PRELIMINARY - SPECIFICATION HIGH TEMPERATURE CHLORIDE MOLTEN SALT VERTICAL TURBINE PUMP

SANDIA NATIONAL LABORATORIES GEN 3 LIQUID-PATHWAY

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1. OBJECT

This specification provides to the supplier with requirements for design, manufacturing, inspection and testing in works and cleaning, painting, packing and protection for transport to site for the hot molten salt pumps, receiver circulation pumps and the attemperation molten salt pumps to be used at Sandia National Laboratories, Albuquerque, NM, NSTTF Solar Power Tower.

2. GENERAL

The Hot molten salt pump is a Variable Speed Drive (VSD) vertically mounted turbine pump supplying 740 ºC molten salt from the hot salt storage tank to the supercritical carbon dioxide (sCO_2) heat exchangers and back to the cold salt storage tank.

The receiver circulation pump is a VSD vertically mounted turbine pump supplying 500ºC molten salt from the cold salt storage tank to the Receiver vessel.

The attemperation salt pump is a VSD vertically mounted turbine pump, supplying 500ºC molten salt from the cold salt storage tank to the sCO_2 heat exchanger, for the following functions:

- Maintain a salt flow rate to the sCO_2 heat exchanger during startup
- Modulate the flow of cold salt to sCO_2 heat exchanger in the transitions to overnight following a sCO_2 heat exchanger trip.
- Flow salt to sCO_2 heat exchanger during overnight hold to maintain system temperature over 500ºC.

All pumps are mounted on a deck extending over the cold and hot salt storage. The pump column and shaft will pass through a hole on top of the salt tank and extend down into the molten salt, taking suction directly from the heel. In the space between the deck and the top of the tank, the pump column will be surrounded by an insulated metal bellows. The pump discharge flange will be accessible above the horizontal plane of the deck and will interface with the facility piping via a flanged connection. The pump motor will be mounted vertically above the pump discharge housing.

The variable frequency drive unit will be located nearby in an environmentally controlled room.

The molten salt properties are described in attached Molten Salt Vertical Pump Data Sheets, see Excel Spreadsheet attachment file.

Tank and pump height, and liquid levels are described in attached Pump/Tank diagram, Appendix A.

2.1. SERVICE REQUIREMENTS

Plant location and environmental conditions are described as follows:

- Site Location: Albuquerque, NM, Sandia National Laboratories, NSTTF
- Site Elevation: 5300 ft.
- Summer Outdoor Design Conditions: 96 °FDB, 60 °FWB

- Winter Outdoor Design Conditions: 16 °FDB

2.2. QUALITY ASSURANCE

Control the quality of items and services to meet the requirements of this Specification, referenced codes and standards, and other contract documents.

Contractor and its sub-Contractors, as applicable, shall have a quality Management System that complies with the applicable requirements of ISO 9001:2000 or equivalent International or National Standard (e.g., BS5750 Part 2, EN 29002 and ANSI/ASQC Q9002)

Owner reserves the right to evaluate Contractor's Quality Management System Documentation to decide if the systems meet the requirements of this project. Owner or they representatives also reserve the right to carry out appraisals and Quality Audits of Contractors' and their Sub-Vendors' Quality Management System during the period of the contract to verify compliance with and maintenance of the quality system and contract requirements

All material, parts, components, equipment, service and associated documentation are subject to examination by the owner or his representative, as specified in Annex 4.

