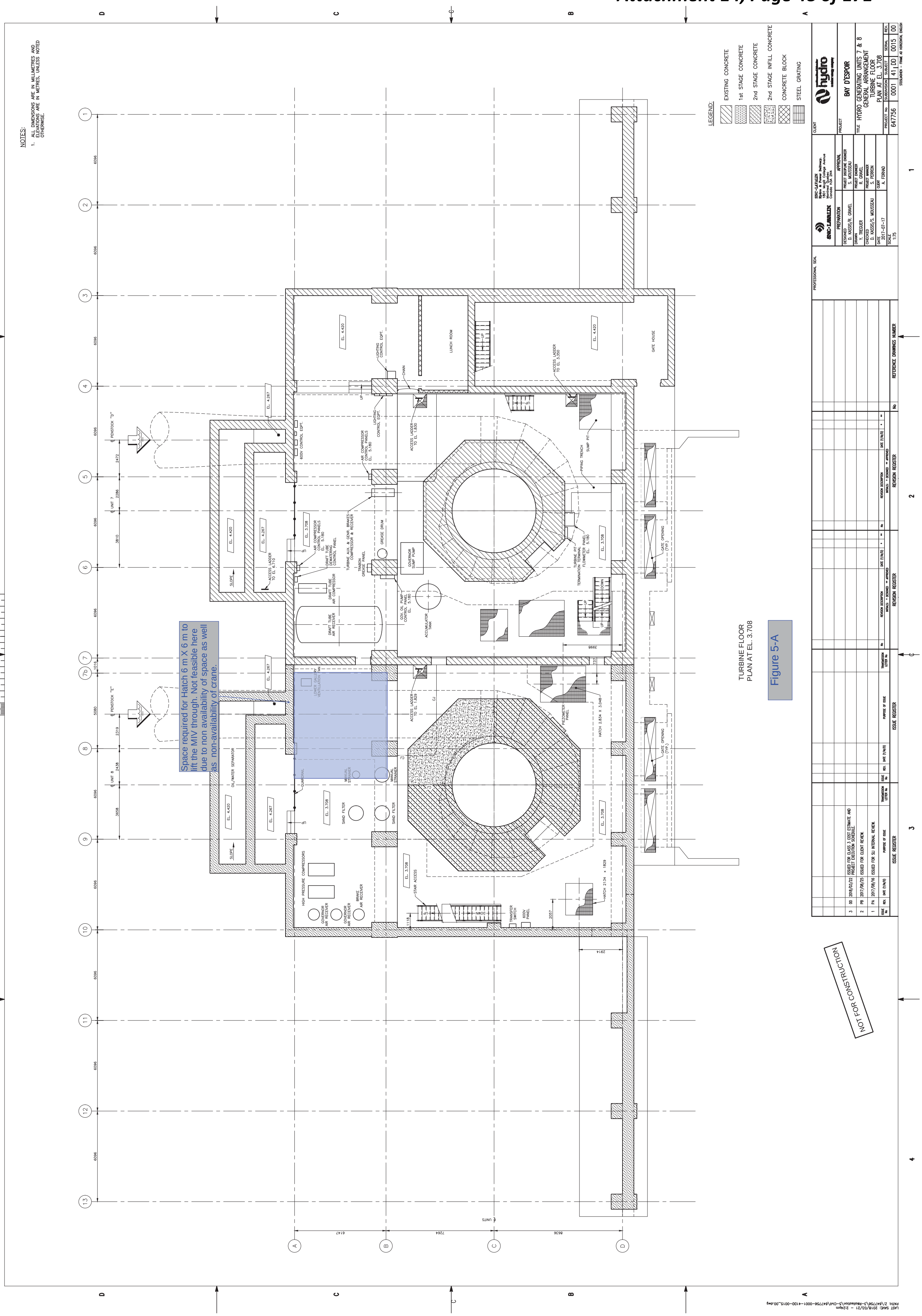
DRAWN Y. TREGUER
CHECKED D. KASSIS/S. MOUSSEAU
DATE 2017-07-17
SCALE 1:75
PROJECT BAY D'ESPOIR
TITLE HYDRO GENERATING UNITS 7 & 8 GENERAL ARRANGEMENT SPIRAL CASE ACCESS FLOOR PLAN AT EL 0.305
647756 0001 41 DD 0016 00

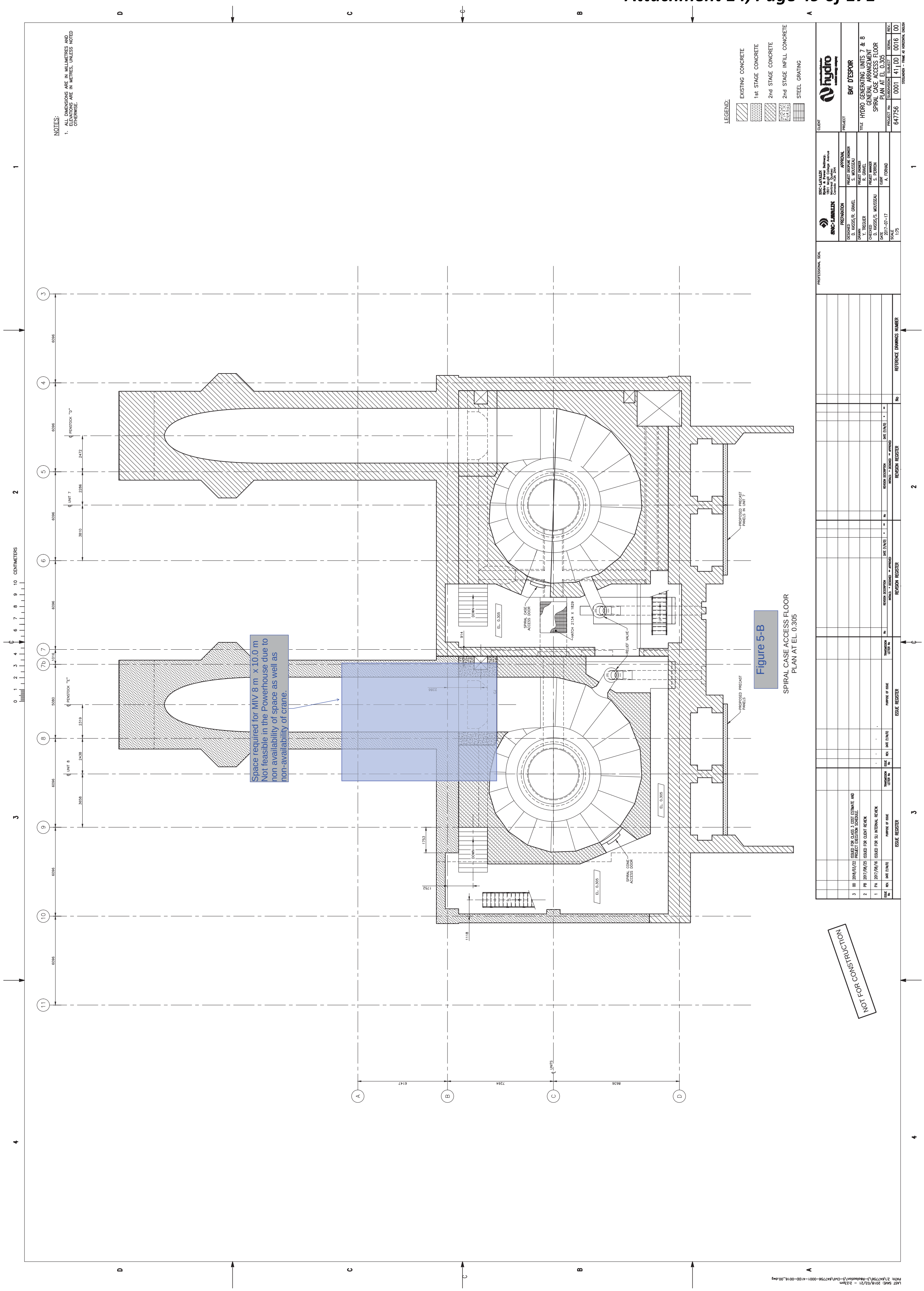
Sketch 2

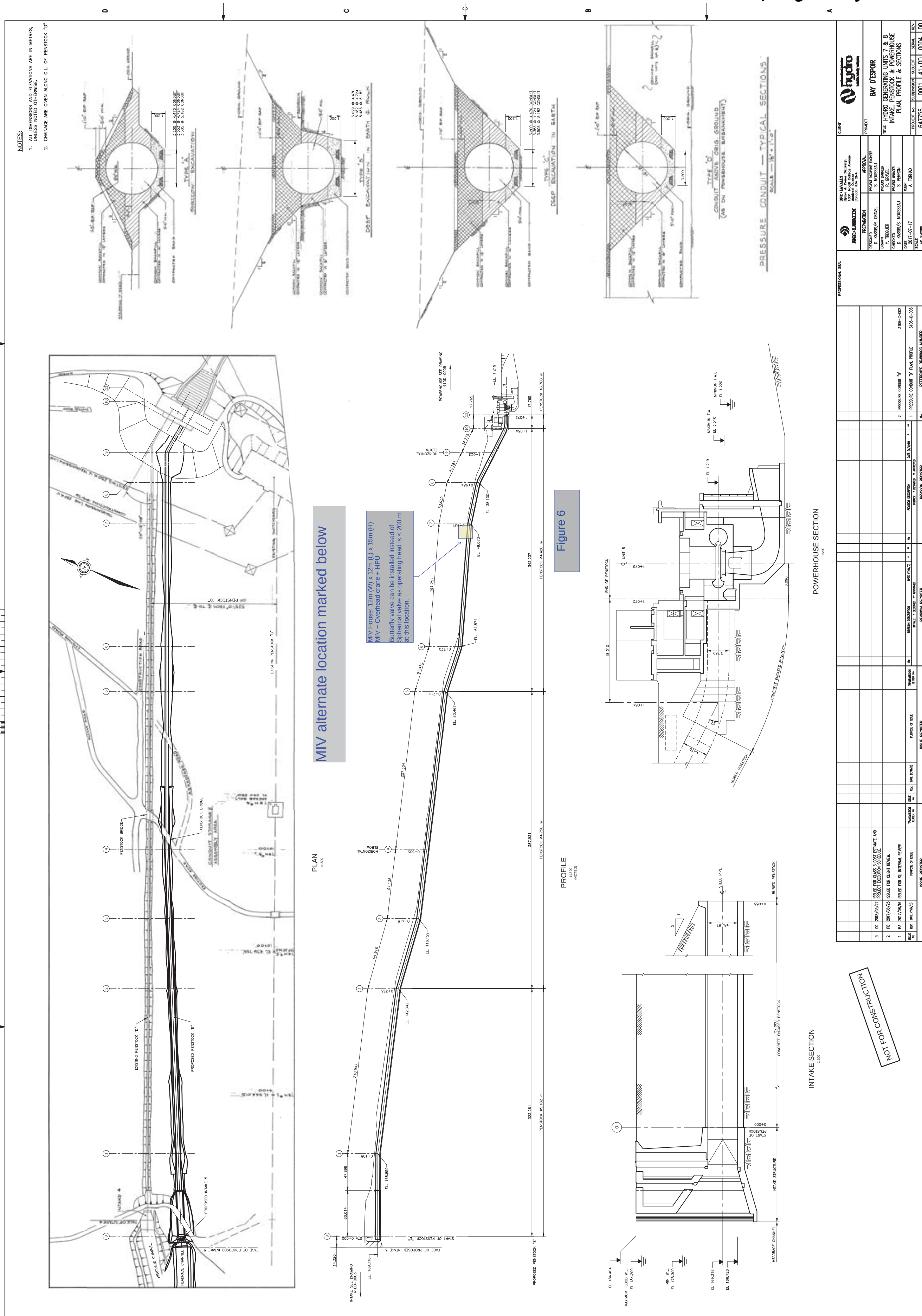
Spherical Valve Space requirement

Drawings found herein are extracted from the 2018 proposed Bay d’Espoir Generating Unit 8 study by SNC Lavalin.


Spherical valve - Inside Diameter. 4.2 m
Overall space requirement : 8m (W) x 10m (L) x 10m (H) - Figure 4 and 5
See Figure 6 for alternate location.
Spherical valve space requirement 10m (L) x 10m (H)
Not feasible inside the powerhouse due to non availability of space and location of IPB above blocking crane access from the top.
IN MILLIMETRES AND METRES, UNLESS NOTED
CENTIMETERS
OVERHEAD GROUND WIRE TO EXISTING 230kV SWITCH YARD
TOP OF COLUMN EL 29.919
230 KV LINE
SUSPENSION INSULATORS
H.V. BUSHING
H.V. LIGHTNING ARRESTOR
BRIDGE CRANE
UNDERSIDE OF BEAM EL 23.356
TOP OF RAIL EL 18.479
GENERATOR STEP-UP TRANSFORMER (GSU)
FIREWALL
M.O.D
ISOLATED PHASE BUS
C.T.
STATION SERVICE TRANSF.
PRESUMED ORIGINAL GROUND SURFACE
CONCRETE SLAB
EL 12.446
EL 10.366
OIL-WATER SEPARATOR
PT & SURGE PROTECTION
EXCITATION TRANSFORMER
GRD SW
ROTOR
UPPER BRACKET
STATOR
LOWER BRACKET
MAIN FLOOR EL 11.582
GENERATOR FLOOR EL 7.315
EL 6.172
LIMIT OF 270 TON HOOK EL 4.915
EL 4.420
TURBINE FLOOR EL 3.708
CENTRELINE OF DISTRIBUTOR EL 1.219
SPIRAL CASE ACCESS FLOOR EL 0.305
MAXIMUM T.W.L. EL 3.510
MINIMUM T.W.L. EL 1.220
EL 7.315
EL 4.267
CABLE ROOM
EL 3.708
PENSTOCK
SPIRAL CASE
TURBINE RUNNER
GALLERY No 5
GALLERY No 5 EL -1.829
CONE ACCESS CORRIDOR (GALLERY No 3) EL -2.743
GALLERY No 3
DRAFT TUBE CONE LINER
DRAFT TUBE ELBOW
PROPOSED PRECAST PANELS
EXISTING DRAFT TUBE OUTLET
EL -4.191
EL -9.449
EL -10.363
6147
7264
8636
330
5639
5791
UNITS
SLOPE
41DD-0011
Figure 4
SECTION B-B - UNIT 8
41DD-0005
LEGEND:
EXISTING CONCRETE
1st STAGE CONCRETE
2nd STAGE CONCRETE
2nd STAGE INFILL CONCRETE
ROCK
BACKFILL OR OVERBURDEN
NOT FOR CONSTRUCTION
3 | 00 | 2018/03/22 | ISSUED FOR CLASS 3 COST ESTIMATE AND PROJECT EXECUTION SCHEDULE.
2 | PB | 2017/08/25 | ISSUED FOR CLIENT REVIEW.
1 | PA | 2017/08/16 | ISSUED FOR SLI INTERNAL REVIEW.
ISSUE REGISTER
REVISION REGISTER
REFERENCE DRAWINGS NUMBER
PROFESSIONAL SEAL
SNC-LAVALIN
SNC-LAVALIN Hydro & Power Delivery. 1801 McGill College Avenue Montreal Quebec Canada H3A 2N4
PREPARATION
APPROVAL
DESIGNED D. KASSIS/R. GRAVEL
PROJECT DISCIPLINE ENGINEER S. MOUSSEAU
DRAWN Y. TREGUER
PROJECT ENGINEER R. GRAVEL
CHECKED D. KASSIS/S. MOUSSEAU
PROJECT MANAGER S. PERRON
DATE 2017-07-17
CLIENT A. FORHAD
SCALE 1:75
CLIENT
hydro
PROJECT BAY D'ESPOIR
TITLE HYDRO GENERATING UNIT 8 GENERAL ARRANGEMENT TRANSVERSE SECTION
PROJECT No 647756
SUBDIVISION 0001
SUBJECT 41 DD
SERIAL 0010
REV. 00
LAST SAVE: 2018/03/21 - 2:24pm
PATH: Z:\647756\3-Realisation\3-Civil\647756-0001-41DD-0010_00.dwg


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
LEGEND:
EXISTING CONCRETE
1st STAGE CONCRETE
2nd STAGE CONCRETE
2nd STAGE INFILL CONCRETE
CONCRETE BLOCK
STEEL GRATING
Space required for Hatch 6 m X 6 m to lift the MIV through. Not feasible here due to non availability of space as well as non-availability of crane.
TURBINE FLOOR
PLAN AT EL. 3.708
Figure 5-A
NOT FOR CONSTRUCTION
LUNCH ROOM
GATE HOUSE
HIGH PRESSURE COMPRESSORS
OIL/WATER SEPARATOR
SAND FILTER
ACCUMULATOR TANK
GOVERNOR SUMP PUMP
GREASE DRUM
STAIR ACCESS
BAY D'ESPOIR
HYDRO GENERATING UNITS 7 & 8
GENERAL ARRANGEMENT
TURBINE FLOOR
PLAN AT EL. 3.708
647756
ISSUE REGISTER
REVISION REGISTER
REFERENCE DRAWINGS NUMBER

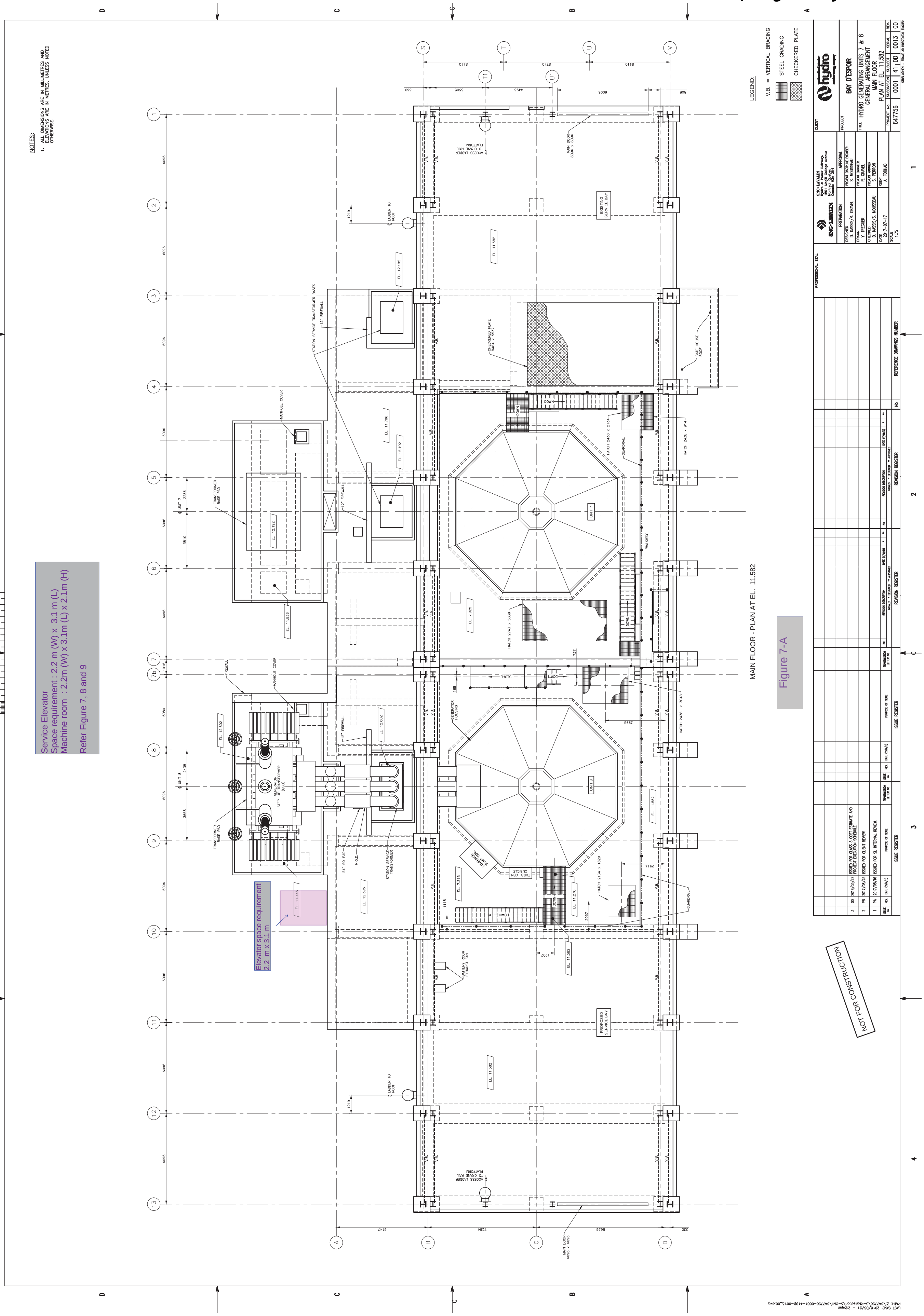

NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
LEGEND:
EXISTING CONCRETE
1st STAGE CONCRETE
2nd STAGE CONCRETE
2nd STAGE INFILL CONCRETE
STEEL GRATING
Space required for MIV 8 m x 10.0 m Not feasible in the Powerhouse due to non availability of space as well as non-availability of crane.
Figure 5-B
SPIRAL CASE ACCESS FLOOR PLAN AT EL. 0.305
PROPOSED PRECAST PANELS IN UNIT 7
PROPOSED PRECAST PANELS
SPIRAL CASE ACCESS DOOR
HATCH 2134 X 1829
RELIEF VALVE
EL. 0.305
DOWN
PENSTOCK "D"
PENSTOCK "E"
UNIT 7
UNIT 8
NOT FOR CONSTRUCTION
BAY D'ESPOIR
HYDRO GENERATING UNITS 7 & 8
GENERAL ARRANGEMENT
SPIRAL CASE ACCESS FLOOR
PLAN AT EL 0.305
647756
ISSUE REGISTER
REVISION REGISTER
REFERENCE DRAWINGS NUMBER