2.3. CODES AND STANDARDS

The selection of materials and equipment and the design, construction, maintenance and repair of equipment and facilities covered by this Specification shall comply with latest editions, revisions or supplements of the following referenced codes, standards (to the extent defined in this specification) and local laws in effect on the date of contract.
Where the requirements of this specification differ from the requirements of the codes or standards referenced herein, the following order of priority shall apply

- Specification requirements and Data Sheet
- Codes and Standards herein after
- Supplier Standards

2.3.1. Specific Codes and Standards

The pump design, calculations, construction and testing shall be based on the following codes, standards, rules and guidelines as far as applicable

- ANSI/HI 2.3 – "Rotodynamic (Vertical) Pumps for Design and Application"
- ANSI/HI 2.4 – "Rotodynamic Pumps for Manuals Describing Installation, Operation and Maintenance"
- ANSI/HI 2.6 – "Vertical Tests"
- ANSI/HI 9.4 – "General guidelines for Sound Measurements"
- ANSI/HI 9.6.2 – "Centrifugal and Vertical Pumps for Allowable Nozzle Loads"
- ANSI/HI 9.6.4 –" Centrifugal and Vertical Pumps for Vibration Measurements and Allowable Values"

- ANSI/HI 9.6.5 – Centrifugal and Vertical Pumps for Condition Monitoring.
- API 610/ISO 13709 : “Centrifugal pumps “
- API 682/ISO-21049: “Pumps-Shaft sealing systems”
- ASME B 1.20 – “Pipe threads, general purpose”
- ASME B16.5 – “Steel Pipe Flanges”.
- ASME BPVC Section VIII, DIV. 1. – “Pressure vessels”
- ASME BPVC Section V. – “Non Destructive Examination”.
- ASME BPVC Section IX – “Qualification Standard for Welding and Brazing”
- ASTM standards for materials and testing requirements
- MSS-SP-55 – “ Quality standard for Steel Castings for valves, flanges and fittings and other piping”
- OSHA: Occupational Safety and Health Administration regulations.
- ASTM D3951 – 98(2004) Standard Practice for Commercial Packaging
- ASTM D6198 – 07 Standard Guide for Transport Packaging Design
- Code of Federal Regulations (CFR), Title 49 - Transportation”

In all instances of conflict between the applicable codes, standards, specifications, regulations, tests and procedures of organizations listed above, the Contractor shall follow the most stringent and conservative requirements. International codes equivalent to above codes listed may be acceptable subject to Purchaser’s approval

3. SCOPE OF SUPPLY

The scope of supply shall also include the following equipment (but not limited to):

- 1 Receiver Circulating Pump
- 2 Hot Salt Pumps
- 1 Attemperation Salt Pump.

The major components included in the scope will be as follows:

- Motor support frame for attaching a vertically mounted electric motor
- One outlet nozzle and flange to connect to system piping
- Sump head for collecting the pumped fluid from the bottom of the pump and providing a single discharge flange connection
- Thrust bearing for supporting the pump impellers and drive shafts and absorbing axial thrust
- Stuffing box or mechanical seal for isolating the high pressure fluid from the environment
- Series of connected discharge pipes to convey the pumped fluid up to the sump head
- One or more drive shafts to transmit power from the motor to the pump impellers
- One or more bush bearings and couplings to provide support and connections for the drive. One or more drive shafts to transmit power from the motor to the pump impellers shaft(s)
- One or more collectors or volutes for the pumped fluid
- One or more impellers to impart energy to the fluid

- Suction nozzle at the inlet to the impellers to provide low turbulence, low velocity inlet flow
- Electric Motor
- ABB Variable Speed Drive (VSD) for each pump
- Insulated coupling bellows to be installed between the pumps soleplates and the top of the tank flange connection.
- Piping, instrumentation and valves for Nitrogen injection 74 API plan for shaft purging.
- Vibration and temperature monitoring system (Bently Nevada or Rockwell Automation)
- PT-100 cable and vibration cable between primary element and junction box
- Special tools, consumable or any other disposable required for the start-up of the pumps. It is advisable to obtain several sets of spare parts to ensure operational continuity and avoid long-lead times for particular items.
- First load of any oil, lubricant or grease required, Supplier shall provide the specification data sheets.

The Supplier will be responsible for coordinating the design and operation of the pump, motor and VSD.

3.1. PERSONNEL TRAINING

The Supplier shall provide onsite training necessary to ensure safe operation of the equipment by Owner's operation and maintenance staff.

This training will be scheduled for (TBD) trainees and shall include:

- Three (3) days of classroom training (Theoretical part) at the end of erection/start of commissioning stage and
- Two (2) days of hand-on training (Practical part) during commissioning.

The detailed program of staff training will be defined (TBD) months before the beginning of the training.

The Supplier is responsible for the training expenses of their own personnel; training aids and training will be provided in English.

3.2. OTHER CONDITIONS

Equipment and services shall be supplied in accordance with the requirements of this Specification and the applicable requirements of all reference documents specified herein.

At Bidding stage Supplier shall supply one (1) copy in paper and one (1) copy in electronic format. During Project stage Supplier shall supply 3 copies in paper and one (1) copy in electronic format. The language for the documents shall be English.

3.3. TERMINAL POINTS

The following points will be the terminal ends of equipment supply:

- Pump discharge flange.
- Nitrogen injection: inlet flange.
- Flanged Vents, Drains, quenching and Purging.
- Electrical and Instrumentation terminal box up to contactors.
- Terminal connections of Electrical Heat Tracing
- Grounding lugs for the bed plate and motor
- Inlet and outlet terminals of the variable speed drive.
- Terminal boxes for connection with DCS (alarms and signals).
- Instrumentation, auxiliary terminal box and control box for variable speed drive, temperature detectors.
- Lifting lugs.
- Soleplate including screw and nuts.

The following materials, equipment and services will be supplied by others:

- Grouting, foundations and associated civil works.
- External piping and associated valves, other than those specified herein, not forming an integral part of each pump.
- Power and control equipment, such us motor contactors, relays and all other items required for operation.
- Electrical and instrumentation wiring (control signals wiring with DCS).
- Auxiliary instruments, not forming an integral pump of each pump or equipment associated.
- Equipment field unloading, installation.
- Transport to site.

4. DELIVERY DATE

Bidders shall state in his proposal, the delivery data for the complete equipments and their accessories as well as a works schedule including the main manufacturing and testing activities.

The Supplier shall send 15 days after purchase order, the detailed design, engineering, manufacturing, test and delivery program.

The end data for this supply shall be no later than (HOLD).

5. DESIGN AND MANUFACTURING

5.1. DESIGN

The Receiver Circulating system has been designed with 1 pump for operation with the following pump identification VS-2.

The Hot salt pumps has been designed with 2 pumps, 1 for operation and 1 for reserve, with the following pump identification VS-1A and VS-1B.

The attemperation system has been designed with 1 pumps for operation with the following pump identification VS-3.

Each pump shall be operated at variable speed.

5.1.1. General

- This specification covers the following vertical centrifugal pumps:
  - Vertical turbine pumps, open suction with Single or multistage diffuser design and extended shaft
- The pumps shall be identical in design. All replacement parts shall be interchangeable.
- Design for pumps and auxiliaries shall be according to a minimum service life of 30 years (excluding normal wear parts) and at least two years of continuous operation.
- Purchaser Data Sheet specify the pump's operation and rated points, as well as any other anticipate operating conditions.
- Arrangement of equipment, piping, and auxiliaries shall provide adequate clearance areas and safe access for operation and maintenance.
- Supplier shall establish in the proposal the pump setting and any distances required for a trouble free pump operation or maintenance
- Supplier shall assume unit responsibility for all pumps and auxiliary systems included in the scope of the order.
- Pump, motors, electrical components, and electrical installations shall be suitable for the area classification (class, group, division, or zone) specified by the purchaser.