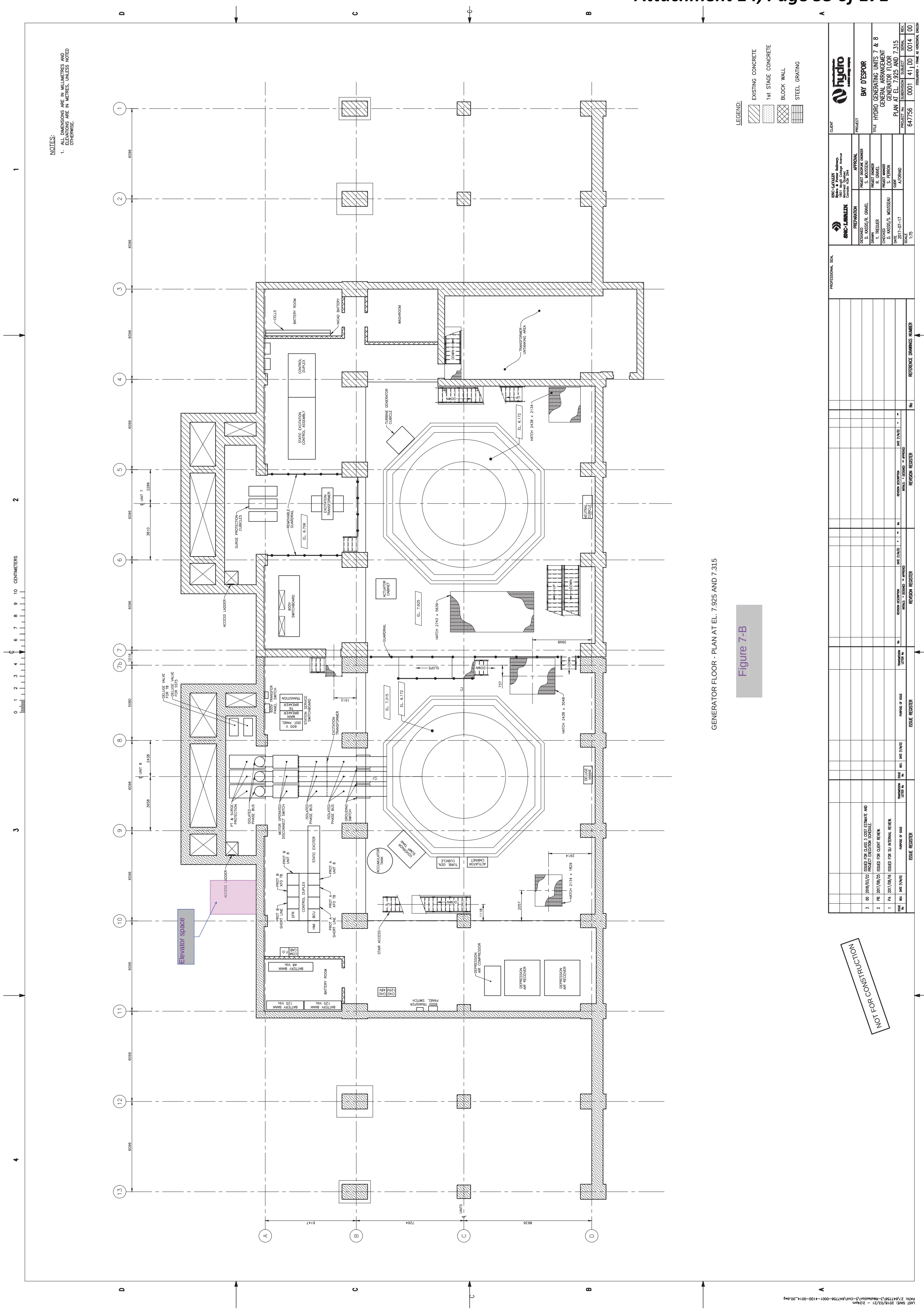

MIV alternate location marked below
MIV House: 12m (W) x 12m (L) x 15m (H)
MIV + Overhead crane + HPU
Butterfly valve can be installed instead of Spherical valve as operating head is < 200 m at this location.
Figure 6
PLAN
PROFILE
POWERHOUSE SECTION
INTAKE SECTION
PRESSURE CONDUIT — TYPICAL SECTIONS
NOT FOR CONSTRUCTION
NOTES:
1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
2. CHAINAGE ARE GIVEN ALONG C.L. OF PENSTOCK "D"
BAY D'ESPOIR
HYDRO GENERATING UNITS 7 & 8
INTAKE, PENSTOCK & POWERHOUSE
PLAN, PROFILE & SECTIONS
647756
ISSUE REGISTER
REVISION REGISTER
REFERENCE DRAWINGS NUMBER

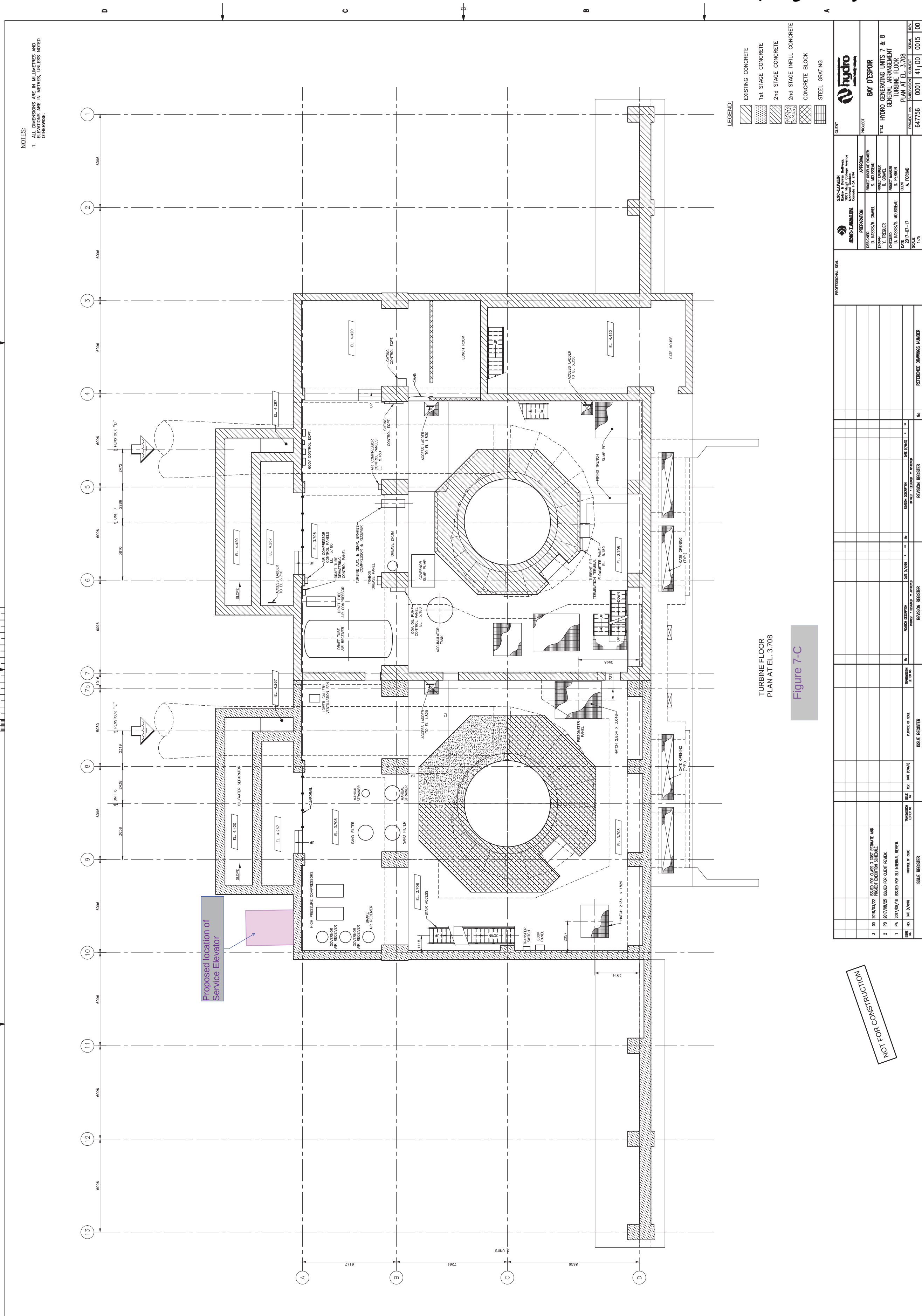
Sketch 3

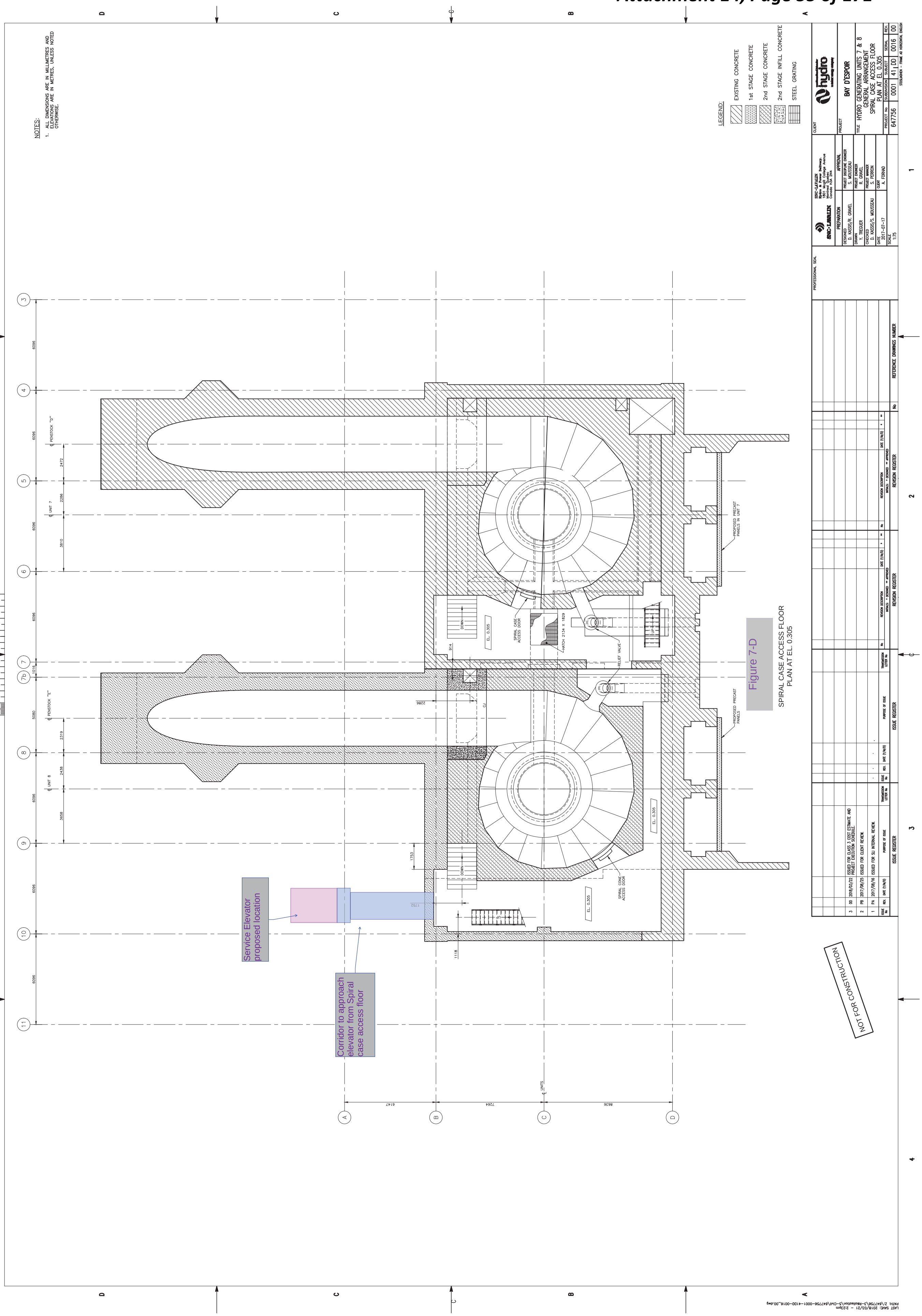
Space requirement and proposed location of Service Elevator

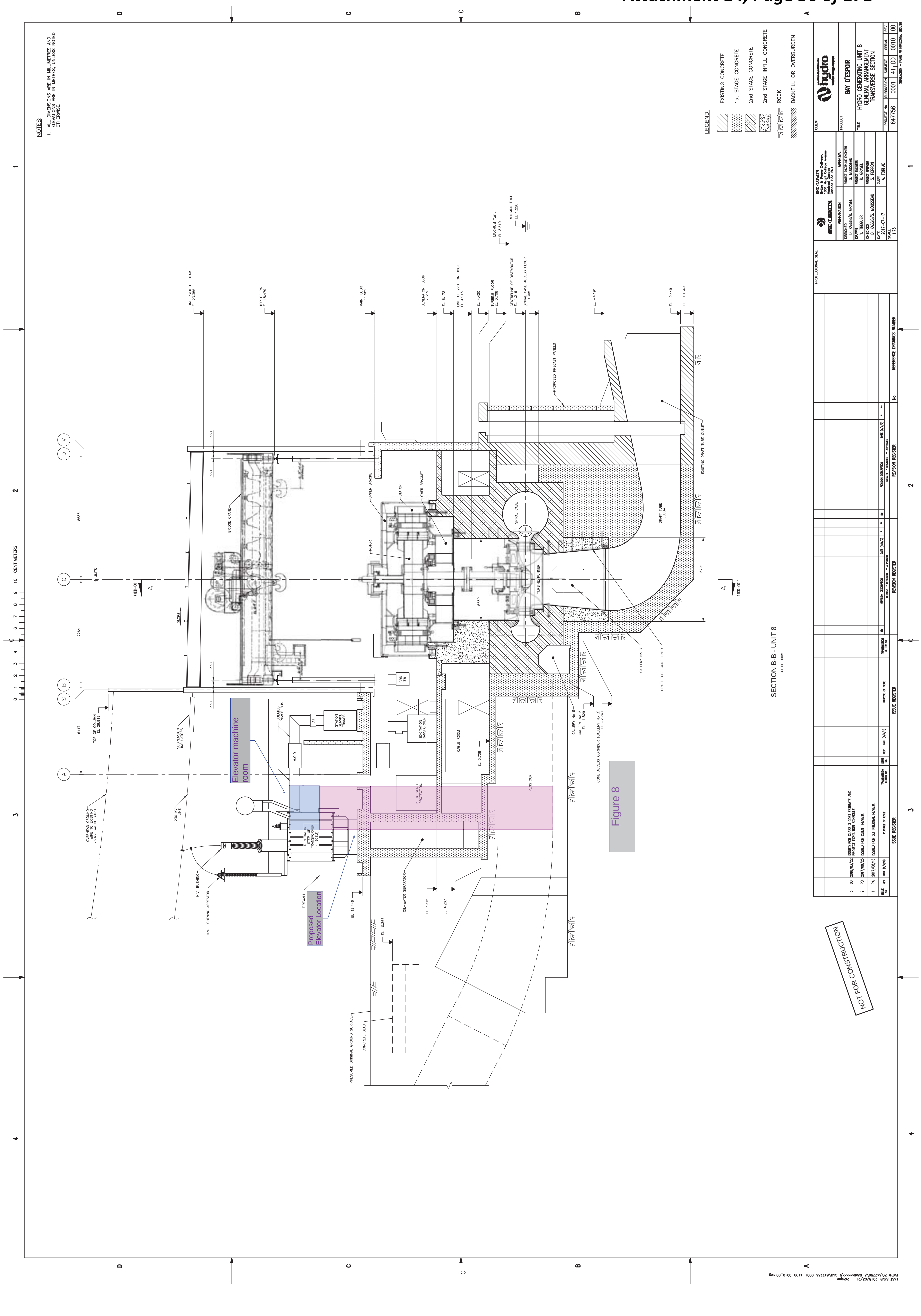
Drawings found herein are extracted from the 2018 proposed Bay d’Espoir Generating Unit 8 study by SNC Lavalin.

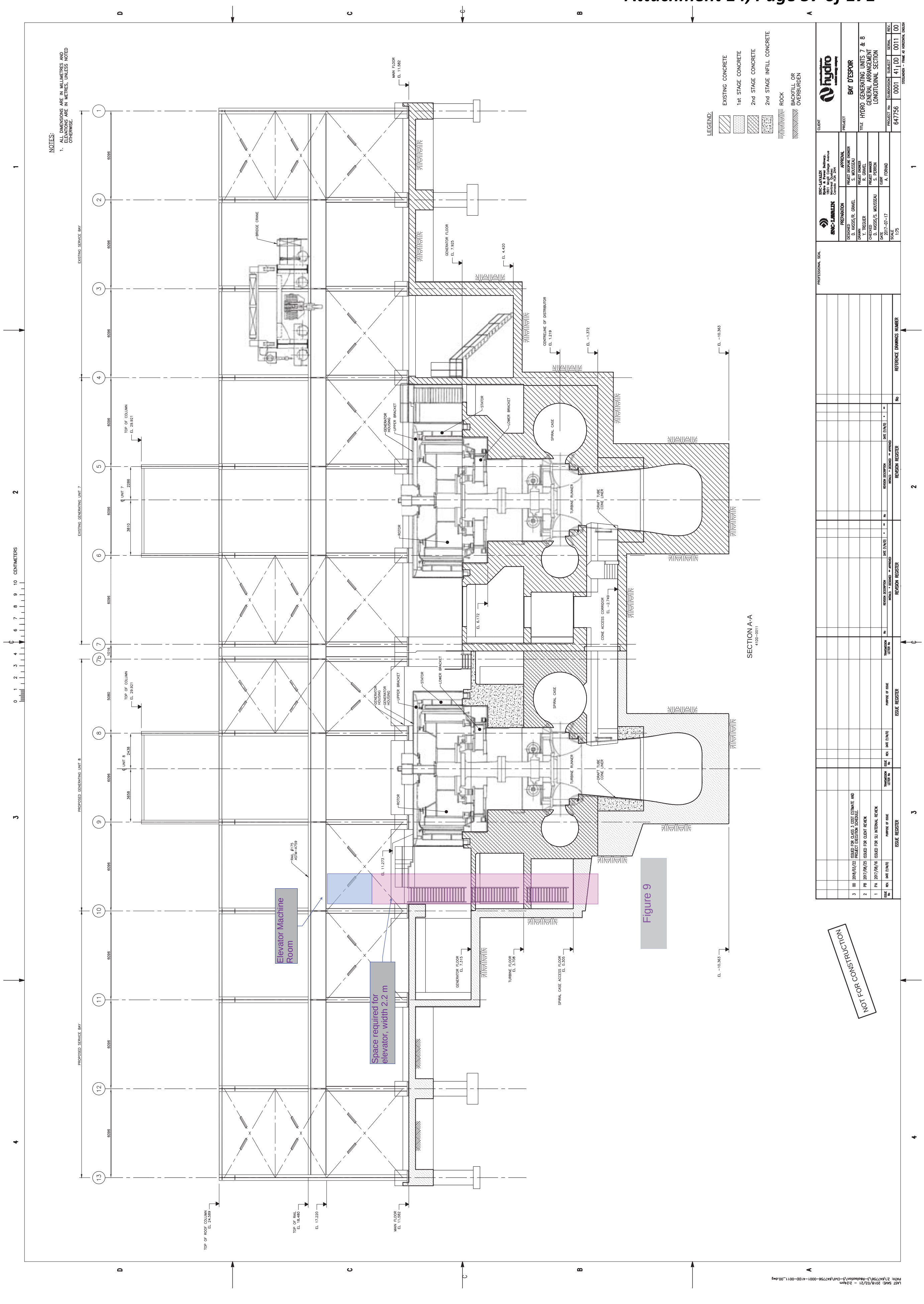

Service Elevator
Space requirement : 2.2 m (W) x 3.1 m (L)
Machine room : 2.2m (W) x 3.1m (L) x 2.1m (H)
Refer Figure 7, 8 and 9
Elevator space requirement
2.2 m x 3.1 m
MAIN FLOOR - PLAN AT EL. 11.582
Figure 7-A
NOT FOR CONSTRUCTION
NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
LEGEND:
V.B. = VERTICAL BRACING
STEEL GRADING
CHECKERED PLATE
BAY D'ESPOIR
HYDRO GENERATING UNITS 7 & 8
GENERAL ARRANGEMENT
MAIN FLOOR
PLAN AT EL. 11.582
647756


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
LEGEND:
EXISTING CONCRETE
1st STAGE CONCRETE
BLOCK WALL
STEEL GRATING
GENERATOR FLOOR - PLAN AT EL. 7.925 AND 7.315
Figure 7-B
Elevator space
NOT FOR CONSTRUCTION
BAY D'ESPOIR
HYDRO GENERATING UNITS 7 & 8
GENERAL ARRANGEMENT
GENERATOR FLOOR
PLAN AT EL. 7.925 AND 7.315
647756
BATTERY ROOM
WASHROOM
TRANSFORMER UNTANKING AREA
STATIC EXCITATION CONTROL ASSEMBLY
CONTROL DUPLEX
SURGE PROTECTION CUBICLES
EXCITATION TRANSFORMER
600V SWITCHBOARD
ACTUATOR CABINET
ACCESS LADDER
STATIC EXCITER
ACCUMULATOR TANK
STAIR ACCESS
DEPRESSION AIR COMPRESSOR
DEPRESSION AIR RECEIVER
ISSUE REGISTER
REVISION REGISTER
REFERENCE DRAWINGS NUMBER


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
LEGEND:
EXISTING CONCRETE
1st STAGE CONCRETE
2nd STAGE CONCRETE
2nd STAGE INFILL CONCRETE
CONCRETE BLOCK
STEEL GRATING
TURBINE FLOOR
PLAN AT EL. 3.708
Figure 7-C
Proposed location of Service Elevator
NOT FOR CONSTRUCTION
BAY D'ESPOIR
HYDRO GENERATING UNITS 7 & 8
GENERAL ARRANGEMENT
TURBINE FLOOR
PLAN AT EL. 3.708
647756
LUNCH ROOM
GATE HOUSE
HIGH PRESSURE COMPRESSORS
SAND FILTER
MANUAL STRAINER
OIL/WATER SEPARATOR
REVISION REGISTER
ISSUE REGISTER
REFERENCE DRAWINGS NUMBER


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
LEGEND:
EXISTING CONCRETE
1st STAGE CONCRETE
2nd STAGE CONCRETE
2nd STAGE INFILL CONCRETE
STEEL GRATING
Figure 7-D
SPIRAL CASE ACCESS FLOOR
PLAN AT EL. 0.305
Service Elevator proposed location
Corridor to approach elevator from Spiral case access floor
NOT FOR CONSTRUCTION
BAY D'ESPOIR
HYDRO GENERATING UNITS 7 & 8
GENERAL ARRANGEMENT
SPIRAL CASE ACCESS FLOOR
PLAN AT EL. 0.305
647756
ISSUE REGISTER
REVISION REGISTER
REFERENCE DRAWINGS NUMBER


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
LEGEND:
EXISTING CONCRETE
1st STAGE CONCRETE
2nd STAGE CONCRETE
2nd STAGE INFILL CONCRETE
ROCK
BACKFILL OR OVERBURDEN
Elevator machine room
Proposed Elevator Location
Figure 8
SECTION B-B - UNIT 8
NOT FOR CONSTRUCTION
BAY D'ESPOIR
HYDRO GENERATING UNIT 8 GENERAL ARRANGEMENT TRANSVERSE SECTION
ISSUE REGISTER
REVISION REGISTER
REFERENCE DRAWINGS NUMBER


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
LEGEND:
EXISTING CONCRETE
1st STAGE CONCRETE
2nd STAGE CONCRETE
2nd STAGE INFILL CONCRETE
ROCK
BACKFILL OR OVERBURDEN
BRIDGE CRANE
STATOR
LOWER BRACKET
UPPER BRACKET
GENERATOR HOUSING
SPIRAL CASE
ROTOR
TURBINE RUNNER
DRAFT TUBE CONE LINER
CONE ACCESS CORRIDOR
SECTION A-A
Elevator Machine Room
Space required for elevator, width 2.2 m
Figure 9
NOT FOR CONSTRUCTION
BAY D'ESPOIR
HYDRO GENERATING UNITS 7 & 8
GENERAL ARRANGEMENT
LONGITUDINAL SECTION
647756
ISSUE REGISTER
REVISION REGISTER
REFERENCE DRAWINGS NUMBER

APPENDIX C: Turbine Main Inlet Valve

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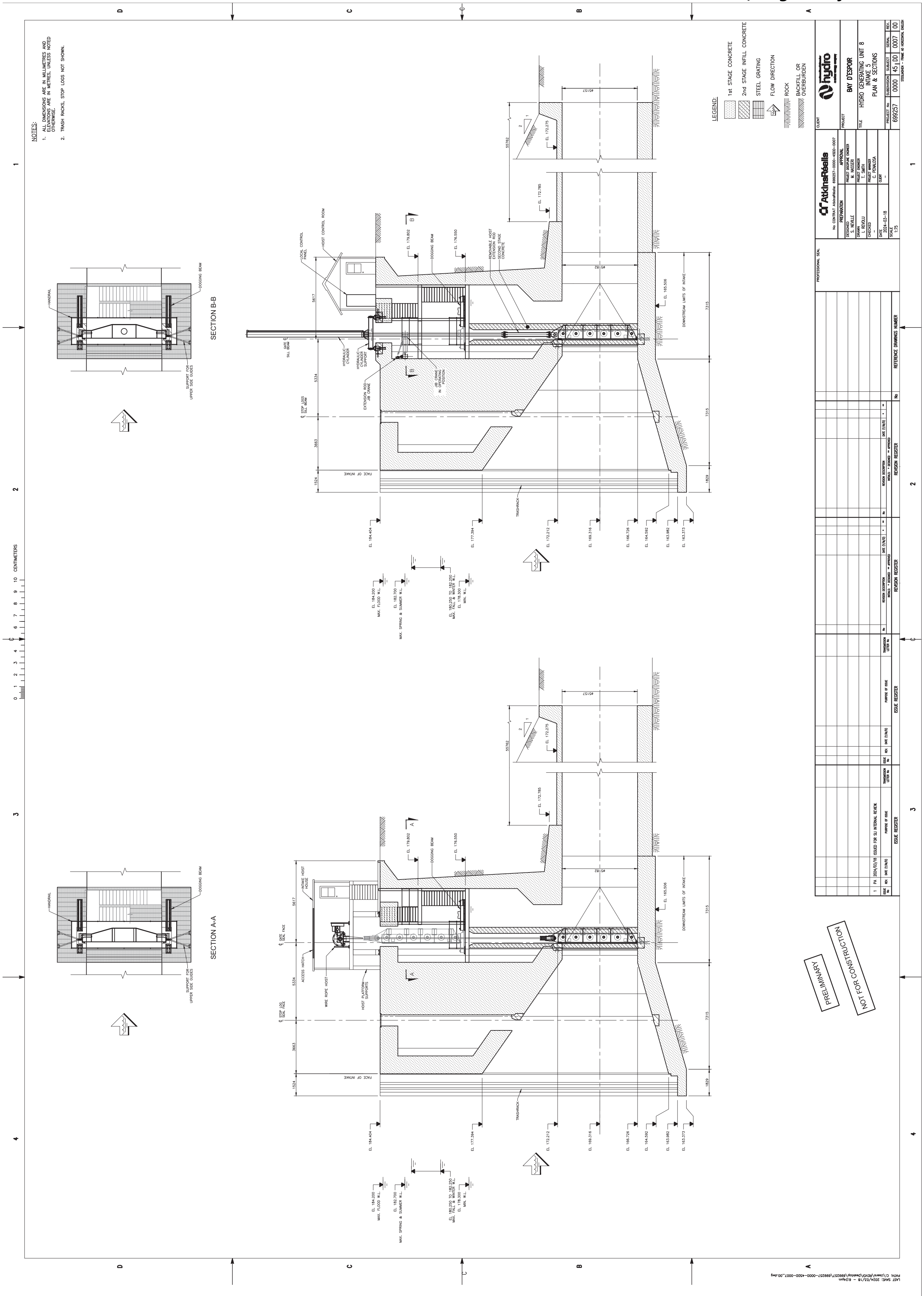
APPENDIX D: Intake Head Gate Arrangement


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES, UNLESS NOTED OTHERWISE.
2. TRASH RACKS, STOP LOGS NOT SHOWN.
LEGEND:
1st STAGE CONCRETE
2nd STAGE INFILL CONCRETE
STEEL GRATING
FLOW DIRECTION
ROCK
BACKFILL OR OVERBURDEN
SECTION B-B
SECTION A-A
PRELIMINARY
NOT FOR CONSTRUCTION
AtkinsRéalis
hydro
BAY D'ESPOIR
HYDRO GENERATING UNIT 8
INTAKE 5
PLAN & SECTIONS
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2024-03-18
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ISSUE REGISTER
REVISION REGISTER
REFERENCE DRAWINGS NUMBER
ISSUED FOR SU INTERNAL REVIEW
PROFESSIONAL SEAL
FACE OF INTAKE
DOWNSTREAM LIMITS OF INTAKE
TRASHRACK
DOGGING BEAM
HANDRAIL
EL 184.404
EL 177.394
EL 172.212
EL 169.316
EL 166.726
EL 164.592
EL 163.982
EL 163.373
EL 179.802
EL 176.550
EL 185.506
EL 172.785
EL 172.275
EL 184.200 MAX. FLOOD W.L.
EL 182.700 MAX. SPRING & SUMMER W.L.
EL 180.250 TO 182.250 MAX. FALL & WINTER W.L.
EL 178.300 MIN. W.L.

APPENDIX E: Greaseless Wicket Gate Bushing

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THORDON

Thordon Hydro-Turbine Bearing & Seal Product Guide to Oil & Grease Free Solutions

Updated: 2024

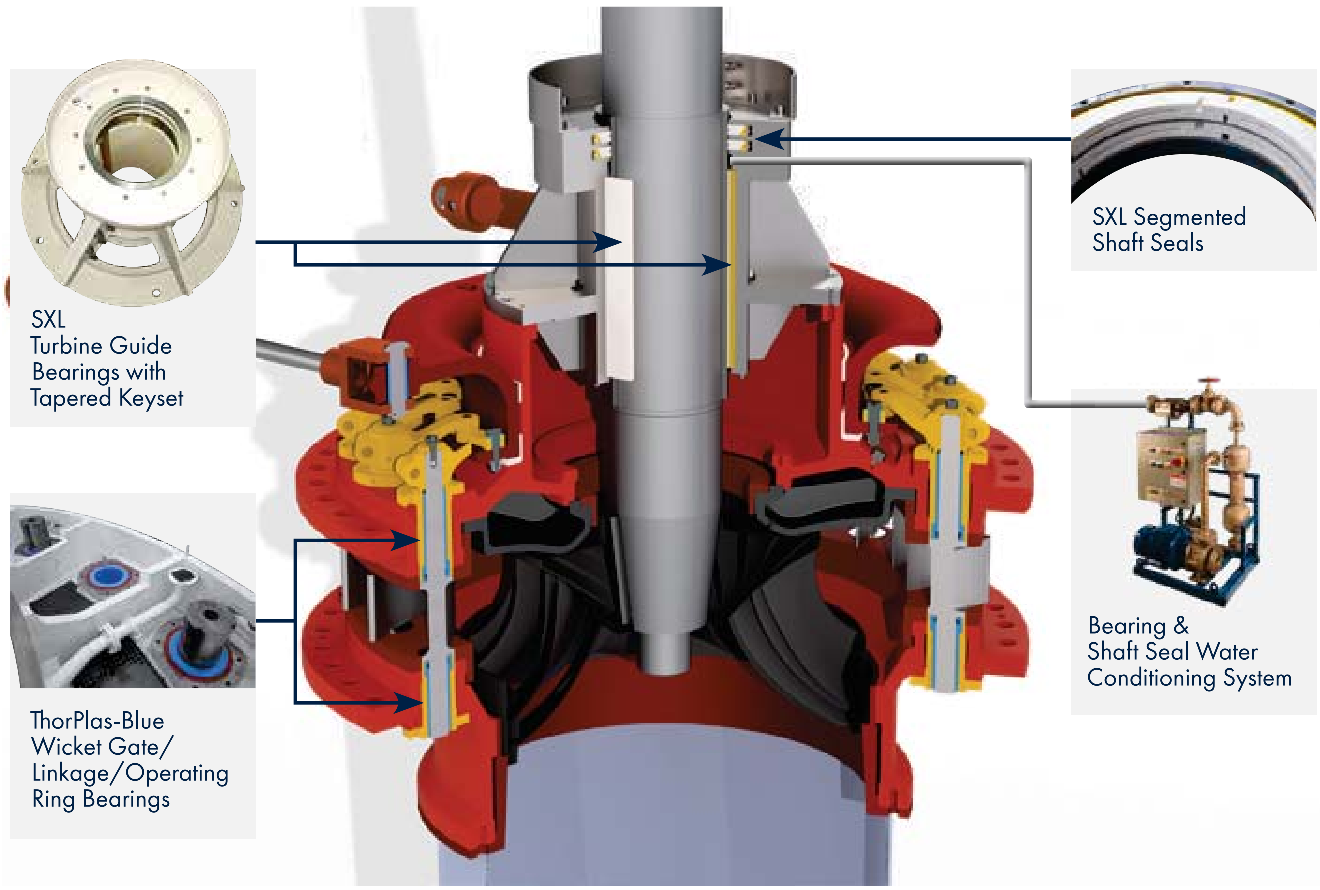
Table of Contents

1. The Thordon Turbine Bearing System

1.a Scope of Supply

Thordon's complete turbine bearing system for utilities includes the following components:

i. Water lubricated turbine guide bearing with tapered keyset
ii. Thordon Bearing and Shaft Seal Water Conditioning System
iii. Thordon SXL axial or radial segmented shaft seal
iv. ThorPlas-Blue wicket gate, operating mechanism, linkage bearings, operating ring wear pads and thrust bearings
v. Thordon Bearing Condition Monitoring – Hydro
vi. Shaft Sleeves



1.a.i Water Lubricated Turbine Guide Bearing with Tapered Keyset

Depending on the cleanliness of the water, Thordon offers two grades for turbine guide bearings:

- SXL
- GM2401

See the chart below for recommendations.

A water lubricated turbine bearing eliminates risk of oil or grease pollution. The elastomer bearing shell allows better load distribution over the bearing surface compared with stave type bearings and has a high tolerance for shock loading and vibration. Grooves in the bearing provide water to the bearing surface for cooling and lubrication.

A Thordon tapered key allows an interference fit of the bearing shell without bonding or additional mechanical fastening. The tapered key design allows for easy removal and replacement of SXL bearing shell, without removing the shaft or split metal bearing housing in as little as one hour - start to finish. This installation method allows for bearing inspection or renewal at any time reducing downtime and maintenance costs.

Thordon Recommendations for Turbine Guide Bearings

Water Lubrication	Recommended Thordon Grades	Notes
Clean/Conditioned Water	SXL with Thordon Water Conditioning System	SXL is best suited in combination with Thordon's Water Conditioning System which provides conditioned water flow, giving predictable bearing wear and maximum bearing life.
With High Abrasive Content	GM2401 with hard shaft sleeve	GM2401 is the best dirty water bearing on the market with proven history in extremely abrasive environments with no water filtration required. Use of a hardened shaft sleeve ensures abrasives will not wear down the shaft surface.

Thordon's homogeneous turbine guide bearings are easily installed into many different configurations:

- Tapered key design for fast and easy installation or removal
- Bonded/mechanically fastened into split or non-split bearing housings
- Full form cylindrical tubes
- Multiple pad-style arrangements for large diameter bearings >2.0m (6.5 ft.)
- Stave configurations available to directly replace worn out rubber, wood, or phenolic staves
- Other custom designed bearing solutions to fit any age or style of turbine

1.a.ii Thordon Bearing and Shaft Seal Water Conditioning System

Thordon's integrated monitoring and alarm on bearing water flow rate minimizes risk of bearing failure and provides an early warning of potential problems. The conditioning system removes abrasive particles larger than 100 microns to maximize bearing life and provide consistent wear behavior. There are multiple flow capacity ranges available depending on requirement. PLC operation allows for extensive customization, remote operation, and full integration with turbine controls. Available in Single or Duplex configurations for redundant back-up capability.

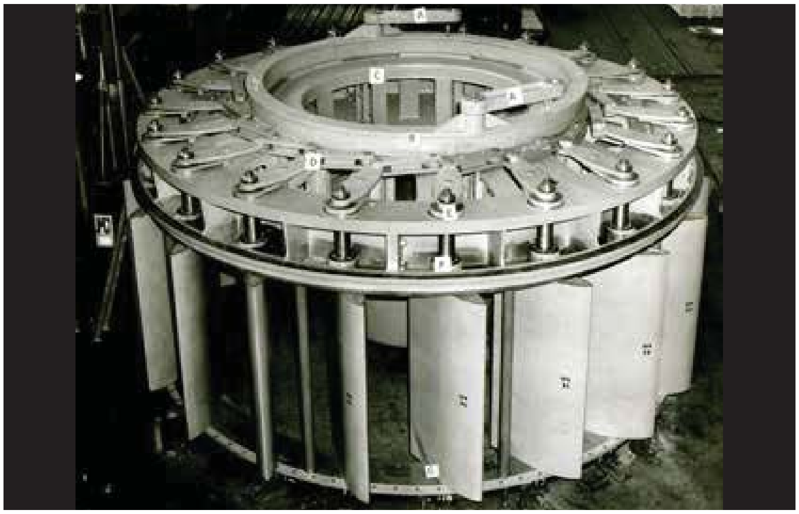
1.a.iii Thordon SXL Segmented Shaft Seals

Thordon SXL segmented axial and radial seals last longer and have a proven track record as a segmented shaft seal material replacing carbon graphite seals. The SXL material is almost unbreakable and eliminates the extra costs due to damaged seal segments, and the maintenance headaches of frequent changes. Thordon SXL seals are many times more abrasive resistant than other commonly used seal materials. Thordon segmented shaft seals are a proven solution working in both clean and abrasive laden waters.

The main factors that determine whether axial or radial seals shall be used are a) sealed water pressure and b) shaft size. As a general guideline, if shaft diameter is greater than 1000mm (39.4"), axial seals are typically recommended. Above rules are generally used for new build turbines. For existing turbines, Thordon has to check the detail arrangement of the existing seal and evaluate the pressure of sealed water to determine whether an SXL segmented seal design would be suitable for that application.

1.a.iv ThorPlas-Blue Wicket Gate, Operating Mechanism, Linkage Bearings, Operating Ring Wear Pads and Thrust Bearings

ThorPlas-Blue is a homogeneous, self-lubricating polymer bearing capable of withstanding operating pressures up to 45 MPa (6,527 psi) installed in a full-form, interference-fit configuration. It is an engineered thermoplastic offering very low wear in non-abrasive environments with several tests showing low friction and low wear. Thordon wicket gate, operating mechanism, linkage bearings, operating ring wear pads and thrust washers operate wet or dry and eliminate the cost, maintenance and pollution risk associated with greased bearings. These materials are also backed by an industry leading 15 year bearing wearlife guarantee. ThorPlas-Blue can be easily machined and sized to final dimensions on-site prior to installation or easily line bored after installation to correct misalignment and dimensional inconsistencies encountered during turbine rehabilitation.



A: Servo Linkage Bearings *[connects servos (usually 2x hydraulic cylinders) to drive the operating ring]*

B: Operating Ring

C: Operating Ring Assembly

D: Wicket Gate Linkage Bearings *(connecting the operating ring to the various wicket gate stems)*

E: Upper Wicket Gate Bearing

F: Intermediate Wicket Gate Bearing

G: Lower Wicket Gate Bearing

1.a.v Thordon Bearing Condition Monitoring - Hydro

Thordon's BCM-Hydro system delivers real-time information, providing plant operators with the ability to monitor bearing clearances remotely and instantly. Power stations can avoid unnecessary downtime by having access to accurate information on the turbine guide bearing wear performance, improving the ability to better manage outage planning. The BCM-Hydro system provides a remote reading and signal output that can be connected and integrated with turbine and plant control systems. Optional temperature sensors may be included to provide the operator with information about the bearing cooling water temperature within the bearing space. This can provide an early warning of potential bearing water supply interruption or blockages.

1.a.vi Shaft Sleeves

Thordon can provide stainless-steel sleeves for main turbine shafts that can be split and either welded or bolted.

1.b Water Lubricated Turbine Guide Bearing System Specification

The turbine guide bearing design shall take into consideration the following information:

- The guide bearing assembly shall be a water lubricated design, with full axial water grooves and an "open-loop" forced water system, with cooling water delivered to the bearing, passing through the bearing grooves, and exiting to the turbine runner
- Guide bearing material shall be made of an elastomeric polymer alloy. Physical properties of the elastomeric polymer should be within the range specified here: Tensile strength between 35 to 42 MPa (5076 to 6092 psi), Young's Modulus between 575 and 650 MPa (83,397 and 94,275 psi) and hardness between 65 to 70 Shore D
- The housing components shall be of stainless steel and the design includes easy installation and replacement of all components without removing the shaft or disassembly of any major structural components
- The disassembly and reinstallation of the elastomeric polymer alloy guide bearing for inspection or replacement shall be possible without damaging the bearing material
- Any recommended standard instrumentation shall be included in the design of the guide bearing.

1.c Turbine Guide Shaft Seal Specification

The shaft seal design shall take into consideration the following information:

- The shaft seal shall be a radial or axial type segmented seal assembly and shall be a proven design, previously used for similar applications.
- The shaft seal segments shall be made of an elastomeric polymer alloy. Physical properties of the elastomeric polymer should be within the range specified here: Tensile strength between 35 to 42 MPa (5076 to 6092 psi), Young's Modulus between 575 and 650 MPa (83,397 and 94,275 psi) and hardness between 65 to 70 Shore D.
- The shaft seal components shall be replaceable without removing the turbine guide bearing as they will be located above the turbine guide bearing.
- The shaft seal will also be manufactured in sufficient components and the design includes easy installation and replacement of all seal components without removing the shaft or disassembly of any major structural components.
- At least two (2) connections shall be provided in the seal housing for internal water supply to the synthetic polymer seal segments.
- The shaft seal assembly shall consist of all stainless-steel components except for the synthetic polymer seal ring segments.
- Any recommended standard instrumentation shall be included in the design of the shaft seal assembly.

1.d Wicket Gate, Operating Mechanism, Linkage Bearings, Operating Ring Wear Pads and Thrust Bearings Specification

The bearings shall be of an engineered thermoplastic, homogenous, self-lubricating polymer material capable of withstanding operating pressure up to 45MPa (6527 psi) installed in a full form, interference fitted configuration. The bearing material should have typical physical properties that include, but are not limited to, Tensile Modulus of Elasticity at 2930 MPa (424,961 psi), Elongation at break at 10%, Compressive Young's Modulus of Elasticity at 2410MPa (349,541 psi) and Compression Strain at Yield of 8%. The typical hardness of the material should be between 81 and 85 Shore D. The material should have no distinct layers or fibrous material that may crack or delaminate. The material should exhibit long term immersion volumetric swell values less than 0.15%. Grease and /or oils shall NOT be required for lubrication, providing an environmentally friendly bearing application. The bearing material shall be tolerant of minor misalignments and shall be capable of absorbing some shock and impact loads without damage.

1.e 15 Year Bearing Wearlife Guarantee for ThorPlas-Blue Wicket Gate, Operating Mechanism and Linkage Bearings

Thordon now offers a 15 Year Bearing Wearlife Guarantee in wicket gate applications, demonstrating our confidence in ThorPlas-Blue bearings and their proven experience. Since the introduction of ThorPlas-Blue to the hydro-turbine market over 20 years ago, the excellent wear life and low friction levels achieved worldwide is significant.