5.1.2. Design Conditions

- The pump shall be designed for frequent startup and shutdown. It is anticipated that the pump shall be subjected to daily start-up and shutdown.
- Start-up of all pumps shall be with the corresponding discharge valve closed. When the pump stops, the discharge valve will shut slowly to ensure a shock free transient.
- Pumps shall be designed to drain completely when removed from the salt tanks. All lines carrying salt will be sloped to drain completely, without low points or pockets.
- Pump/ motor unit shall be capable of withstanding reversing rotational speed, caused by the system head when the pump trips. No anti-reverse rotation device shall be used.
- Pumps are required that have stable head/capacity curves from run out to minimum flow

- The head at minimum flow shall be within 110% to 140% of the head at rated flow.
- The Best Operating Point (BEP) should be between Operating and Rated points
- Supplier shall state in the proposal the minimum stable continuous flow.
- Pumps shall be sized to allow of at least a 10% head increase considering the use of the variable speed driver to meet this requirement or by replacement of the impeller(s) with impeller(s) of larger diameter.
- Motor sized to end of pump curve run out. Manufacturer's NPSHr pump curves shall be based on 3% head drop with cold water.
- All wetted surfaces shall be machined or hand finished to a smooth surface.
- The VSD shall be responsible for starting and stopping the pump, as well as driving the pump to the commanded speed. The VSD will be responsible for keeping the pump speeds outside of any unsafe operating ranges, including speeds where unsafe shaft responses may occur.
- Rated pump speed shall be based on a Suction Specific Speed (Nss) value of 8,500 (US units) and the NPSH available. Nss up to a maximum value of 10,000 (US units) may be used after Purchaser's written approval.
- All pressure retaining parts shall be sized in accordance with ASME VIII, Div. 1 or 2.
- Rated pump speed must differ at least 25% of the first wet critical speed with twice the normal wear and bushing clearances.
- The pump/motor unit natural frequency shall be predicted by Supplier, based on Finite Element Analysis. Natural frequencies shall be neither < 25% below rated speed nor < 30% above rated speed. The Purchaser will provide structure information and pipe discharge loads. "
- Rotor shall be dynamically balanced to ISO 1940-1 grade 2.5.
- Variable speed pumps shall operate over their specified speed range without exceeding the vibration limits of ANSI/HI 9.6.4
- Pump vertical thrust must be double that required for water pumps due to the specific gravity of the pumped fluid. Pump rotor thrust loads will be carried out by thrust bearings located in the pump lantern ring. The thrust bearing will be capable of carrying thrust loads in both directions.

- The relative positions of the pumps and the tanks will change as the tanks expand and contract due to changes in the temperature of the tank inventory. The Supplier will supply a coupling bellows which shall be capable of absorbing the thermal expansion of the tank, considering the following temperatures:

	Cold Salt Tank	Hot Salt Tank
Ambient Minimum temperature, °C(ºF)	-10 (14)	-10 (14)
Maximum temperature, °C (ºF)	550 (1022)	740 (1364)

- To avoid any molten salts freezing around the shaft area beneath the soleplate the Supplier shall include the required insulation and heat tracing for the coupling bellows.
- Supplier shall state in the proposal the minimum distance between pump centerline and any tank element such us pump nozzle wall, tank wall, heaters, piping, etc.

5.1.3. Pump design and construction details

5.1.3.1. Pressure casing

- The design pressure of the discharge and head shall be based on the rated impeller shut off head, at maximum speed and maximum suction pressure, as well as at minimum operating temperature.
- Pump discharge column assembly shall have enough length to ensure adequate submergence at minimum salt tank level and they shall include the required lugs and reinforcements for lifting, operation and transport loads without any permanent deformation.
- Pressure casing shall be designed with a corrosion allowance that shall meet the minimum requirements laid down:
- Carbon steel materials and Castings 1.6 mm.
- Stainless steels materials: 0.7 mm.
- Nickel based steel materials: 0.7 mm.
- Discharge column and discharge pipe if exists shall consider the thermal expansion of the pumps. Discharge pipe shall included the required loops in order to minimize the thermal stresses.

5.1.3.2. Nozzle and pressure casings connections

- Pump discharge nozzle shall be flanged RTJ type, in accordance with ANSI B 16.5

- Connections other than discharge nozzle shall be at least 1/2 NPS and RF type in accordance with ANSI B 16.5.
- Pipe nipples welded to the casing will include an isolation valve. Such connections shall be properly secured with supports and terminate in a flange. Valves shall not be welded to the pump casing.
- Allowable discharge nozzle loads shall be in accordance with API -610, Table 4, for the connecting pipe sizes
- Supplier shall submit allowable forces and moments for auxiliary connections, as well as the expected loads for the baseplate.

5.1.3.3. Impellers and Diffuser

- Impellers shall be semi open mixed flow or closed types, fabricated from single casting with solid hubs.
- Due to the variable speed required the maximum impeller diameter should be used. Nevertheless Supplier can consider the use of an intermediate diameter, for this case Supplier shall submit with his proposal, impeller diameter offered as well as minimum and maximum impeller diameters
- Each impeller shall be dynamically balanced to ISO 1940-1, grade 2.5.
- Impellers shall not be modified to correct hydraulic performance by under filling, overfilling or polishing without writing approval by the Purchaser.
- Impellers shall be keyed and individually secured to the shaft by a shoulder or split ring against the axial thrust in both directions.

5.1.3.4. Wear Rings

Renewable wear rings shall be furnished only on the casing side and be held in place by positively tight to the bowl/case. Integral wear rings shall be considered for the impeller side. Hardenable materials compatible with impeller material and exhibiting low galling tendencies shall be selected. Supplier will consider that the only lubrication medium shall be the molten salts

5.1.3.5. Shafts and sleeves

- Shafts shall be forged hardened steel. If pump length requires several shaft stages, they shall be assembled with keyed couplings to prevent disassembly during reverse rotation.
- Shaft shall include replaceable wearing sleeves with increased hardness protecting the shaft at the sliding areas with the sleeve bushings. Wearing sleeves have to include positive fixing by means of bolting or other alternate method.

- Shaft material selection and lubrication have to consider lubrication with the molten salt.
- Shafts shall be machined and finished throughout their length so that the total runout is not more than 0.25 mm. Shafts runout shall be measured and with they supported on V blocks or rollers adjacent to its bearing.

5.1.3.6. Shaft sealing systems

- Mechanical seals are not allowed for these services.
- Shaft sealing shall include a throttle bushing positioned and held in place by a shaft nut and with an overflow port to the outside of the shaft column. Contact seals are not allowed.
- A system composed by a 74 API plan Nitrogen injection system and a labyrinth seal shall be used to seal the upper section of the shaft and avoid the molten salt to reach the soleplate or the bearing housing. Supplier shall submit with the offer the Nitrogen requirements (Flow, Pressure and max. Temperature) shall be included

5.1.3.7. Bearing and bearing housing

- Pump shall be furnished with radial bearings and one thrust bearing.
- Thrust bearing shall be double ball angular contact type, designed for 50.000 operation hours at rated point. And they shall be able to withstand the maximum pump thrust load in both directions.
- Thrust bearing lubrication shall be oil bath lubricated, Its housing shall be sealed to avoid the oil contamination into the molten salts
- Upper bearing housing shall be arranged so that bearings can be replaced without dismantling pump.
- Column bushings shall be lubricated by the pumped medium

5.1.4. Auxiliary Systems

5.1.4.1. Cooling system

- Upper bearing housing should be cooled by a fan attached to the pump shaft. Supplier can consider the use of an alternate design and in this case shall submit with the proposal a detailed explanation.
- Upper shaft shall be thermally isolated by a suitable method such as insulation or shield casing in order to control the shaft climbing

5.1.4.2. Coupling and guards

- Coupling and guard between driver and driven equipment shall be provided
- Coupling hubs shall be steel. flexible disk type couplings shall have disks of corrosion-resistant material and electrically isolated
- Spacer shall have a nominal length that permits removal of the coupling and rotor as applicable, without disturbing the driver or the suction and discharge piping.
- Flexible couplings shall be keyed to the shaft
- Coupling service factor shall be at least 1.5 for the maximum driver power.
- Removable coupling guards shall conform to the requirements of OSHA regulations