Thordon Guarantees that the diametric clearance of ThorPlas-Blue Wicket Gate & Linkage Bearings after 15 years in service will not exceed 5x the original installed clearance, or Thordon Bearings will supply new bearings free of charge.

Eligibility

All new or refurbished Hydro-turbines with wicket gate and linkage bearings having a shaft/gate stem diameter equal or greater than 50.8mm (2″).

Requirements

The end-user utility must clearly specify ThorPlas-Blue (see below) in order to qualify for the 15 year wear life guarantee. There will be a full technical signoff by Thordon Bearings prior to issuance of the 15 year wear life guarantee to the utility. A copy of the specification is available from Thordon.
(Bearings may be supplied to OEM or End-user customer directly, depending on project requirement)

ThorPlas-Blue Wicket Gate and Linkage Bearings

The specification includes:

1. ThorPlas-Blue wicket gate bearings (upper, middle, lower), and be fitted with Thorseals for all bearing positions in contact with water, to ensure a clean operating environment
2. ThorPlas-Blue linkage bearings and thrust washers, (if new linkage bearings are required)
3. Thordon SXL operating ring wear pads, (if new wear pads are required)

What is the Guarantee?

Thordon guarantees that the diametric clearance of ThorPlas-Blue wicket gate and linkage bearings after 15 years in service will not exceed 5x the original installed clearance, or Thordon Bearings will supply new bearings free of charge. The guarantee is limited to the supply of replacement bearings delivered to the end-user utility. It does not include replacement of any other Thordon supplied components nor any additional costs associated with the installation of replacement bearings.

Worked Example:

ThorPlas-Blue wicket gate bearings to fit a Ø203mm (7.992″) shaft and Ø223mm (8.779″) housing

Original installed diametrical clearance = 0.27mm (0.011″)

If the clearance is found to exceed 1.27mm (0.055″) before 15 years of service life, then Thordon Bearings will supply new ThorPlas-Blue bearings free of charge.

Conditions of Guarantee

- If third party machining of the bearings is used - Thordon must provide bearing sizing calculation & approve finished bearing dimensional report before installation
- Thordon Engineering to review & approve installed dimensions
- If existing operating ring wear pads and/or linkage bearings are to be re-used rather than replaced with new, Thordon to confirm that their condition is still suitable for use with new wicket gate bearings

1.f Options

Thorseals

Thorseals are made of a Thordon proprietary elastomer with no shelf life limit nor degradation of properties over time. They are customized seals to be made for your specific application. They are used in hard-to-reach wicket gate bearings to prevent contamination by abrasive laden waters or to seal water from entering the plant. They can also be integrated into ThorPlas-Blue bearing designs for easy one-piece installation. In hydraulic/pneumatic applications, high performance, tough Thorseal self-lubricating polymer lip seals offer positive sealing up to 100 MPa (15,000 psi). Thorseals provide long wear life with no need for periodic adjustments; resist tearing and extrusion; and as a result of their internal lubricants, operate with less drag and reduced cylinder wear.

Thorseals are not only available in a wide range of standard sizes, but can also be quickly machined to custom size requirements up to 1.5 m (60") in diameter. With over 40 years of experience designing and optimizing sealing applications Thorseal is the right material for your application.

Thorseal applications include:

Wicket Gate Seals, Kaplan Hub, Servo Motors, Turbine Brake Seals (Cup or Lip style), and to replace rubber or fabric chevron or v-packing sets.

Servomotor and Servo-Link Bearings

ThorPlas-Blue servomotor and servo-link bearings operate grease-free with a dry low coefficient of friction.

1.g Design Considerations for a Water Lubricated Turbine Guide Bearing System

A typical turbine guide bearing system has these basic functions:

- High Speed, Low Load Application
- Stabilize the turbine shaft: Provide location and support to turbine runner, stabilizing turbine shaft within the rotating system
- Force Balance: Hydrodynamic fluid film pressure at bearing/shaft interface must balance the applied radial load resulting from hydraulic forces on the runner
- Heat Balance: Friction heat at bearing/shaft interface must be removed by the cooling system (includes cooling water flow + conduction loss through shaft, bearing, and housing)

A stable full film lubrication should be the target for any turbine guide bearing design.

- Reduce sliding friction and losses
- Reduce wear rates of bearing material
- Reduce heat generated at the interface

Hydrodynamic bearings rely on the shaft rotation, bearing material, and groove configuration to build the fluid film. Hydrostatic bearings create the fluid film by introducing fluid at high pressure and special lift pocket/groove design (typical for thrust bearings), but hydrostatic water bearings exist.

Design considerations for a water lubricated turbine guide bearing:

- Load capacity, fluid film thickness
- Stiffness & damping characteristics
- Bearing running clearance
- Water quality (filtration level)
- Water flow rate requirement
- Bearing material selection
- Bearing load and Length/Diameter ratio
- Power loss, friction heat removal
- Bearing condition monitoring
- Machine orientation (horizontal/vertical)
- Shaft condition in bearing area
- Shaft geometry (flanged, or straight)
- Mounting support structure
- Space limitations
- Shaft sealing considerations
- Vacuum below bearing, restricter rings
- Bearing construction & fitting (split, bonded, interference fit, mechanical fastening)

Understanding The Turbine Guide Bearing Load

When dealing with old turbines, the load is not usually known – but can be calculated. In a new design, the manufacturer will know the loading for various operating conditions. The loading on a vertical turbine is primarily due to hydraulic forces acting on the runner. In a horizontal turbine, the weight of shaft & runner is more significant

- Radial bearing load determines bearing pressure
- Bearing pressure affects fluid film development and bearing life
- Therefore, higher load requires more area
- More bearing area requires more length &/or diameter!

Guideline for Bearing Length/Diameter ratio

Shaft Orientation	Recommended L/D Maximum	Recommended L/D Minimum
Vertical	2 : 1	0.3 : 1
Horizontal	3 : 1	0.75 : 1

Guideline for Bearing Pressure

Turbine Orientation	"Normal" Operating Condition Pressure	"Runaway" or Peak Transient Pressure
Vertical or Horizontal	0.4 MPa (60 psi)	0.9 MPa (130 psi)

Select Bearing Wall Thickness

Wall thickness selection is influenced by:

- Shaft outside diameter and new housing inside diameter (or existing housing size)
- Fitting method (interference vs. bonded vs. mechanical fastening)
- Wear down allowance (especially in staved type bearings)
- Groove design, shape & depth

In general, try to minimize wall thickness (Typical ~15 to 25mm, or 0.5" to 1")

Minimizing wall thickness helps to control these parameters:

- Thermal expansion allowance
- Water absorption allowance
- Bearing clearance

Calculate the Correct Bearing Clearance

Minimum bearing clearance depends primarily on operating temperatures, wall thickness, and thermal expansion & absorption allowances, but in general:

- Bonded bearings can be fit with thinner walls than interference fit bearings
- Thinner walls allow tighter clearances due to reduced absorption & thermal allowances
- Tightly controlled temperature range will allow a smaller clearance, but reduces safety margin against overheating

Minimum Installed Clearance

= Running Clearance (Rcl)
+ Water Swell Allowance (WS)
+ Thermal Expansion Allowance (TE)

Water Flow Requirements

Water flow provides 3 critical functions:

- Flooding of bearing space for hydrodynamic fluid film
- Removal of friction heat from bearing/shaft interface
- Flushing of abrasive particles (positive pressure in bearing space)

Clean, consistent flow is more important than flow direction

- Typically flow enters at top of bearing, down through the bearing, and out through turbine – inlet may also be at bottom
- Estimate minimum cooling water flow rate as follows:
    - 0.3 L/min per mm of shaft diameter (e.g. 300mm shaft requires 90 L/min)
    - 2.0 GPM per inch of shaft diameter (e.g. 12” shaft requires 24 GPM)
- Flow monitoring with low flow alarm is strongly recommended

Other Design Advice

- Limit corrosion – Use stainless steel or metallizing to protect shaft against corrosion in the bearing and seal working area
- Minimize abrasive entry – Keep a slight positive water pressure in the bearing space by maintaining adequate water flow at all times
- Don’t design water filtration systems at the limits – Too much cooling water is always better than not quite enough!
- Consult OEM’s. – The bearing manufacturer’s engineering team does a thorough review of water lubricated turbine bearings based on over 40 years of experience

1.h Design Considerations for Wicket Gate, Operating Mechanism and Linkage Bearings

Mating Surfaces (wicket gate stem outer diameter)

- Min. hardness of 20 Rockwell C to reduce abrasive wearing of the surface
- Surface should be of a corrosion resistant material – typically a stainless steel sleeve over the gate stems, or metallization surface treatments (HVOF, hard chrome, etc.)
- Surface finish should be 0.8 – 1.6 micrometers Ra (32 - 63 micro-inch)

Mounting Surface (housing inner diameter)

- Housing surface should be smooth & free of severe corrosion in the bushing area
- Accurate housing measurements should be used for sizing bearings, ideally four measurements per opening (at the top and bottom of the bore, and in both X & Y directions)

Method of Securing Bushings

- Self-lubricated bearings are secured by interference press-fit or freeze fit into the housing
- Interference between finished bearing OD and housing ID should be calculated by Manufacturer
- Anti-rotation or locking pins/screws may be required to secure the bushings, depending on Manufacturer

Fitting of Thorseals

- Thorseals should be fitted with the bushings directly above and below the wicket gate, to minimize entry of abrasive water into the bearing space.
- Thorseals may be integrated into the ID of the bearing, or fitted separately into the housing
- Thorseals may also serve the function of sealing the head cover against water leakage, or separate seals or packing may be fitted depending on turbine design

Other Design Advice

- Limit corrosion - Use stainless steel or metallizing to protect shaft stem
- Minimize abrasive entry – Use lip seals (not o-rings), integrated in bearing
- Don't design at the limits – be conservative when considering real-life friction characteristics

1.i List of Thordon Manuals and Brochures

The following manuals and brochures are available:

- Hydro-Turbine Bearings & Seals Brochure
- Thordon Engineering Manual
- ThorPlas Bearings Engineering Manual
- SXL Water Lubricated Main Shaft Guide Bearings
- SXL Segmented Shaft Seals Brochure
- Water Quality Package Brochure for Hydro Applications

1.j Research Papers

1.j.i Turbine guide bearing papers

- TBI - Load Capacity and Water film thickness of fully Grooved Main Guide Bearings for Hydro Turbines
- TBI - Water Film Stiffness and Damping Analysis of Water Lubricated Turbine Bearings_08_08_2016G
- TBI - Reducing Maintenance with Water Lubricated Turbine Guide Bearings
- TBI - An Oil to Water Conversion of a Hydro Turbine Main Guide Bearing

1.j.ii Wicket gate, operating mechanism and linkage bearing papers

- TBI - Challenging Edge loading - A Case Study in Polymer Bearings
- TBI - Friction and Wear Characteristics of ThorPlas Bearings and their Applications in Hydro-turbines
- Lulea U - Vattenfall wicket gate Bearing test paper Feb 2013
- Lulea U - Thordon ThorPlas test with increasing load
- Lulea U - Performance and surface characteristics of slow oscillating journal bearings subjected to various motion patterns

1.j.iii Segmented shaft seal papers

- TBI - Design Aspects - Radial Seals_2005
- TBI - Design Aspects - Axial Seals_2007
- TBI - Hydro-Turbine Main Shaft Axial Seals of Elastic Polymer - Principle & Practice

1.k Thordon Videos

These videos are posted on Thordon's YouTube channel or available:

- Thordon SXL Hydro Turbine Guide Bearing with Tapered Keyset Assembly
  Thordon's SXL turbine guide bearing with tapered keyset and SXL radial shaft seal assembly provides a fully integrated solution, engineered for the application and entirely free of oil and grease for environmental compliance
- Oil to Water: A Hydro Turbine Gets Greener
  A short film highlighting the process of converting a hydro-turbine main shaft guide bearing from an oil lubricated system to water
- Hydro-Turbine Segmented Shaft Seals - Thordon SXL vs. Carbon Graphite
  Thordon SXL segmented axial and radial seals last longer and reduce life-cycle costs compared to carbon graphite seals. This video shows why Thordon SXL is so much easier to handle and install compared to carbon graphite
- Thordon Wicket Gate Bearing Application
  ThorPlas wicket gate bearings are installed in New Zealand
- Thordon Water Quality Package
  Thordon Water Quality Package Animation
- Thordon Bearings Interviewed at HydroVision International
  Thordon Bearings' Hydro Manager being interviewed about the use of Thordon in Hydro Turbine Applications

2. Thordon's Unique Selling Proposition (USP)

2.a Water Lubricated Turbine Guide Bearing System

For hydro-turbine utilities, a Thordon Water lubricated Turbine Guide Bearing System offers the longest bearing wear life with the lowest operating maintenance costs with the ability to replace existing materials with minimal additional machine modifications. In new turbine designs, the water lubricated bearing allows easier access to the shaft seal and gives the designer flexibility to locate the guide bearing support closer to the runner centerline.

2.b ThorPlas-Blue Wicket Gate, Operating Mechanism and Linkage Bearings

For hydro-turbine utilities, ThorPlas-Blue wicket gate, operating mechanism and linkage bearings offers low friction, no galling from edge loading and excellent bearing wear life guaranteed for 15 years unlike any other bearing manufacturer in the world.

3. Top 10 Reasons to Use Thordon Hydro-turbine Wicket Gate, Linkage & Operating Mechanism Bearings

1. Long wear life
2. Stands up to edge loading
3. Homogeneous Polymer - won't delaminate or wear low friction layer away
4. Simple and safe to machine - no harmful dust created
5. Stable Friction - uniform lubricant throughout entire bearing
6. Self-lubricating in wet or dry operation with NO oil or grease lubrication
7. Withstands operating pressures up to 45 MPa (6500psi)
8. Guaranteed: 15 year bearing wear life
9. Many stock sizes available and quick delivery on custom orders
10. Technical support from concept through to implementation

4. Understanding Water Pollution Regulations

In the near future, oil discharges into our oceans, seas, lakes and rivers will no longer be allowed. New environmental regulations in the U.S. have seen a crackdown on oil discharges not only for marine vessels but also for hydro-electric generating facilities. The recent ruling against 8 U.S. Army Corps of Engineers (USACE) power stations along the Columbia River may have set a precedence that other hydro facilities need to be aware of.

In 2013, Columbia Riverkeeper (an environmental group focused on protecting and restoring the water in the Columbia River) filed three federal count complaints against the USACE due to violations of the Clean Water Act (CWA) caused by generation facilities located along the Columbia and Snake Rivers in Washington State. The Columbia Riverkeeper group gathered dozens of reports documenting oil spills from these dams and some of the oil contained PCBs (polychlorinated biphenyls) which has been linked to cancer. Through further investigation, the Columbia Riverkeeper group found that oil leakage was considered standard operating practice by the dam operators.

The August 2014, settlement required all eight of the USACE facilities (Columbia River dams: Bonneville, John Day, The Dalles, and McNary plus the Lower Snake River dams: Ice Harbor, Lower Monumental, Little Goose, and Lower Granite) to honor the following binding obligations:

a. If any facility discharges lubricants into the waterways it must undergo analysis and public reporting
b. Within 18 months the facility must convert to Environmentally Acceptable Lubricants (EALs) if feasible
c. Apply for pollution permits from the Environmental Protection Agency (EPA) to address any discharges that may occur from their facilities

With the knowledge of this settlement, hydro generating facilities need to be proactive to ensure that they follow the CWA regulations of the U.S. Environmental Protection Agency (EPA). A simple proven solution is to convert any oil lubricated main guide bearings and wicket gate bearings to Thordon's grease and oil free bearings.

Thordon's SXL Main Guide Bearings and ThorPlas-Blue bearings (used for wicket gates and operating linkage bearings) work without any oil or grease. Thordon has a proven track record in the hydro industry and offers a pollution free solution for Hydro power plant operators.

5. Frequently Asked Questions

Q: What is the best shaft mating material for Thordon turbine guide bearings?

A: Many materials are acceptable - Bronzes, stainless steels and various hard coatings available. For high abrasives content, best results obtained using 40 Rc with suitable corrosion resistance.

Q: Can staves be supplied for turbine guide bearing conversions?

A: YES – SXL is available in staves.

Q: What is the bearing material used for wicket gate bearings?

A: ThorPlas-Blue is the preferred material for wicket gate & linkage applications.

Q: What makes ThorPlas-Blue wicket gate bearings unique compared to most other materials?

A: Unlike most other competitive materials used in wicket gate bearing applications, ThorPlas-Blue bearings are homogeneous with solid lubricant uniformly distributed through the entire bearing wall. There are no layers, plugs, or fibers that can lead to unpredictable or inconsistent wear and friction performance.

Q: Should stainless steel liners be used with ThorPlas-Blue wicket gate bearings?

A: Yes – a corrosion resistant surface should be always used when grease is removed from a bearing interface exposed to water. Stainless steel liners, hard chrome, and other metallization procedures on the wicket gate stem are all suitable.

Q: What is the max. operating pressure for ThorPlas-Blue wicket gate bearings?

A: The maximum operating pressure is 45 MPa (6500 psi) when in a dynamic or moving condition, and can withstand loading up to 60 MPa (8700 psi) in a static or stationary load condition.

Q: Can we continue using grease with ThorPlas-Blue wicket gate bearings?

A: Greasing of the ThorPlas-Blue self-lubricated bearing material is not necessary, nor is it recommended. In case it is still required by the operator for some reason, there is no concern with material compatibility, but once grease is applied to the bearing it must be maintained as it will reduce the ability of the material to maintain a self-lubricating condition.

Q: How are ThorPlas-Blue wicket gate bearings fitted into the housings?

A: They are normally fitted by press or freeze fitting with an interference fit between the housing ID and bearing OD. The interference fit is larger than for an equivalent metallic bearing and should be calculated using the Thordon Bearing Sizing Program.

Q: Can we machine the ID of the ThorPlas-Blue bearing after fitting to achieve a tighter tolerance?

A: Yes, the bearings can be supplied and installed with a slight overbuild on thickness to allow a final machining pass after fitting. This is only necessary if trying to achieve the tightest possible clearance. For most customers and installations an acceptable fit is achieved when the bearings are fully machined before fitting.

THORDON

THORDON BEARINGS INC.

A Thomson-Gordon Group Company - Innovating since 1911

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www.ThordonBearings.com

ZERO POLLUTION | HIGH PERFORMANCE | BEARING & SEAL SYSTEMS

ThorPlas-Blue Wicket Gate and Linkage Bearings
15 Year Wear Life Guarantee

Eligibility

All new or refurbished Hydro-turbines with wicket gate and linkage bearings having a shaft diameter equal or greater than 50.8mm (2").

Requirements

The end-user utility must clearly specify ThorPlas-Blue (see below) in order to qualify for the 15 year wear life guarantee. There will be a full technical signoff by Thordon Bearings prior to issuance of the 15 year wear life guarantee to the utility. A copy of the specification is available from Thordon.

(Bearings may be supplied to OEM or End-user customer directly, depending on project requirement)

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The specification includes:

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What is the Guarantee?

Thordon guarantees that the diametric clearance of ThorPlas-Blue wicket gate and linkage bearings after 15 years in service will not exceed 5x the original installed clearance, or Thordon Bearings will supply new bearings free of charge. The guarantee is limited to the supply of replacement bearings delivered to the end-user utility. It does not include replacement of any other

Thordon supplied components nor any additional costs associated with the installation of replacement bearings.

Worked Example:

ThorPlas-Blue wicket gate bearings to fit a Ø203mm (7.992") shaft and Ø223mm (8.779") housing

Original installed diametrical clearance = 0.27mm (0.011")

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- If 3rd party machining of the bearings is used - Thordon must provide bearing sizing calculation & approve finished bearing dimensional report before installation
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THORDON
THORDON BEARINGS INC.

nalcor energy

ThorPlas-Blue Wicket Gate & Linkage Bearings

15 YEAR WEAR LIFE GUARANTEE

15 YEAR BEARING WEARLIFE GUARANTEE

[redacted]

[redacted]

[redacted]

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OILES

OILES SELF-LUBRICATING BEARINGS

for HYDRO POWER & GATES

OILES CORPORATION

Table of Contents

Who is OILES Corporation

In 1932, an encounter of Sozo Kawasaki, the founder of OILES corporation, opened the door to the history of OILES as well as the history of oil-less bearings in Japan.

One day, when Kawasaki, by then the mechanical agent chief of the monopoly bureau, was disassembling a cigarette-rolling machine imported from America, he found a bearing that did not require the use of oil.
The wood bearing had no oil hole. It was a self-lubricating bearing that had never been produced in Japan.

Since then, OILES experienced incredible growth with its leading technology in the tribology field, and now OILES bearing is used in many applications in many industries.

Specifically for hydro power and water gate, OILES has been supplying self-lubricating bearings to those industries for over 60 years, and now, OILES bearing is used in more than 2,000 facilities of Hydropower industry throughout the world.

With this long experience, OILES established a reputation for quality and reliability in these markets.

The Benefits of OILES Bearings

Maintenance-free
Reduce the lubrication quantity and frequency or can be used without oil or grease.

Environment-friendly
Protects the environment against contamination from oil.

Reduction of running costs
Reduces lubricating oil consumption and equipment maintenance costs and enables a remarkable reduction in operating costs.

Corrosion resistance
Can be used in corrosion environments, such as wet environments.

Flexibility
It's possible to choose from metallic bearings and plastic bearings according to the conditions for use. There are various sizes of standard products and it's also possible to make custom-made products.

Hydro Power Applications

Since OILES 500 Series Bearings were first adopted as Wicket Gate Bushings in 1967, OILES Corporation has been a Leading Supplier for Self-lubricating Bearings for Hydro Power Generation.