5.1.4.3. Baseplate

- The pumps will have a mounting soleplate to attach the pump to a structural steel platform above the salt tanks. Vibration analysis will be performed to show that the pumps do not generate excessive vibration through the flow range within the minimum continuous and the run-out flow.
- Pump mountings will be designed to minimize vibration and fatigue stresses over the entire Life of the plant.
- The supports for the motor will be separated from the supports for the pumps such as the motor can be removed from the pump lantern without dismantling the pump. Lifting lugs will be provided for the motor and the lantern ring (or the motor supports) and on the pump body to facilitate the installation and removal of the motor and the pump.
- Baseplate shall be provided with at least four lifting lugs. Lifting baseplate with all equipment mounted, shall not distort the baseplate or equipment. Additionally, soleplate shall include grounding lugs.

5.1.4.4. Heat Tracing

- Supplier design shall take into account that pumped salts will freeze at 842 °F (450 ºC), so an electrical heat tracing system is required to avoid this inside the upper section of the pump. The maximum exposure temperature on the hot salt pump is 1364 °F (740 °C)
- Heating system shall consider at least the following operational requirements
- Allow pre-heat of the pumps for first run.

- Keep the pumps hot when in stand-by
- Provide enough salt melting capacity to unblock and drain the pumps when removed for maintenance.

5.1.5. Drivers

5.1.5.1. Electrical Motors

- The motors have to be suitable to be fed through ABB VSD (insulated bearings, special winding, VSD-motor combined test and curves, etc), rated voltage of 4160 or 480 VAC for hot salt pumps motors and cold salt pumps motors, and of 480 VAC for cold salt auxiliary pump motor, and frequency according to its design point.
- Electric motors will follow requirements of herein standards: NEMA MG, ANSI C50.41, NFPA 70Y ANSI MC96.1.
- Enclosures for mechanical protection shall meet NFPA70.
- Electric motor have to be designed to reach the run-out point (120% of design point) with a power reserve margin required to guarantee unlimited operation time with no overheating, adverse effects or premature wear or damages and considering the Service Factor required.
- The motors are for vertical installation and their insulation class has to be F for a B temperature rise class application.
- For thermal protection, the motors offered shall have 2 PT100 thermistances per phase (6 in total) and 1 PT100 thermistance duplex per bearing (4 in total)
- The motors shall have heating elements to avoid condensation (suitable for 120Vac / 208Vac / 277Vac - 60Hz controlled by the VSD)
- The electric motor proposed has to consider the following design:
- Vertical flanged type.
- IP-55 enclosure, suitable for weather exposition with weather protected NEMA type II
- IP-65 dedicated junction box for power connection with weather protected NEMA type II.
- IP-65 dedicated junction box for Space Heaters connection on Low Voltage with weather protected NEMA type II.
- IP-65 dedicated junction box for windings and bearing PT-100 wiring with weather protected NEMA type II.
- Motors shall include their own lifting lugs.
- Motors shall have air cooling refrigeration by means of a direct shaft connected aluminum fan with protector.
- Supplier shall consider that motor refrigeration system proposed

have to provide enough cooling capacity when motor is operating at reduced speed due the VSD.
- Customer will provide a single Power supply.

5.1.5.2. ABB Variable Speed Drives

- Motor Speed control shall be done via a VSD, and shall consider the following:
- VSD shall be according to ANSI and will comply the following codes and standards:
- IEEE 519- Standard practices and requirements for harmonic control in electrical power systems
- NEMA ICS 3.1-Safety standards for construction and guide for installation and operation of adjustable speed drive systems
- IEEE 444–Standard practices and requirements for thermistor converters and motor drives
- Pump shall be able to operate under stable conditions at full speed from 30% of the rated flow up to 120% of the design point, with an acceptable efficiency without cavitation, abnormal noise or vibration.
- Customer will provide the following feeders: main power (4160 Vac 60Hz) and auxiliary power (120Vac / 208Vac / 277Vac - 60Hz) for hot salt pumps motors and cold salt pumps motors. Auxiliary power shall be enough for VSD auxiliaries and motor heating resistances.