Okutadami Power Station

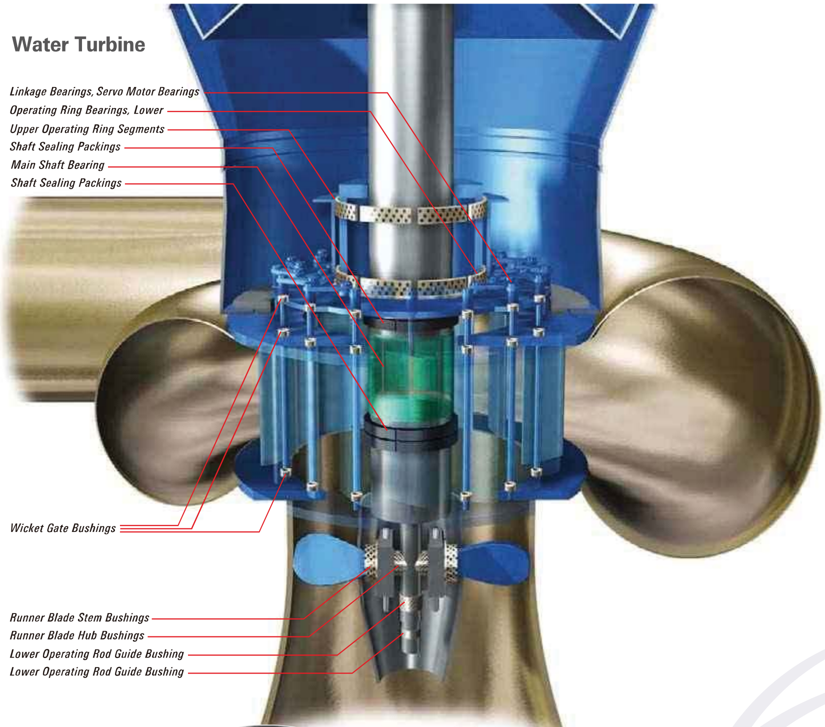
Kaplan Runner Bushings

Wicket Gate Control Rod Bushings

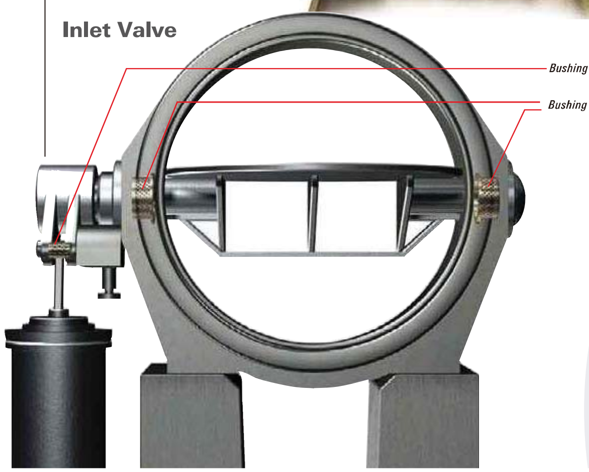
Upper Wicket Gate Bushings

Lower Wicket Gate Bushings

Water Turbine



Inlet Valve



OILES's History On Hydro Power

In Japan, hydro power was introduced in the latter part of the 19th century to supply commercial power to users and has served as a major power generation source to meet the country's energy demand.
Recently, with the development of thermal and nuclear power generation technologies, the share of hydro power has decreased.
Since hydro power can quickly follow the fluctuation of power demand and features environment-friendly renewable energy, it provides substantial benefits.
For this reason, hydro power technologies have attracted attention around the world from viewpoints of high-efficiency energy and low environmental loads.

Formerly, sliding bearings that were made of bronze or phosphor bronze and greased with an automatic lubrication system were used to configure sliding areas in guide vane bearings and vane operating mechanisms. Self-lubricating bearings that do not need periodic lubrication have been in use since the 1960s and contributed to control of grease-induced river water pollution and reduction of maintenance loads.
The following characteristics are required for the self-lubricating bearings used to configure sliding areas in guide vane bearings and vane operating mechanisms.

1. Must be capable of operating in atmosphere, fresh water, and muddy water.
2. Must be capable of operating under high surface pressure conditions.
3. Must withstand large-angle oscillating motion and be intact even if vanes are vibrated by the hydraulic pressure and minute oscillating motion is generated by the minute-angle operation control.
4. Can offer corrosion resistance.

For movable blade water turbines such as Kaplan turbines, the runner hub incorporates bearings that support vanes and operating mechanisms and lubricates sliding bearings (such as brass) used in these sliding areas and oil is therefore filled in this hub.
On the other hand, there is a risk of direct outflow of oil from the runner hub into rivers if the seal packing of the runner vane shaft is worn or damaged. To eliminate such risk, self-lubricating bearings have recently been used to configure sliding areas in runner vane bearings and vane operating mechanisms.

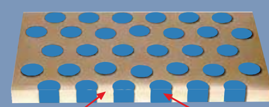
With the development of hydro power in Japan, OILES Corporation has supplied self-lubricating bearings.
We believe the hydro power will continue to develop to fulfill higher efficiency, lower environmental loads, and longer system service life.
Although self-lubricating bearings are simply mechanical elements, they have a large effect on the functional improvement of complete systems and the reduction of environmental loads, and we will therefore develop these bearings toward the future as functional components that will play an important role in the development of hydro power.

For Wicket Gate, Runner Blade and More

OILES 500 Series

Benefits

- Exhibits incomparable performance under a high load, low speed operation. Usable without lubrication.
- Excellent wear resistance in such places where an oil film is difficult to be formed due to reciprocating, oscillating motions and frequently intermittent operations.
- Remarkable resistance to corrosion and resistance to chemical attack.
- Available in various dimension standard products.



Currently, self-lubricating bearings embedded with lead-free solid lubricant are widely used to configure sliding areas in Wicket Gate Bushings, Runner Blade Hub Bushings, and vane operating mechanisms. Similar to general sliding bearings, self-lubricating bearings go through a transient phase of initial running-in, such as decrease in surface roughness due to friction surface wear and plastic deformation, improvement of geometrical conformity between rubbing surfaces, and formation of lubrication film in the initial stage of operation, and eventually transition to stationary friction/wear condition. Since guide vane and runner vane bearings are used in the water, vanes are vibrated by the hydraulic pressure, and minute oscillating motion is generated by the minute-angle operation control, it takes a certain amount of time to complete the initial conformability (particularly, formation of lubrication film). For this reason, one tendency being observed is that the frictional coefficient is relatively high in the initial stage of operation and will be stabilized at a lower value after the initial conformability.

We developed new lead-free solid lubricants (SL464LT) with improved initial conformability in underwater and minute oscillating motion conditions. The new solid lubricants offer increased spreadability and fluidity and improved lubrication film formation capability through the increased fluidization with the help of the heat generated by the relative sliding motion between the bearing and shaft. The new solid lubricants represent lower and stable frictional coefficient compared to conventional solid lubricants. Since the new lead-free solid lubricants are superior in spreadability and fluidity even in the low-temperature underwater environment around 0°C at which the spreadability of the resin material is easily decreased, lower frictional coefficient has been observed.

Although conventional lead-free solid lubricants have been used in different types of hydro power systems and exhibited stable performance, the new lead-free solid lubricants allow various actuators to fulfill labor and space saving thanks to the new materials' low friction characteristic under initial and low-temperature operating conditions.

Lineup of OILES 500 Series

Product	Benefits
OILES 500 SP1	Proven standard products
OILES 500 SP4	ASTM-compliant products (C86300)
OILES 500 SP5	Usable under high load conditions. Exhibits superior wear resistance compared to OILES 500 SP1.
OILES 500 AB	Usable in seawater. Exhibits excellent performance in corrosive environments.

Types of Solid Lubricants

SL types	SL Color	Major Material	Application	Temperature Range °C	Feature	Exclusive Lubricant Grease
SL464		PTFE, lead-free	General Use, Underwater	-40 to +80	General Use	SL464g
SL464LT		PTFE, lead-free	General Use, Underwater	-40 to +60	•Low friction at low water temperature •Low friction during minute movement	SL464LTg

The exclusive lubricant is grease or coating agent that has the same contents as the solid lubricant embedded in the OILES 500. It is used to improve the initial stage of operation. OILES 500SP1-SL464LT were tested at Powertech Labs Inc. to the USACE CERL TR 99/104 test specification and survived the performed tests.

OILES 500 Series Service Range and Mechanical Properties

	Type of Base Metal			OILES 500SP1	OILES 500SP4	OILES 500SP5	OILES 500AB
Service Range	P max. N/mm^2{kgf/cm²}			49(150) {500(1,530)}	49(150) {500(1,530)}	73(170) {745(1,735)}	34(100) {347(1,020)}
	V max. m/s(m/min)			0.25(15)	0.25(15)	0.25(15)	0.25(15)
	PV max. $N/mm^2 \cdot m/s${kgf/cm²·m/min}			1.65(1,010)	1.65(1,010)	1.65(1,010)	1.65(1,010)
Mechanical Properties [Base Metal]	Density	-	g/cm^3	7.8	7.8	7.8	7.6
	Tensile Strength	JIS Z 2241	N/mm^2 {kgf/mm²}	755(77)	755(77)	785(80)	590(60)
	Tensile Elongation at Break	JIS Z 2241	%	12	12	10	15
	Compressive Strength	-	N/mm^2 {kgf/mm²}	345(35) (Note1)	345(35) (Note1)	390(40) (Note1)	240(24) (Note2)
	Hardness	JIS Z 2243	-	HB210	HB223	HB235	HB160
	Modulus of Longitudinal Elasticity	JIS Z 2241	N/mm^2	105,000	105,000	98,000	108,000
	Coefficient of Liner Expansion	-	$\times 10^{-5}$°C^{-1}	2.1	2.1	2.1	1.6
	Applicable Material Standard	-	-	High-strength brass	ASTM B22 C86300	Special high-strength brass	Aluminum bronze

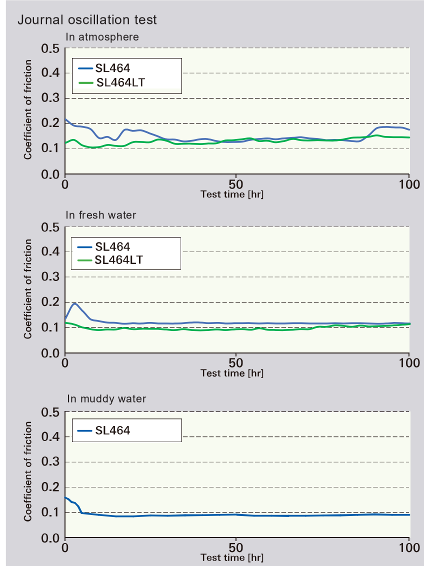
※ Static allowable pressure: pressure in ( ) is allowable pressure in the condition with no sliding or with sliding at quite low speed, which is 0.0017 m/s [0.1m/min] or less.
※ The service range represents the data obtained from SL-4 series products.
(Note1) Compressive strength is 0.1%.
(Note2) Compressive strength is 0.2%.

OILES 500 Series Test Data

TEST CONDITION

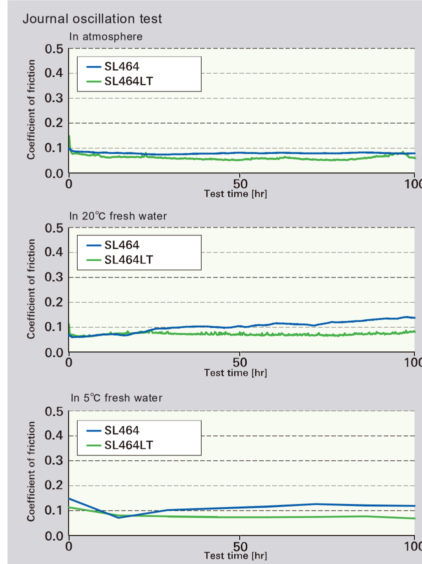
Test environment	In atmosphere / In fresh water / In muddy water (Note)
Mode of motion	Mating shaft oscillation
Mating shaft material	Stainless steel
Bearing dimensions	Φ60×Φ75×L50 mm
Contact pressure	24.5 N/mm^2
Sliding velocity	0.008 m/s
Oscillating angle	4° (±2°)
Test time	100 hr
Test temperature	20°C (In fresh water / In muddy water)
Lubricant	Non-lubricating (in atmosphere, in fresh water) Initial lubricating (in muddy water)

(Note) JIS test powders 1, Class 7 (JIS Z 8901), 0.1wt%



TEST CONDITION

Test environment	In atmosphere / In fresh water
Mode of motion	Mating shaft oscillation
Mating shaft material	Stainless steel
Bearing dimensions	Φ60×Φ75×L50 mm
Contact pressure	24.5 N/mm^2
Sliding velocity	0.019 m/s
Oscillating angle	90° (±45°)
Test time	100 hr
Test temperature	20°C / 5°C (In fresh water)
Lubricant	Initial lubricating

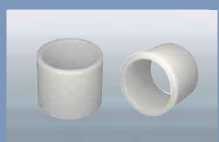


For Wicket Gate, Runner Blade and More

OILES Plastic Composite Bearings

Fiberflon OH and Fiberflon GH has been developed for hydro application.
Fiberflon series is high performance composite material composed of main resin, woven fabric, and special additives and is superior to conventional composite materials for hydro application in sliding performance.
Stable and lower coefficient of friction and higher wear resistance are shown in atmosphere, fresh water, and seawater with any motion types, especially micro-motion.
Lower swelling rate against conventional phenol material makes dimensional design easier because of less dimensional change in water.
Fiberflon series can cover wide range hydro application as high performance composite material.

Fiberflon GH NEW



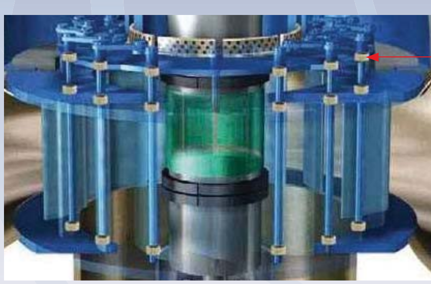
Features

- Fiberflon GH is a self-lubricating bearing composed of unsaturated polyester resin added by lubricant and reinforced by special fiber woven fabric.
- Forms lubrication film even in micro-motion environments and exhibits excellent sliding performance.
- Can be used not only in atmosphere but also in water and seawater.
- Exhibits excellent sliding performance even in muddy water environments.
- Features minimum water absorption and swelling-induced dimensional change, providing excellent dimensional stability.
- Exhibits excellent chemical resistance.

Fiberflon OH

Features

- Fiberflon OH is a self-lubricating bearing composed of phenol resin added by lubricant and reinforced by special fiber woven fabric.
- Forms lubrication film even in micro-motion environments and exhibits excellent sliding performance.
- Can be used not only in atmosphere but also in water and seawater.
- Exhibits excellent sliding performance even in muddy water environments.
- Features minimum water absorption and swelling-induced dimensional change, providing excellent dimensional stability.
- Consists of a sliding layer containing a lubricant component and fiberglass reinforced back layer, providing excellent load bearing and creep resistance capabilities.
- Exhibits excellent chemical resistance.
- More sophisticated than the Fiberflon GH (with respect to wear resistance and low friction).



OILES Fiberflon Series Service Range and Mechanical Properties

	Material			Fiberflon OH	Fiberflon GH
Service Range	P max. N/mm²{kgf/cm²}			80(150){815(1,530)}	60(100){612(1,020)}
	V max. m/s{m/min}			0.22{13.2}	0.16{9.6}
	PV max. N/mm²·m/s{kgf/cm²·m/min}			1.6{979}	1.2{734}
	Service Temperature Range (℃)			-40〜+120	-40〜+100
Mechanical Properties	Specific Gravity	JIS K 6911	-	1.7	1.3
	Tensile Strength	JIS K 6911	N/mm²	165	110
	Flexural Property	JIS K 6911	N/mm²	127	90
	Compressive Strength	JIS K 6911	N/mm²	238	300
	Hardness	JIS K 6911	-	HRM60	HRM85
	Modulus of Longitudinal Elasticity	-	N/mm²	2,400 (sliding layer) 9,900 (back layer)	3,400
	Coefficient of Liner Expansion	ASTM D 696	$\times10^{-5}$℃$^{-1}$	5〜8	5〜9
	Swelling Rate of Thickness(23℃) (reference value)	-	%	0.35	0.10

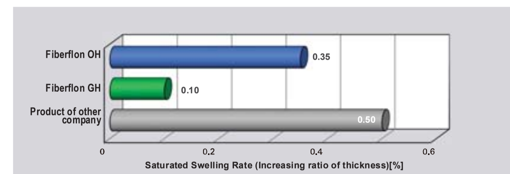
※Value for Fiberflon OH includes fiberglass layer.
※Static allowable pressure in ( ) is allowable pressure in the condition with no sliding or with sliding at quite low speed, which is 0.0017 m/s [0.1m/min] or less.

OILES Fiberflon Test Data

Plastic composite bearings are being manufactured and sold by many companies and you can not judge the performance by appearance. It is important to select bearings with low wear amount and maintaining stable coefficient of friction under variable using conditions, such as oscillation angle, atmosphere, water, velocity and operating time.
This test indicates the difference in performance between OILES and similar plastic composite bearing.

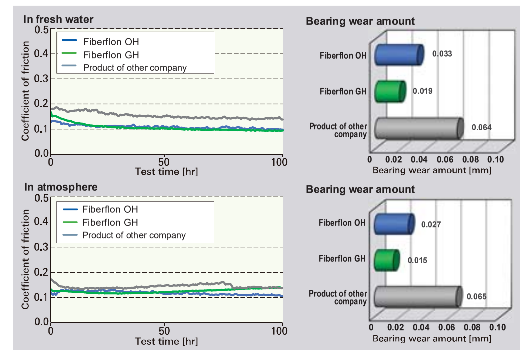
TEST CONDITION

Dimension of test pieces	Φ60×Φ75×L50 mm
Test method	Test pieces are immersed in tap water
Water temperature	23℃
Test time	300 days



TEST CONDITION

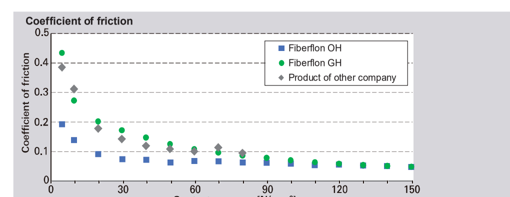
Test environment	In atmosphere / In fresh water
Mode of motion	Journal shaft oscillation
Mating shaft material	Stainless steel
Bearing dimensions	Φ60×Φ75×L50 mm
Contact pressure	24.5 N/mm²
Sliding velocity	0.0021 m/s
Oscillating angle	1°(±0.5°)
Test time	100 hr
Test distance	750 m
Test temperature	20℃ (In fresh water)
Lubricant	Non-lubricanting



TEST CONDITION

Test environment	In atmosphere
Mode of motion	Mating shaft oscillation
Mating shaft material	Chrome molybdenum steel
Bearing dimensions	Φ60×Φ75×L50 mm
Contact pressure	5 ~ 150 N/mm² (Note 1)
Sliding velocity	0.017 m/s
Oscillating angle	90° (±45°)
Cycle number	170 cycles every contact pressure conditions
Lubricant	Non-lubricanting

(Note 1) It is the maximum ability of the testing machine.
(Note 2) The test was terminated because the product of other company was destroyed at 80 N / mm².



For Main Shaft

OILES Plastic Composite Bearings

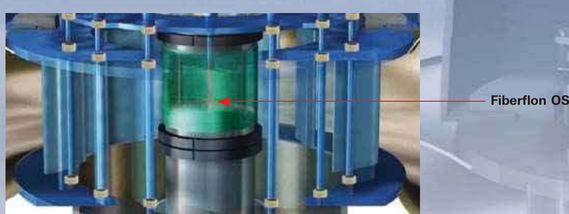
Based on the phenol resin composite materials used as main water-lubricated bearings for water turbines, we have developed a new material composed of sophisticated phenol resin added by lubricants such as PTFE, and special plastic base material. Using the sophisticated phenol resin material drastically improves the swelling characteristic, which has been a drawback of phenol resin composite bearings. Also, introduction of polymer blend technology further increases the load capacity under water lubrication conditions. In the underwater swelling tests, the plate thickness change rate (swelling ratio) of the bearing made of the new material is about 1/15 of conventional phenol resin composite bearings. In addition, the reduction of the swelling ratio can eliminate measures against dimensional change brought from pre-finish underwater swelling treatment. Compared with conventional phenol resin composite bearings, the new material shows lower frictional coefficient even at a low Sommerfeld number. Under high surface pressure and low speed conditions, the Sommerfeld number becomes low and resultantly the fluid film will be thinned to make it difficult to keep the fluid lubrication. This shows the possibility that more compact bearings can be designed and low frictional coefficient can reduce sliding-induced heat generation and resultantly eliminate the water-cooling system.

Fiberflon OS

Features

- Fiberflon OS is a water-lubricated bearing composed of phenol resin added by lubricant and is reinforced by special fiber woven fabric.
- Highly compatible with water, proving high load capacity under water lubrication conditions and low frictional coefficient.
- Features minimum water absorption and swelling-induced dimensional change, providing excellent dimensional stability.
- Stably exhibits low frictional coefficient even in muddy water environments.
- Exhibits excellent chemical resistance.

	Material			Fiberflon OS
Service Range	P max. N/mm²{kgf/cm²}			10{102}
	V max. m/s{m/min}			20{1,200}
	PV max. N/mm²·m/s{kgf/cm²·m/min}			10{6,120}
	Service Temperature Range (℃)			-40～+90
Mechanical Properties	Specific Gravity	JIS K 6911	-	1.4
	Tensile Strength	JIS K 6911	N/mm²	76
	Flexural Property	JIS K 6911	N/mm²	101
	Compressive Strength	JIS K 6911	N/mm²	252
	Hardness	JIS K 6911	-	HRM104
	Modulus of Longitudinal Elasticity	-	N/mm²	4,000
	Coefficient of Liner Expansion	ASTM D 696	×10⁻⁵℃⁻¹	6～7
	Swelling Rate of Thickness(23℃)	-	%	0.15

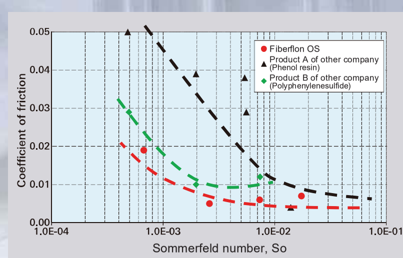


TEST CONDITION

Test environment	In fresh water
Mode of motion	Mating shaft rotation
Mating shaft material	Stainless steel
Bearing dimensions	Φ60×Φ75×L50 mm
Contact pressure	0.1 ~ 0.65 N/mm²
Sliding velocity	1.26 ~ 5.03 m/s
Test temperature	30℃

Sommerfeld number : $S_0 = \left(\frac{D}{C}\right)^2 \cdot \frac{\eta \cdot N}{P}$

S_0: Sommerfeld number [−]
D: Bearing inner diameter [mm]
C: Clearance [mm]
η: Water viscosity [Pa·s]
N: Rotation speed [s⁻¹]
P: Contact pressure [Pa]



For Sealing Packing

OILES Plastic Bearings

OILES 470-02

Features

- OILES 470-02 is a water-lubricated bearing composed of phenol resin added by lubricant and reinforced by carbon fiber and special fiber.
- Highly compatible with water, proving high load capacity under water lubrication conditions and low frictional coefficient.
- Superior to carbon bearing with respect to wear resistance, foreign matter resistance, and impact resistance.
- Exhibits excellent chemical resistance.

	Material			OILES 470-02
Service Range	P max. N/mm²{kgf/cm²}			15{153}
	V max. m/s{m/min}			16.5{990}
	PV max. N/mm²·m/s{kgf/cm²·m/min}			8.15{4,990}
	Service Temperature Range (℃)			-40～+90
Mechanical Properties	Specific Gravity	JIS K 6911	-	1.4
	Tensile Strength	JIS K 6911	N/mm²	45{4.6}
	Flexural Property	JIS K 6911	N/mm²	75{7.7}
	Compressive Strength	JIS K 6911	N/mm²	124{12.7}
	Hardness	JIS K 6911	-	HRM103
	Coefficient of Liner Expansion	ASTM D 696	×10⁻⁵℃⁻¹	2～2.5
	Swelling Rate of Thickness(23℃)	-	%	1.0

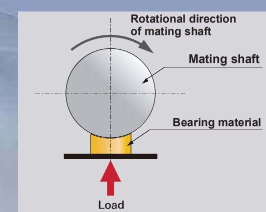
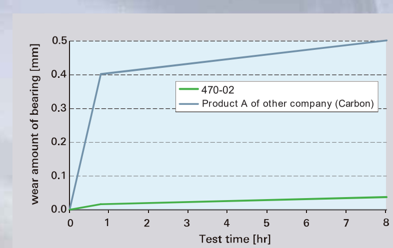


Figure 1

TEST CONDITION

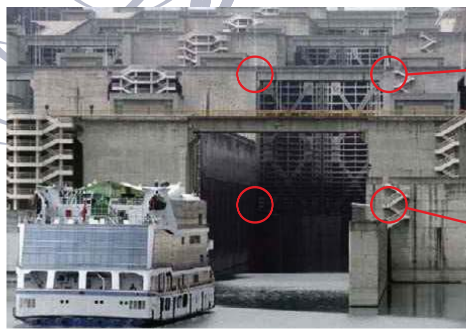
Test environment	In muddy water (Note)
Mode of motion	Mating shaft rotation
Mating shaft material	Stainless steel
Bearing dimensions	□20×R60mm (Figure 1)
Contact pressure	1.9N/mm²
Sliding velocity	5m/s
Test time	8 hr
Test temperature	20℃

(Note) JIS test powders 1, Class 7 (JIS Z 8901), 0.1wt%



Dam, Gate and Lock Applications

With years of our self-lubricating technology
OILES Corporation has supported clean river environment without being seen.



Three Gorges Ship Lock (China)

Upper: Cylinder Bearing 480×530×L500

Bottom: Pintle Bearing 1000×1140×L585

Sakuma Dam (Japan) [OILES 500]

Maheshwar Dam (India), Radial Gate [OILES 500]

Hyakkengawa Estuary Rising Sector Gate (Japan) [OILES 500]

Nakdong River (Korea), Rising Sector Gate [OILES 500]

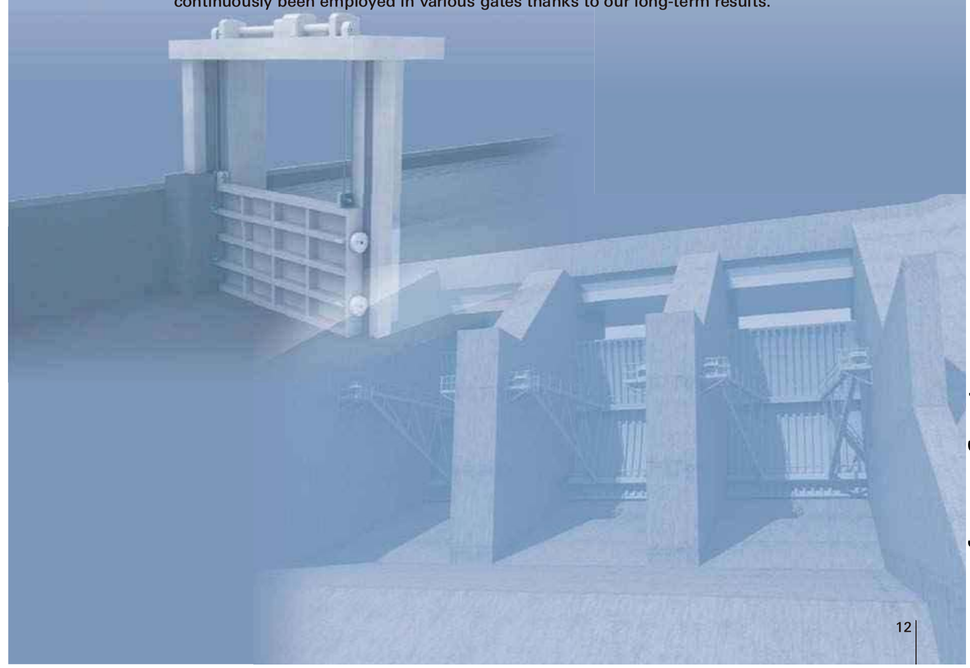
OILES Large-Size Bearings

Big diameter spherical bearing (ID 750 to OD 2100 mm) for the pivot shaft of the World's first floating swing bridge (Japan) [OILES 500]

OILES's History On Dam,Gate and Lock

In Japan, the history of sluice gates begins in the 1940s. In response to the fact that damage caused by typhoons was serious and lots of towns were under water at that time, flood control gates were constructed all over Japan with the growth of national power.
Although gunmetals were used for sliding areas in bearings under periodic lubrication, OILES Corporation promoted self-lubricating bearings (OILES 500) and the fact that "bearings can be used without lubrication" gained public favor and those products have been widely employed since then.

In the 1990s, on the initiative of the Japan Association of Dam & Weir Equipment Engineering, the Ministry of Land, Infrastructure, Transport and Tourism (the Ministry of Construction at that time) and association members (gate manufacturers and component manufacturers including OILES Corporation) studied drastic measures to optimize the gates.
Lots of discussions and experiments were carried out to determine optimal self-lubricating bearings for sluice gates and eventually "Technical Standards for Dam and Weir Equipment" was established.
Since we already had technical standards for gates, we greatly contributed to the establishment of "Technical Standards for Dam and Weir Equipment."
In addition, we developed lead-free solid lubricants (SL464) to prevent outflow of harmful substances into rivers for the purpose of environmental conservation, contributing to society.
"Gates that ensure safety, security, and reliable operation" have been in strong demand since the Great East Japan Earthquake in 2011 and our products have continuously been employed in various gates thanks to our long-term results.



For Dam, Gate and Lock

OILES 500 Series

Benefits

- Exhibits incomparable performance under a high load, low speed operation. Usable without lubrication.
- Excellent wear resistance in such places where an oil film is difficult to be formed due to reciprocating, oscillating motions and frequently intermittent operations.
- Remarkable resistance to corrosion and resistance to chemical attack.
- Available in various dimension standard products.

Lineup of OILES 500 Series

Product	Benefits
OILES 500 SP1	Proven standard products
OILES 500 SP4	ASTM-compliant products (C86300)
OILES 500 SP5	Usable under high load conditions. Exhibits superior wear resistance compared to OILES 500 SP1.
OILES 500 AB	Usable in seawater. Exhibits excellent performance in corrosive environments.

Types of Solid Lubricants

SL types	SL Color	Major Material	Application	Temperature Range ℃	Feature	Exclusive Lubricant Grease
SL464		PTFE, lead-free	General Use, Underwater	-40 to +80	General Use	SL464g

The exclusive lubricant is grease or coating agent that has the same contents as the solid lubricant embedded in the OILES 500. It is used to improve the initial stage of operation. OILES 500SP1-SL464LT were tested at Powertech Labs Inc. to the USACE CERL TR 99/104 test specification and survived the performed tests.

OILES 500 Series Service Range and Mechanical Properties

	Variation of Base Metal			OILES 500SP1	OILES 500SP4	OILES 500SP5	OILES 500AB
Service Range	P max. N/mm² {kgf/cm²}			49(150) {500(1,530)}	49(150) {500(1,530)}	73(170) {745(1,735)}	34(100) {347(1,020)}
	V max. m/s{m/min}			0.25{15}	0.25{15}	0.25{15}	0.25{15}
	PV max. N/mm²·m/s{kgf/cm²·m/min}			1.65{1,010}	1.65{1,010}	1.65{1,010}	1.65{1,010}
	Coefficient of Friction (NO ext. lube)			0.12~0.15	0.12~0.15	0.12~0.15	0.14~0.17
	Coefficient of Friction (Underwater)			0.08~0.12	0.08~0.12	0.08~0.12	0.10~0.14
Mechanical Properties [Base Metal]	Density	-	g/cm³	7.8	7.8	7.8	7.6
	Tensile Strength	JIS Z 2241	N/mm² {kgf/mm²}	755{77}	755{77}	785{80}	590{60}
	Tensile Elongation at Break	JIS Z 2241	%	12	12	10	15
	Compressive Strength	-	N/mm² {kgf/mm²}	345{35} (Note1)	345{35} (Note1)	390{40} (Note1)	240{24} (Note2)
	Hardness	JIS Z 2243	-	HB210	HB223	HB235	HB160
	Modulus of Longitudinal Elasticity	JIS Z 2241	N/mm²	105,000	105,000	98,000	108,000
	Coefficient of Liner Expansion	-	$\times10^{-5}$℃$^{-1}$	2.1	2.1	2.1	1.6
	Applicable Material Standard	-	-	High-strength brass	ASTM B22 C86300	Special high-strength brass	Aluminum bronze

※ Static allowable pressure: pressure in { } is allowable pressure in the condition with no sliding or with sliding at quite low speed, which is 0.0017 m/s {0.1m/min} or less.
※ The service range represents the data obtained from SL-4 series products.
(Note1) Compressive strength is 0.1%.
(Note2) Compressive strength is 0.2%.

OILES 500 Series Test Data

There are many companies who are manufacturing and selling bronze cast bearings embedded with solid lubricant in the market. You can not easily distinguish each bearing by appearance. When you select bearings, considering how you could lower coefficient of friction to suppress drive force and how you could minimize the wear amount for using long life is the important factor. This test was performed to indicate the difference in performance between OILES and other products.

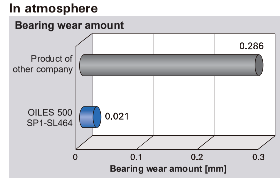
TEST CONDITION

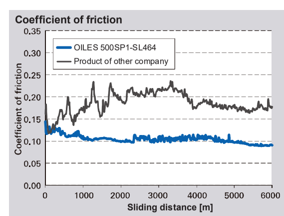
Test environment	In atmosphere / In fresh water / In muddy water (Note)
Mode of motion	Mating shaft rotation
Mating shaft material	X5CrNi18-10 (ISO/DIN), 304 (AISI), SUS304 (JIS)
Bearing dimensions	Φ60×Φ75xL50 mm
Contact pressure	23 N/mm²
Sliding velocity	0.008 m/s
Test distance	6,000 m
Lubricant	Initial greasing

(Note) JIS test powders 1, Class 7 (JIS Z 8901), 0.1wt%

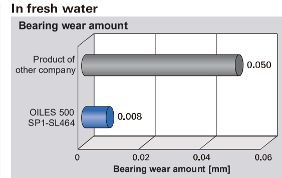
Journal Rotation Test

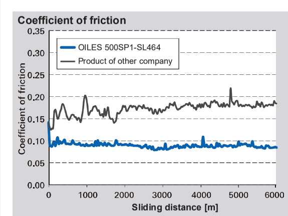
In atmosphere



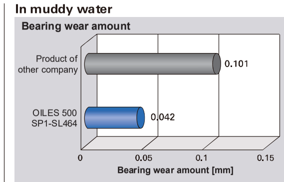


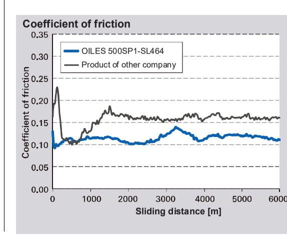
In fresh water





In muddy water



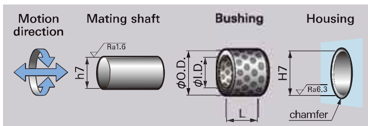


Product of other company: Copper alloy bearing with embedded solid lubricants from other supplier. Similar design to OILES 500.

On Design for Dam, Gate and Lock

OILES 500 Dimension Table

How to install	Interference fit
Tolerance of housing bore	H7
Tolerance of bushing inner diameter	See below chart
Tolerance of bushing outer diameter	See below chart
Tolerance of shaft diameter	h7
Surface roughness of bushing	Ra 1.6 - 6.3 μm
Surface roughness of shaft	Ra 1.6 μm or less



Fitting standard table for water gate application (OILES 500SP1-SL464 / OILES 500SP1-SL464LT)

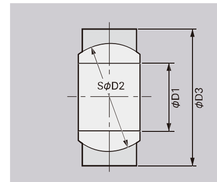
(unit : mm)

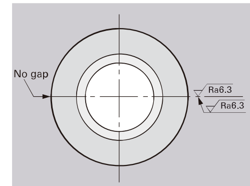
Bushing dimension (Note)			Shaft diameter (h7)		Bushing I.D. before fitting		Bushing I.D. after fitting (Reference)		Bushing O.D. before fitting		Housing bore (H7)		Interference between bushing O.D. and housing		Clearance between bushing I.D. and shaft (Reference)	
Inner diameter	Wall thickness	Outer diameter	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
up to 10	1.5 - 6.0	up to 10	0	-0.015	+0.097	+0.075	+0.082	+0.060	+0.034	+0.019	+0.015	0	+0.034	+0.004	+0.097	+0.060
		above 10, up to 18	0	-0.015	+0.100	+0.078	+0.082	+0.060	+0.041	+0.023	+0.018	0	+0.041	+0.005	+0.097	+0.060
above 10,	2.0 - 6.5	above 10, up to 18	0	-0.018	+0.142	+0.115	+0.124	+0.097	+0.041	+0.023	+0.018	0	+0.041	+0.005	+0.142	+0.097
up to 18		above 18, up to 30	0	-0.018	+0.146	+0.119	+0.124	+0.097	+0.049	+0.028	+0.021	0	+0.049	+0.007	+0.142	+0.097
above 18,	3.0 - 7.0	above 18, up to 30	0	-0.021	+0.195	+0.162	+0.173	+0.140	+0.049	+0.028	+0.021	0	+0.049	+0.007	+0.194	+0.140
up to 30		above 30, up to 50	0	-0.021	+0.200	+0.167	+0.173	+0.140	+0.059	+0.034	+0.025	0	+0.059	+0.009	+0.194	+0.140
above 30,	4.5 - 8.0	above 30, up to 50	0	-0.025	+0.266	+0.227	+0.239	+0.200	+0.059	+0.034	+0.025	0	+0.059	+0.009	+0.264	+0.200
up to 50		above 50, up to 80	0	-0.025	+0.273	+0.234	+0.239	+0.200	+0.073	+0.041	+0.030	0	+0.073	+0.011	+0.264	+0.200
above 50,	7.0 - 10.0	above 50, up to 80	0	-0.030	+0.360	+0.314	+0.326	+0.280	+0.073	+0.041	+0.030	0	+0.073	+0.011	+0.356	+0.280
up to 80		above 80, up to 120	0	-0.030	+0.368	+0.322	+0.326	+0.280	+0.089	+0.051	+0.035	0	+0.089	+0.016	+0.356	+0.280
above 80,	8.0 - 12.5	above 80, up to 120	0	-0.035	+0.468	+0.414	+0.426	+0.372	+0.089	+0.051	+0.035	0	+0.089	+0.016	+0.461	+0.372
up to 120		above 120, up to 180	0	-0.035	+0.478	+0.424	+0.426	+0.372	+0.108	+0.063	+0.040	0	+0.108	+0.023	+0.461	+0.372
above 120,	12.0 - 16.0	above 120, up to 180	0	-0.040	+0.595	+0.532	+0.543	+0.480	+0.108	+0.063	+0.040	0	+0.108	+0.023	+0.583	+0.480
up to 180		above 180, up to 250	0	-0.040	+0.607	+0.544	+0.543	+0.480	+0.130	+0.077	+0.046	0	+0.130	+0.031	+0.583	+0.480
above 180,	14.0 - 20.0	above 180, up to 250	0	-0.046	+0.736	+0.664	+0.672	+0.600	+0.130	+0.077	+0.046	0	+0.130	+0.031	+0.718	+0.600
up to 250		above 250, up to 315	0	-0.046	+0.749	+0.677	+0.672	+0.600	+0.150	+0.094	+0.052	0	+0.150	+0.042	+0.718	+0.600
above 250,	16.0 - 24.0	above 250, up to 315	0	-0.052	+0.838	+0.757	+0.761	+0.680	+0.150	+0.094	+0.052	0	+0.150	+0.042	+0.813	+0.680
up to 315		above 315, up to 400	0	-0.052	+0.850	+0.769	+0.761	+0.680	+0.171	+0.108	+0.057	0	+0.171	+0.051	+0.813	+0.680
above 315,	17.0 - 29.0	above 315, up to 400	0	-0.057	+0.943	+0.854	+0.854	+0.765	+0.171	+0.108	+0.057	0	+0.171	+0.051	+0.911	+0.765
up to 400		above 400, up to 500	0	-0.057	+0.957	+0.868	+0.854	+0.765	+0.195	+0.126	+0.063	0	+0.195	+0.063	+0.911	+0.765
above 400,	21.0 - 35.0	above 400, up to 500	0	-0.063	+1.085	+0.988	+0.982	+0.885	+0.195	+0.126	+0.063	0	+0.195	+0.063	+1.045	+0.885
up to 500		above 500, up to 630	0	-0.063	+1.144	+1.047	+0.982	+0.885	+0.235	+0.158	+0.070	0	+0.235	+0.088	+1.045	+0.885
above 500,	23.0 - 38.0	above 500, up to 630	0	-0.070	+1.212	+1.102	+1.050	+0.940	+0.235	+0.158	+0.070	0	+0.235	+0.088	+1.120	+0.940
up to 630		above 630, up to 800	0	-0.070	+1.246	+1.136	+1.050	+0.940	+0.280	+0.192	+0.080	0	+0.280	+0.112	+1.120	+0.940
above 630,	25.5 - 41.0	above 630, up to 800	0	-0.080	+1.291	+1.166	+1.095	+0.970	+0.280	+0.192	+0.080	0	+0.280	+0.112	+1.175	+0.970
up to 800		above 800, up to 1000	0	-0.080	+1.330	+1.205	+1.095	+0.970	+0.329	+0.230	+0.090	0	+0.329	+0.140	+1.175	+0.970
above 800,	28.0 - 45.0	above 800, up to 1000	0	-0.090	+1.385	+1.245	+1.150	+1.010	+0.329	+0.230	+0.090	0	+0.329	+0.140	+1.240	+1.010
up to 1000		above 1000, up to 1250	0	-0.090	+1.435	+1.295	+1.150	+1.010	+0.395	+0.280	+0.105	0	+0.395	+0.175	+1.240	+1.010
above 1000,	31.5 - 50.0	above 1000, up to 1250	0	-0.105	+1.490	+1.325	+1.205	+1.040	+0.395	+0.280	+0.105	0	+0.395	+0.175	+1.310	+1.040
up to 1250		above 1250, up to 1600	0	-0.105	+1.560	+1.395	+1.205	+1.040	+0.486	+0.349	+0.125	0	+0.486	+0.224	+1.310	+1.040

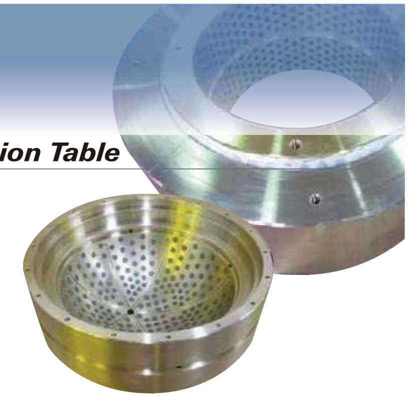
Note: As for the products with other dimension or thickness, please contact us.

OILES 500 Spherical Bearing Dimension Table

Split outer race type with I.D. of up to ϕ1,250mm







(unit : mm)

Bearing Nominal Dimension (D1)			Recommended Shaft (h7)		I.D. Tolerance (D1)		Clearance		Inner Race O.D. Tolerance (D2) Outer Race I.D.		Inner Race O.D.(e8)		Clearance		Recommended Hole (H7)		O.D. Tolerance (D3)p7		Interference	
φD1	SφD2	φD3	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
above 10,	above 10, up to 18	above 18, up to 30	0	-0.018	0.124	0.097	0.142	0.097	0.049	0.022	-0.032	-0.059	0.086	0.032	0.021	0	0.043	0.022	0.043	0.001
up to 14	above 18, up to 30	above 30, up to 50	0	-0.018	0.124	0.097	0.142	0.097	0.059	0.026	-0.040	-0.073	0.106	0.040	0.025	0	0.051	0.026	0.051	0.001
above 14,	above 18, up to 30	above 18, up to 30	0	-0.018	0.124	0.097	0.142	0.097	0.055	0.022	-0.040	-0.073	0.106	0.040	0.021	0	0.043	0.022	0.043	0.001
up to 18	above 30, up to 50	above 30, up to 50	0	-0.018	0.124	0.097	0.142	0.097	0.051	0.026	-0.050	-0.089	0.114	0.050	0.025	0	0.051	0.026	0.051	0.001
above 18,	above 18, up to 30	above 30, up to 50	0	-0.021	0.173	0.140	0.194	0.140	0.059	0.026	-0.040	-0.073	0.106	0.040	0.025	0	0.051	0.026	0.051	0.001
up to 24	above 30, up to 50	above 50, up to 80	0	-0.021	0.173	0.140	0.194	0.140	0.071	0.032	-0.050	-0.089	0.128	0.050	0.030	0	0.062	0.032	0.062	0.002
above 24,	above 30, up to 50	above 30, up to 50	0	-0.021	0.173	0.140	0.194	0.140	0.065	0.026	-0.050	-0.089	0.128	0.050	0.025	0	0.051	0.026	0.051	0.001
up to 30	above 50, up to 80	above 50, up to 80	0	-0.021	0.173	0.140	0.194	0.140	0.078	0.032	-0.060	-0.106	0.152	0.060	0.030	0	0.062	0.032	0.062	0.002
above 30,	above 30, up to 50	above 30, up to 50	0	-0.025	0.239	0.200	0.264	0.200	0.065	0.026	-0.050	-0.089	0.128	0.050	0.025	0	0.051	0.026	0.051	0.001
up to 40	above 50, up to 80	above 50, up to 80	0	-0.025	0.239	0.200	0.264	0.200	0.078	0.032	-0.060	-0.106	0.152	0.065	0.030	0	0.062	0.032	0.062	0.002
above 40,	above 50, up to 80	above 50, up to 80	0	-0.025	0.239	0.200	0.264	0.200	0.078	0.032	-0.060	-0.106	0.152	0.060	0.030	0	0.062	0.032	0.062	0.002
up to 50	above 80, up to 120	above 80, up to 120	0	-0.025	0.239	0.200	0.264	0.200	0.091	0.037	-0.072	-0.126	0.180	0.072	0.035	0	0.072	0.037	0.072	0.002
above 50,	above 50, up to 80	above 50, up to 80	0	-0.030	0.326	0.280	0.356	0.280	0.078	0.032	-0.060	-0.106	0.152	0.060	0.030	0	0.062	0.032	0.062	0.002
up to 65	above 80, up to 120	above 80, up to 120	0	-0.030	0.326	0.280	0.356	0.280	0.091	0.037	-0.072	-0.126	0.180	0.072	0.035	0	0.072	0.037	0.072	0.002
above 65,	above 80, up to 120	above 80, up to 120	0	-0.030	0.326	0.280	0.356	0.280	0.091	0.037	-0.072	-0.126	0.180	0.072	0.035	0	0.072	0.037	0.072	0.002
up to 80	above 120, up to 180	above 120, up to 180	0	-0.030	0.326	0.280	0.356	0.280	0.106	0.043	-0.085	-0.148	0.211	0.085	0.040	0	0.083	0.043	0.083	0.003
above 80,	above 80, up to 120	above 120, up to 180	0	-0.035	0.426	0.372	0.461	0.372	0.097	0.043	-0.072	-0.126	0.180	0.072	0.040	0	0.083	0.043	0.083	0.003
up to 100	above 120, up to 180	above 120, up to 180	0	-0.035	0.426	0.372	0.461	0.372	0.106	0.043	-0.085	-0.148	0.211	0.085	0.040	0	0.083	0.043	0.083	0.003
above 100,	above 120, up to 180	above 120, up to 180	0	-0.035	0.426	0.372	0.461	0.372	0.106	0.043	-0.085	-0.148	0.211	0.085	0.040	0	0.083	0.043	0.083	0.003
up to 120	above 180, up to 250	above 180, up to 250	0	-0.035	0.426	0.372	0.461	0.372	0.122	0.050	-0.100	-0.172	0.244	0.100	0.046	0	0.096	0.050	0.096	0.004
above 120,	above 120, up to 180	above 180, up to 250	0	-0.040	0.543	0.480	0.583	0.480	0.113	0.050	-0.085	-0.148	0.211	0.085	0.046	0	0.096	0.050	0.096	0.004
up to 180	above 180, up to 250	above 250, up to 315	0	-0.040	0.543	0.480	0.583	0.480	0.128	0.056	-0.100	-0.172	0.244	0.100	0.052	0	0.108	0.056	0.108	0.004
above 180,	above 250, up to 315	above 250, up to 315	0	-0.046	0.672	0.600	0.718	0.600	0.137	0.056	-0.110	-0.191	0.272	0.110	0.052	0	0.108	0.056	0.108	0.004
up to 250	above 315, up to 400	above 315, up to 400	0	-0.046	0.672	0.600	0.718	0.600	0.151	0.062	-0.125	-0.214	0.303	0.125	0.057	0	0.119	0.062	0.119	0.005
above 250,	above 315, up to 400	above 315, up to 400	0	-0.052	0.761	0.680	0.813	0.680	0.151	0.062	-0.125	-0.214	0.303	0.125	0.057	0	0.119	0.062	0.119	0.005
up to 315	above 400, up to 500	above 400, up to 500	0	-0.052	0.761	0.680	0.813	0.680	0.165	0.068	-0.135	-0.232	0.329	0.135	0.063	0	0.131	0.068	0.131	0.005
above 315,	above 400, up to 500	above 400, up to 500	0	-0.057	0.854	0.765	0.911	0.765	0.165	0.068	-0.135	-0.232	0.329	0.135	0.063	0	0.131	0.068	0.131	0.005
up to 400	above 500, up to 630	above 500, up to 630	0	-0.057	0.854	0.765	0.911	0.765	0.188	0.078	-0.145	-0.255	0.365	0.145	0.070	0	0.148	0.078	0.148	0.008
above 400,	above 500, up to 630	above 500, up to 630	0	-0.063	0.982	0.885	1.045	0.885	0.188	0.078	-0.145	-0.255	0.365	0.145	0.070	0	0.148	0.078	0.148	0.008
up to 500	above 630, up to 800	above 630, up to 800	0	-0.063	0.982	0.885	1.045	0.885	0.213	0.088	-0.160	-0.285	0.410	0.160	0.080	0	0.168	0.088	0.168	0.008
above 500,	above 500, up to 630	above 630, up to 800	0	-0.070	1.050	0.940	1.120	0.940	0.198	0.088	-0.145	-0.255	0.365	0.145	0.080	0	0.168	0.088	0.168	0.008
up to 630	above 630, up to 800	above 800, up to 1,000	0	-0.070	1.050	0.940	1.120	0.940	0.225	0.100	-0.160	-0.285	0.410	0.160	0.090	0	0.190	0.100	0.190	0.010
above 630,	above 630, up to 800	above 800, up to 1,000	0	-0.080	1.095	0.970	1.175	0.970	0.225	0.100	-0.160	-0.285	0.410	0.160	0.090	0	0.190	0.100	0.190	0.010
up to 800	above 800, up to 1,000	above 1,000, up to 1,250	0	-0.080	1.095	0.970	1.175	0.970	0.260	0.120	-0.170	-0.310	0.450	0.170	0.105	0	0.225	0.120	0.225	0.015
above 800,	above 1,000, up to 1,250	above 1,250, up to 1,600	0	-0.090	1.150	1.010	1.240	1.010	0.305	0.140	-0.195	-0.360	0.525	0.195	0.125	0	0.265	0.140	0.265	0.015
up to 1,000	above 1,250, up to 1,600	above 1,600, up to 2,000	0	-0.090	1.150	1.010	1.240	1.010	0.365	0.170	-0.220	-0.415	0.610	0.220	0.150	0	0.320	0.170	0.320	0.020
above 1,000,	above 1,000, up to 1,250	above 1,250, up to 1,600	0	-0.105	1.205	1.040	1.310	1.040	0.305	0.140	-0.195	-0.360	0.525	0.195	0.125	0	0.265	0.140	0.265	0.015
up to 1,250	above 1,250, up to 1,600	above 1,600, up to 2,000	0	-0.105	1.205	1.040	1.310	1.040	0.365	0.170	-0.220	-0.415	0.610	0.220	0.150	0	0.320	0.170	0.320	0.020

Note: I.D. dimension of outer race is H8 after the bearing installed into a housing.

Technical Information

Corrosion Resistance

Corrosion resistance of base resin and base metal used for OILES Bearings.

A: Excellent B: Good C: Fair D: No Resistance - : No Data

Classification		Metallic Bearings		Plastic Composite Bearings				
Base Metal		High Strength Brass Casting	Aluminum Bronze					
Product		500SP1/500SP4/500SP5	500AB	425	470	FF-OH	FF-OS	FF-GH
Acid	40% to 80% Sulfulic Acid	D	B	B	B	B	B	A
	80% to 95% Sulfulic Acid	D	C	C	C	C	C	D
	Hydrochloric Acid	D	C	B	B	B	B	B
	Nitric Acid	D	D	A	A	-	-	D
	Phosphoric Acid	D	B	A	A	A	A	A
	Chromic Acid	D	D	B	B	B	B	C
	Lactic Acid	D	B	A	A	A	A	B
	Hydrogen Peroxide	C	B	C	C	C	C	B
	Chlorine (moist)	D	C	C	C	C	C	C
	Chlorine (dry)	A	A	-	-	-	-	C
Alkaline	Ammonia (moist)	D	D	A	A	A	A	D
	Ammonia (dry)	A	A	A	A	A	A	D
	Ferrous Chloride	D	B	A	A	A	A	-
	Calcium Chloride	D	B	A	A	A	A	A
	Sulfur (moist)	D	D	A	A	A	A	-
	Sulfur (dry)	A	B	A	A	A	A	A
	Calcium Hydroxide	B	A	C	C	C	C	A
Solvent	Methanol	A	A	C	C	C	C	A
	Acetone	A	A	A	A	A	A	C
	Toluene	A	A	-	-	-	-	C
	Ethylene Glycol	B	A	A	A	A	A	A
Oil, Water, Others	Lubricating Oil	A	A	A	A	A	A	A
	Water	B	A	A	A	A	A	A
	Sea Water	C	B	A	A	A	A	A

Selection of Mating Materials

Bearing performance is influenced by the material, hardness, surface roughness, surface treatment of the mating shaft, rust and foreign matter. In order to select appropriate mating material, please refer to the below chart.

Bearing	Contact pressure N/mm2 {kgf/cm2}	Material	Hardness	Surface roughness Ra(Rz)
Metallic Bearings	Up to 24.5{250}	Carbon steel. (S45C, SNC415, SCM435 / C45, 34CrMo4) Corrosion resistant steel. (SUS304, SUS316 / X5CrNi18-10, X5CrNiMo17-12-2)	HB150 or over	Less than 1.6a(6,3s)
	24.5{250} to 49.0{500}	Surface hardening treatment such as induction hardening and carburizing should be implemented for the materials described above.	HB250 or over	
	49.0{500} to 98.0{1,000}	In addition to surface hardening treatment as above, additional surface treatment such as nitriding treatment and hard chrome plating should be implemented.	HRC50 or over	
Plastic Bearings	Up to 49.0{500}	Carbon steel. (S45C, SNC415, SCM435/ C45, 34CrMo4) Corrosion resistant steel. (SUS304, SUS316 / X5CrNi18-10, X5CrNiMo17-12-2)	HB120 or over	Less than 0.8a(3.2s)
	49.0{500} to 98.0{1,000}	Surface treatment such as induction hardening, quenching by carburizing and hard chrome plating should beimplemented for the materials described above.	HRC45 or over	

Mating Materials

Mating Materials for Normal Applications

Japan JIS	International ISO	Europe EN	Germany DIN	USA AISI	USA UNS	France NF	UK BS	China GB
S45C	C45	1.0503	C45	1045	G10450	C45	C45	45
SNC415	-	1.5732	14NiCr10	3415	-	14NC11	-	-
SCM430	-	1.7218	-	4131	G41310	-	-	30CrMo
SCM435	34CrMo4	1.722	34CrMo4	4137	G41370	34CrMo4	34CrMo4	35CrMo
SCM440	42CrMo4	1.7225	42CrMo4	4140	G41400	42CrMo4	42CrMo4	42CrMo

Mating Materials for Corrosive Applications

Japan JIS	International ISO	Europe EN	Germany DIN	USA AISI	USA UNS	France NF	UK BS	China GB
SUS304	X5CrNi18-10	1. 4301	X5CrNi18-10	304	S30400	Z7CN18-09	304S31	0Cr18Ni9
SUS403	-	-	-	403	S40300	-	-	-
SUS 420J1	X20Cr13	1. 4021	X20Cr13	420	S42000	Z20C13	420S29	2Cr13
SUS420J2	X30Cr13	1. 4028	X30Cr13	420	S42000	Z33C13	420S37	3Cr13
SUS 431	X17CrNi16-2	1. 4057	X20CrNi17-2	431	S43100	Z15CN16-02	431S29	-
-	X35CrMo17	1. 4122	X35CrMo17	-	-	-	-	-
SUS630	X5CrNiCuNb16-4	1. 4542	X5CrNiCuNb16-4	630	S17400	Z6CNU17-O4	-	-

Mating Materials for Use in Seawater

Japan JIS	International ISO	Europe EN	Germany DIN	USA AISI	USA UNS	France NF	UK BS	China GB
SUS316	X5CrNiMo17-12-2	1. 4401	X5CrNiMo17-12-2	316	S31600	Z7CND17.11-02	316S31	OCr17Ni12Mo2
SUS316L	X2CrNiMo17-13-2	1. 4404	X2CrNiMo17-13-2	316L	S31603	Z3CND17.11-02	316S11	00Cr17Ni14Mo2
SUS 329J3L	X2CrNiMoN22-5-3	1. 4462	-	S31803	S32205	Z3CNDU22-05Az	-	-
-	X8CrNiMoN27-5	1. 4460	-	-	-	-	-	-

Housing Fiting Method

Cooling Fit

There are two methods to set OILES bearings into a housing.
One is called press fit. For press fit, a mandrel and a press machine are used.
The other is called cooling fit. The cooling fit uses liquid nitrogen or dry ice.
Compared to press fit, cooling fit is efficient and achieves more accurate installation.
Avoid shrink fitting as it may deteriorate bearing function.

Cooling Fit Procedure

1. Equipment and Materials
・Refrigerant: liquid nitrogen, dry ice
・Container: Heat insulation chamber (a chamber covered with heat insulator which is large enough to accommodate bushings)

2. Calculation of amount of shrinkage of outer diameter of bearing caused by cooling (⊿D)
・Where outer diameter of bearing: D
・Where coefficient of thermal expansion of bearing: α
・Where atmospheric temperature: To
・Where cooling temperature: T_1

$\Delta D = D \times \alpha \times (T_o - T_1)$

Thermal expansion of OILES 500SP1(SP4, SP5): α = 2.2 × 10^{-5}/℃
Thermal expansion of OILES 500AB: α = 1.6 × 10^{-5}/℃
* For other materials, please refer to the mechanical properties of each product.

Example: Material OILES 500SP1 Φ100 × Φ130 × L100 mm
By cooling, temperature goes down to −70℃ from 20℃

$\Delta D = 130 \times 2.2 \times 10^{-5} \times (20-(-70)) = 0.211$ mm

*For the bearing whose diameter exceeds 500 mm, consult an OILES representative.

3. Operation Procedure
1. As a cooling agent, use liquid nitrogen or dry ice. The standard cooling temperature is −40℃ to −70℃.
2. Cooling time should be more than one hour. Cooling time needs to be longer if the interference is larger, depending on applicable fitting tolerance. In addition to the cooling fit, press fitting should be used if cooling time needs to be shortened.
3. Measure and confirm outer diameter of the bushing and inner diameter of the housing before cooling. If any defect is found during fitting, it may develop into a major trouble.
4. Bushing should be inserted into the housing soon after taking it out from the cooling agent in chamber. If stopped during fitting, dimension of the bushing goes back to its original size and it is extremely difficult to withdraw the bushing from the housing and do the fitting again.
5. Apply lubricant onto the sliding surface.

Note : Warm housing up to 20℃ to 30℃ if sufficient temperature gap could not be maintained as in winter.

4. Using liquid nitrogen
Place the bearings on a bottom stage in the insulated container. Pour liquid nitrogen into the container slowly.
Do not immerse bearings into liquid nitrogen. Keep atmosphere temperature in container to −70℃ to −40℃.
Sketches of cooling methods show in Fig.1 to 3.

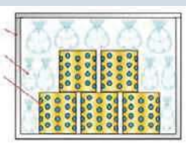


Fig.1 Cooling method by dry ice

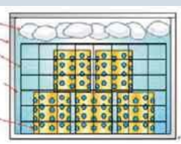


Fig.2 Cooling method by dry ice / organic solvent

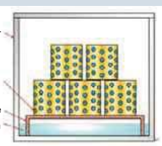
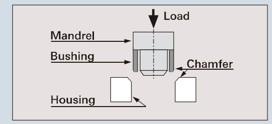


Fig.3 Cooling method by liquid nitrogen

Press Fit

Usually, OILES bearings are press-fitted into the housing. For this procedure, a mandrel and a press machine are used. In case of a metallic bearing with large press fit interference, chamfer outer diameter of the bearing and inner diameter of the housing. Then use a mandrel to facilitate easier press fit.



Bonding

The following adhesives are recommended when fixing with an adhesive.
・CEMEDINE EP007*1
・LOCTITE EA E60-HP*2
Any two-part room temperature curing epoxy adhesive other than the above will also work fine.
*1 CEMEDINE is a registered trademark of CEMEDINE COMPANY, LIMITED CORPORATION in the United States or in other countries.
*2 LOCTITE is a registered trademark of Henkel IP & Holding GmbH LIMITED LIABILITY COMPANY or in other countried.
*3 We do not guarantee the quality and adhesion effect of the adgesive.

Whirl Stop Method

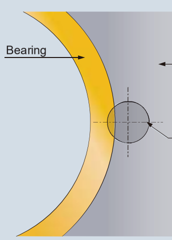
Whirl Stop Method

Drill a hole in a place that is not a load point.
If the boundary line between the bearing and housing is determined as a center of a whirl stop screw hole, the end of the cutting tool may move toward the bearing during the cutting operation.
To avoid this unwanted event, shift the center to the housing side and drill the hole.

As a guideline, make the diameter of the whirl stop screw almost the same as the bearing wall thickness and shift the screw hole center to the housing side by about 25 % of the whirl stop screw diameter.
Cutting a small prepared hole before drilling the whirl stop screw hole can prevent runout of the cutting tool end.
We recommend an end mill as a cutting tool.

Point to Note

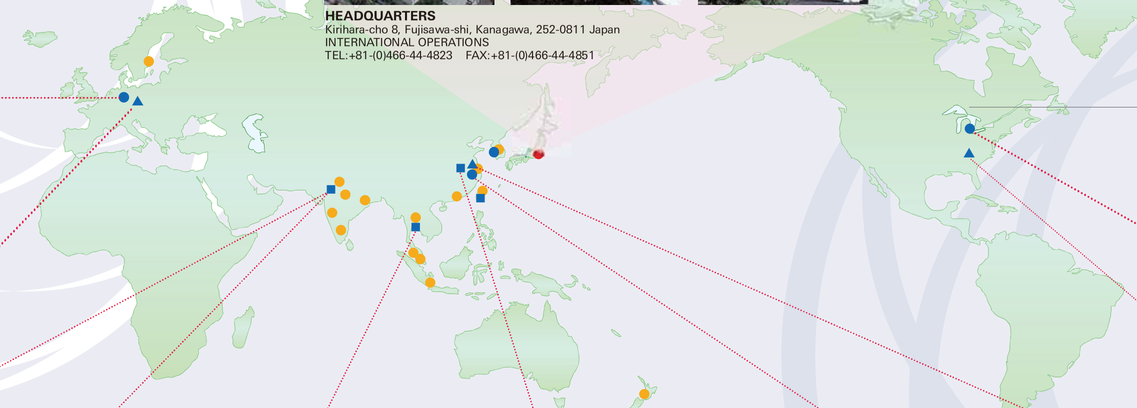
Before drilling the whirl stop screw hole,
fix workpieces (bearing and housing)
and the cutting tool so that they will not be run out.



CAUTIONS

■The typical values of the mechanical and physical characteristics shown in this catalog conform to the corresponding JIS Standards, in principle.
■The allowable maximum bearing pressures, allowable maximum speeds, allowable maximum PV values, etc. are obtained by testing in OILES Corporation's standard bearing test methods. Contact our sales offices for details.
■The contents of this catalog are as of September, 2018.
■The specifications or information in this catalog are subject to change without prior notice.
■OILES, Oiles logo, Fiberflon, are registered trademarks of Oiles Corporation.

OILES Service Network





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OILES DEUTSCHLAND GMBH

OILES CZECH MANUFACTURING S.R.O.

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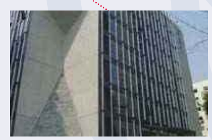
OILES INDIA PRIVATE LIMITED

OILES (THAILAND) CO., LTD.

OILES SUZHOU CORPORATION



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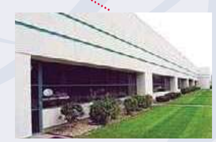
SHANGHAI OILES BEARING INC.

OILES AMERICA CORPORATION



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Corporate Profile

Name of Company	OILES CORPORATION
Incorporation	March 11, 1952
Capital	JPY 8,585,000,000
SalesAmount	52.9Billion JPY (Consolidated account, as of March 2021)
Consolidated Number of Employeer	2,046 (as of March 2021)
	Patents : 2,993 (Foreign 1,417; USA 298, Germany 162, China 211 etc.) Utility Models : 607 Registered Designs : 28 Trademarks : 728, including 293 which we acquired abroad Industry Property nowpending under application : 307, including 203 abroad

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OILES CORPORATION

APPENDIX F: Generator Dust Collector System

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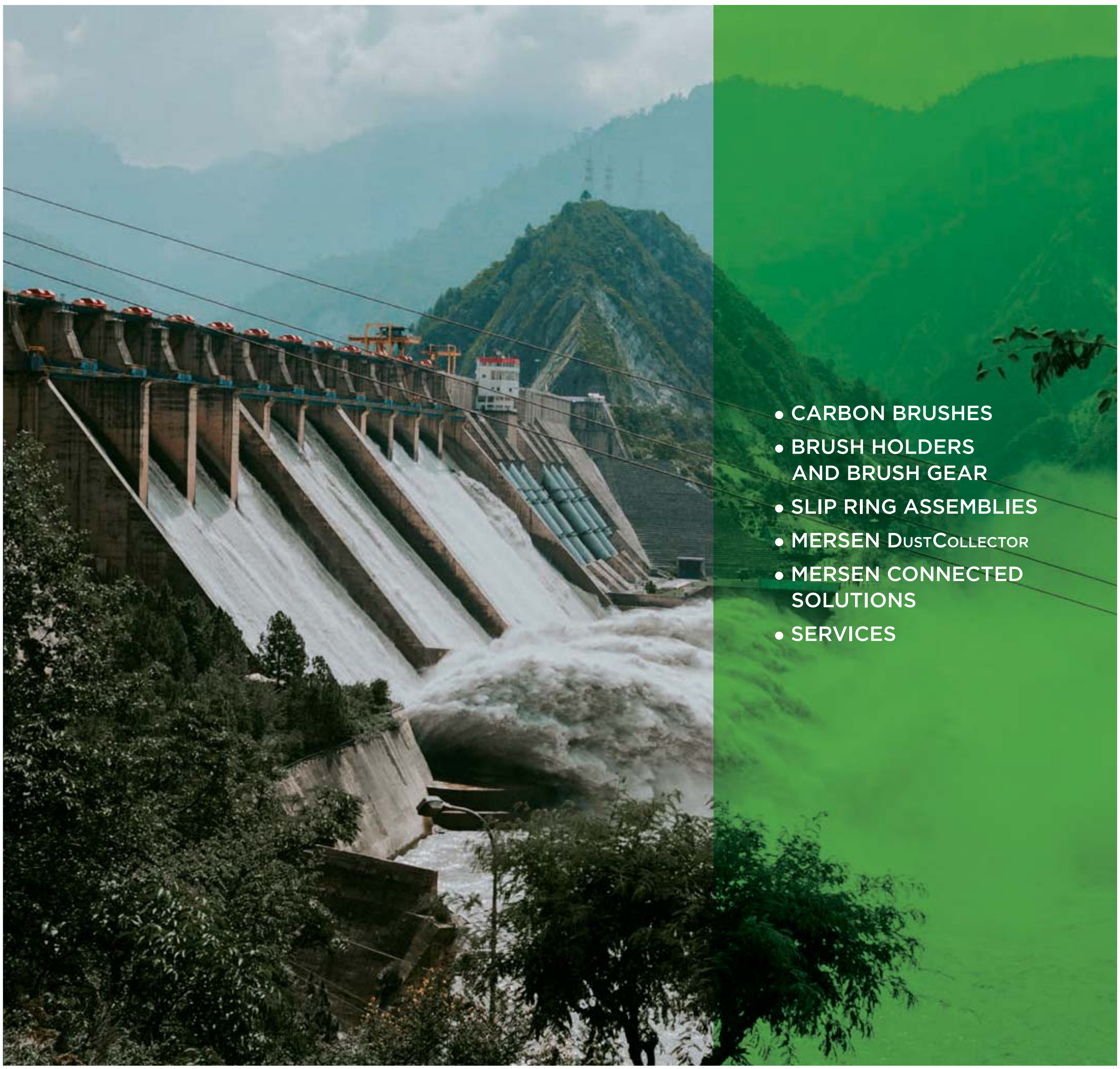
Expertise, our source of energy

ENERGY

SOLUTIONS & SERVICES FOR HYDRO POWER



- CARBON BRUSHES
- BRUSH HOLDERS AND BRUSH GEAR
- SLIP RING ASSEMBLIES
- MERSEN DustCollector
- MERSEN CONNECTED SOLUTIONS
- SERVICES

HIGH QUALITY ENGINEERED SOLUTIONS

Our solutions for hydro power plants are made of carefully chosen quality materials, manufactured on cutting-edge equipment (CNC machines, broaching machines, computer aided measuring instruments, high precision microscopes...).

They benefit from high precision assembly and conform to industrial international standards (IEC, NEMA, ASTM, SAE, DIN...).

We test our solutions for optimum performance under all loads and environmental conditions, thereby helping our customers to reduce maintenance costs.

We have the knowledge to reengineer existing solutions and create maintenance tools to improve the performance of hydro power plants.

CARBON BRUSHES

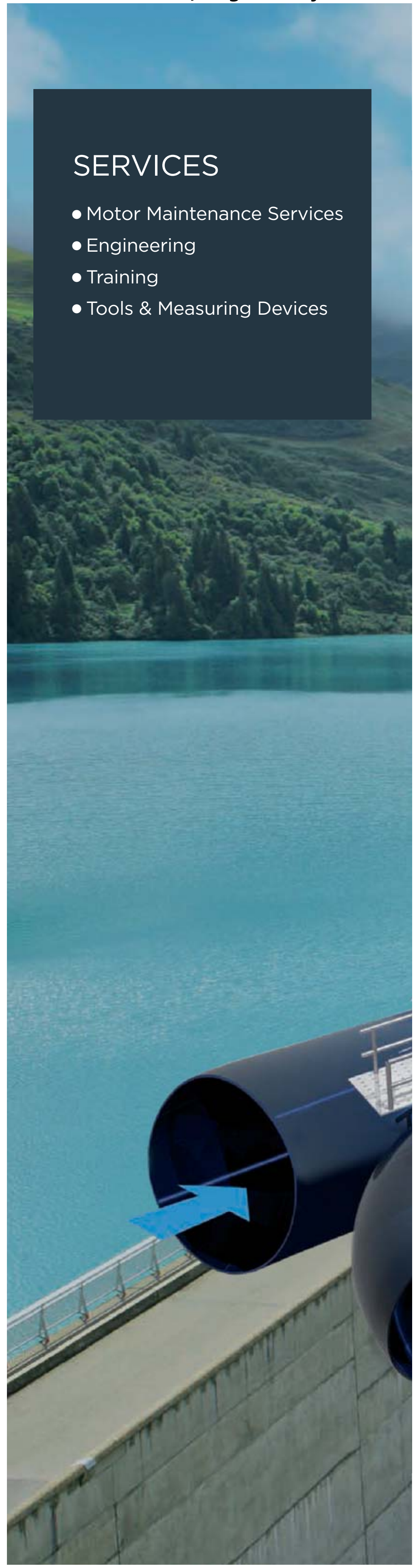
- Renowned grades (e.g. CG651, EG34D, EG389P, L1, M44A)
- Selected materials: graphite, copper...
- High electrical conductivity
- Ideal mechanical stability
- Low friction coefficient
- Low resistivity material
- Wide speed range (15 to 55 m/s)
- Specific design

BRUSH-HOLDERS & BRUSH GEAR

- Wide range: metric & imperial systems
- Selected materials: non-ferrous alloys, anti-corrosion...
- Molded, machined, die-cast, stamped
- Single or multiple boxes
- Fitted with independent pressure system: tension or coil springs
- Brush-rocker assemblies
- Brush-holders available with MERSEN DustCollector systems
- Customized designs

SLIP RING ASSEMBLIES

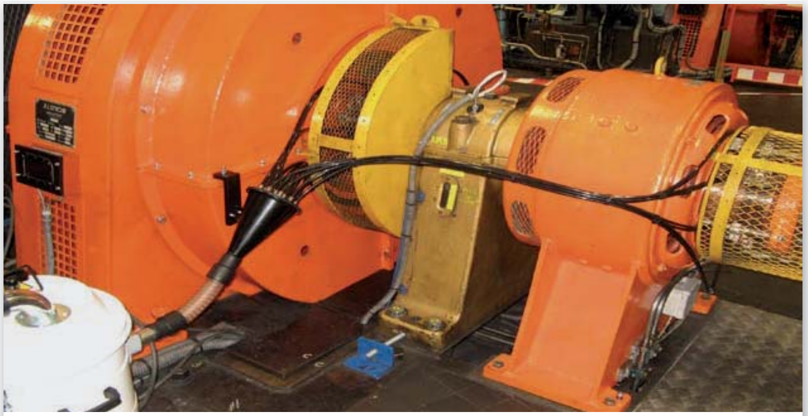
- Selected materials: non-ferrous alloys, stainless steel, insulation dielectric materials...
- Plain or helically-grooved rings
- Finished product compliance
- Customized designs



SERVICES

- Motor Maintenance Services
- Engineering
- Training
- Tools & Measuring Devices

SOLUTIONS & SERVICES FOR HYDRO POWER



MERSEN DustCollector

CARBON DUST IS SUCTIONED AT ITS SOURCE

A SMART CONCEPT DESIGNED TO PREVENT SHORT CIRCUITS CAUSED BY LOW INSULATION RESISTANCE BETWEEN ACTIVE COILS AND GROUND

- For slip rings, commutators and generator brakes
- Requires minimal maintenance
- Completely integrated and customized with plug & play concept
- Designed for new, retrofit and refurbished hydro generators (up to 900 MW)
- An annual preventative maintenance contract is available

A RELIABLE SOLUTION FOR BETTER HYDRO GENERATOR EFFICIENCY AND INCREASED HYDRO GENERATOR RUNNING TIME

- Studies performed by Mersen design offices
- Selection of high quality materials
- Tested on our test benches
- Installed and set up by Mersen experts

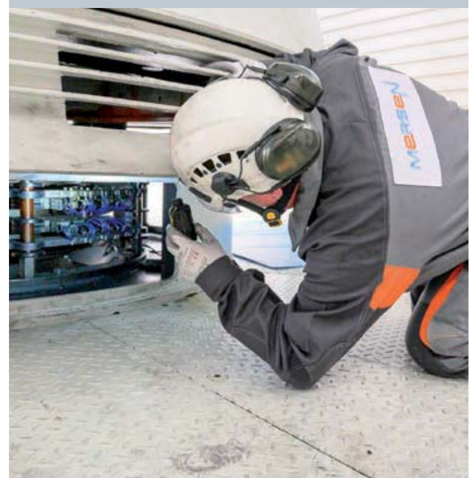
Mersen
Total Monitoring

MERSEN CONNECTED SOLUTIONS

For MERSEN DustCollector
- 3 levels of monitoring systems: Basic, Optimum and Smart

MERSEN TotalMonitoring
- Real time data information of the brushes and brush-holders in operation
- Email/SMS alert system available
- Data management by cloud or local mode (please contact us)

MERSEN
SERVICES



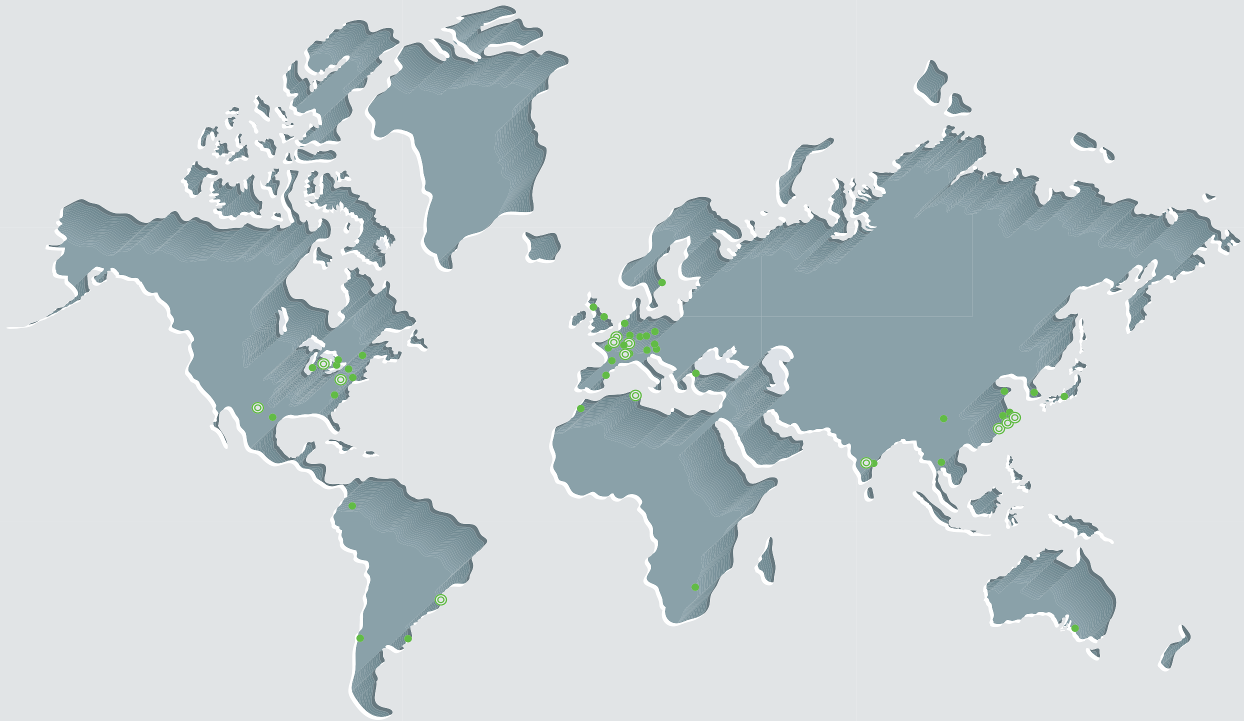
SERVICES

MOTOR MAINTENANCE SERVICES
- MERSEN DustCollector and MERSEN Total Monitoring installation
- Expertise and Diagnostics
- On site machining of slip rings and commutators

ENGINEERING
- Retrofit: refurbishing & reengineering of solutions and components

TRAINING
- Led by technical experts
- According to a defined curriculum or adapted to specific needs
- Transfer of skills
- At either our location or our clients'

TOOLS & MEASURING DEVICES
- CL-Profiler and ComPro2000™
- Grinding stones
- Dynamometers
- Stroboscopes
- Alarm boxes
- Roughness meters



MERSEN
Expertise, our source of energy

GLOBAL EXPERT IN ELECTRICAL
POWER AND ADVANCED MATERIALS

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ZOOM

MERSEN DUSTCOLLECTOR

CARBON DUST COLLECTION SYSTEMS FOR HYDRO GENERATORS

BETTER HYDRO GENERATOR EFFICIENCY

- Over 90 %* of carbon brush dust is suctioned at its source, to avoid dispersion all over the machine
- They offer higher reliability for continuous power production

INCREASED HYDRO GENERATOR RUNNING TIME

- There is less cleaning maintenance

* Efficiency value measured during 5 internal tests on slip ring test benches under specific conditions. This result excludes all brakes applications. For more detail please contact us.

DESIGNED TO AVOID SHORT CIRCUITS CAUSED BY LOW INSULATION RESISTANCE

A SMART CONCEPT

- ✓ **Minimal maintenance**
- ✓ Completely integrated and customized with **plug & play concept**
- ✓ Designed for **new**, **retrofit** and **refurbished** hydro generators (up to 900 MW)

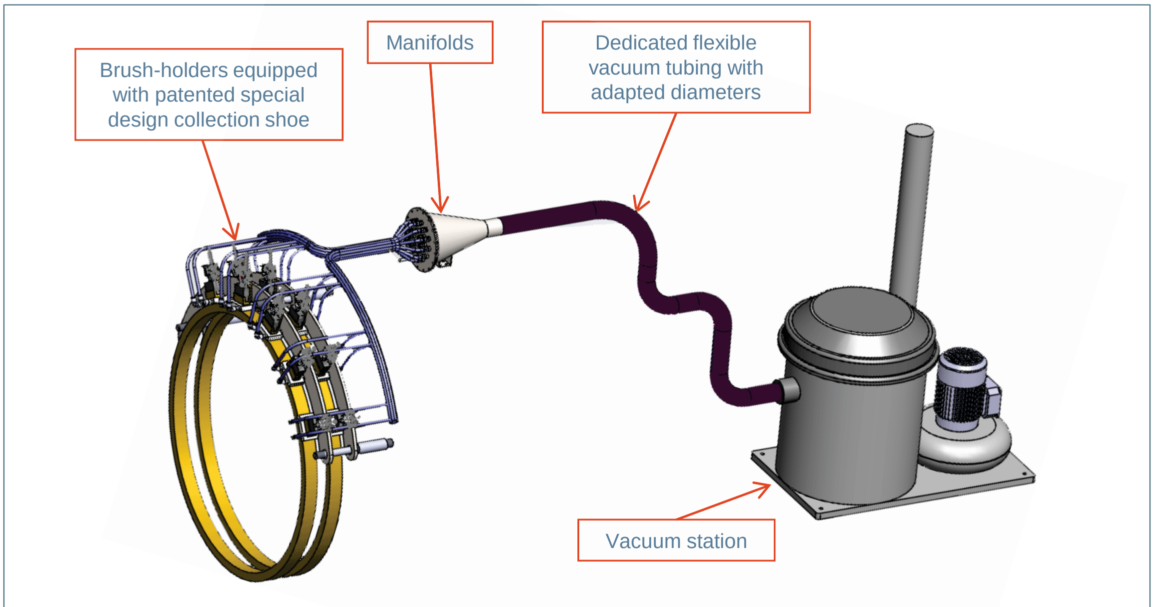
MERSEN PROPERTY

A RELIABLE SOLUTION

- ✓ Studies by Mersen's design offices
- ✓ High quality materials
- ✓ Conformity to CE international standard

⚠ If oil vapor is present, it will seriously affect the MERSEN DustCollector's performance.

MERSEN DUSTCOLLECTOR OPERATING BLOCK DIAGRAM

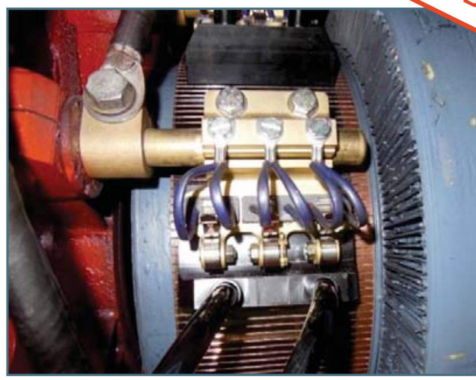


MERSEN DUSTCOLLECTOR OFFERS CONSIDERABLE BENEFITS:

- ✓ Accurate air suction calculation to collect carbon dust **without causing a depression** inside the hydro generator
- ✓ **No effect on carbon brush and slip ring temperatures**
- ✓ **Durability** of components
- ✓ Quick replacement of components with **plug and play concept**
- ✓ Installation and set up by Mersen's experts
- ✓ Optional **monitoring**

DUST SUCTION SHOE

PATENTED BY MERSEN

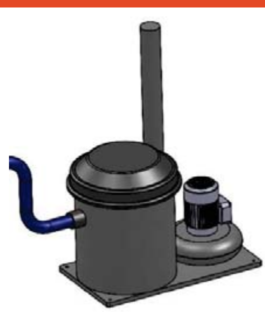


Operating temperature	-40 to 100°C (-40 to 212°F)
Material	POM-C
Mechanical resistance	Over 50 MPa (exceptional mechanical resistance)
Electrical resistance	High insulated

TUBING

Operating temperature	-40 to 100°C (-40 to 212°F)
Material	Polyamide
Mechanical resistance	Flexibility and exceptional mechanical resistance
Wear resistance	High abrasion resistance
Safety	Not flammable
Electrical resistance	High insulated (tested under 10 kV)
Installation	Quick and easy installation

INDUSTRIAL VACUUM UNIT



Duty cycle	24/7
Operating temperature	-10 to 40°C (14 to 104°F)
Low noise level	< 85 dB
Filter	Removable filter with manual unclogging
Dust tank	Removable dust tank

MERSEN PROPERTY

MAIN BENEFITS FOR THE USERS

SAFETY AND HEALTH FOR THE OPERATORS

- ✓ Over 90 % * of carbon dust is suctioned at its source, to avoid dispersion all over the machine and inhalation by the operators

STRONG REDUCTION OF THE NUMBER OF FLASH-OVER OCCURENCES

- ✓ Cost savings on repairs
- ✓ Maximized performance

MAINTENANCE COST REDUCTION

- ✓ Preventive maintenance
- ✓ No need to perform coil cleaning by dry ice blasting

BETTER RELIABILITY TO MAXIMIZE THE BENEFIT FOR ELECTRICAL PRODUCTION

OVER 400 UNITS ALREADY INSTALLED IN MORE THAN 30 COUNTRIES

Australia, Austria, Brazil, Burundi, Canada, Chile, Colombia, Croatia, Czech Republic, Finland, France, Germany, Guatemala, Hungary, Iceland, India, Ireland, Italy, New Zealand, Norway, Peru, Portugal, Russia, Serbia, Spain, Sweden, Switzerland, Turkey, UK, Ukraine, USA, Vietnam, Zambia.

PTT-MDC-EN-2103

* Efficiency value measured during 5 internal tests on slip ring test benches under specific conditions. This result excludes all brakes applications. For more detail, please contact us.

MERSEN PROPERTY

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