VSD must be suitable for an inner short-circuit current of 35kA for 4160 Vac VSD

- Supplier must indicate in the offer if the VSD will contain contactor and fuses or circuit breaker, to protect and operate the system.
- Supplier could suggest in the proposal another voltage to supply to the VSD.
- VSD shall include an IP-42 cabinet suitable to be installed indoor.
- Maximum clearances between transformers and VSD will be 20 meters, clearances between VSD and motors shall be about 100 meters.
- VSD shall have at least the following signals hardwired:
  - Inputs: speed set point (4-20mA from DCS), start signal (24V pulse signal from DCS), stop signal (24V pulse signal from DCS)
  - Output: speed signal (4-20mA), motor working (dry contact), motor stop (dry contact), VSD available for remote control (dry contact), VSD alarm (dry contact),

VSD failure (dry contact).

5.1.6. Instrumentation

The instrumentation per each pump-motor shall include at least the following items:

1 Vibration and temperature monitoring system including all auxiliary components such as relays, terminals, interconnecting cables, power source, etc. for the following measurements:

- 3 x accelerometers (2 per pump and 1 for motor)
- 2 x PT100 pump bearing housing
- 4 x PT100 motor bearing housing
- 6 x PT100 motor winding (wiring directly from motor to monitoring system.
- 1 cabinet IP-66
- Configuration and operation software

Vibration and Temperature Monitoring System enclose shall be IP 65, one (1) per pump. Total 9

In order to reduce common components and optimize control network, quote one unique enclose per each pump type (total 3)

- Receiver Circulating Pumps
- Hot Salt Pumps
- Attemperation salt pump.

Offer shall include preliminary drawings of monitoring system encloses
The supplier has to configure the vibration/temperature monitoring system with all the alarms and protection.

At Bidding Stage Supplier shall supply one (1) copy in electronic format of the monitoring system logic. During Project stage Supplier shall supply ONE (1) copy in electronic format

The vibration/temperature monitoring system and probes shall be readjusted and tuned by the supplier during the pumps commissioning and leave the system working.

Temperature detector in pump immersed bearing is not provided. The instrumentation will not be ATEX classified. Interface signals between vibration monitoring system and DCS shall be:

Digital relays:

- Vibration trip
- temperature trip
- temperature alarm
- vibration motor alarm

- vibration pump alarm
- Monitoring system status

Analog signals 4-20mA from the vibration and temperature modules will be hardwired to DCS.

The rest of information will be sent to DCS via communications, each Vibration monitoring system should have a communication interface link. The way to group the pump communication interface links to send to DCS will be done by others.

Interface signals between VSD and DCS:

Command orders from DCS to VSD will be pulse type (start/stop) and will be polarized by the DCS. Digital outputs from VSD to DCS will supply dry contacts to be polarized by DCS at 24 Vdc.
Analog signals from DCS to VSD (i.e. speed set point) will be passive signals from VSD (powered from DCS). Analog signals from VSD to the DCS, (i.e. speed signal), will be always energized by the VSD.

VSD Communication link with DCS should be preferably Modbus TCP, in order to homogenize all plant communication links with DCS.

The VSD will protect the motor, the fail reason will be sent to the DCS via ModBUS. The supplier shall provide alarms and trip set points and normal operation values.

5.2. MANUFACTURING, PACKING AND SHIPMENT

- Materials for pump parts shall conform to purchaser's data sheet. When the material is not specified, it shall be selected by the pump manufacturer.
- Materials shall be clearly identified in the proposal with their applicable standard, including the material grade. If no such designation is available, the supplier's material specification, giving physical properties, chemical composition, and test requirements, shall be included in the proposal.
- Materials, casting factors, and the quality of any welding shall be according to those required by
- Section VIII, Division 1.

5.2.1. Castings

- Castings shall be sound and generally free from porosity, hot tears, shrink holes, blow holes, cracks, scale, blisters, and similar defects.
- Surfaces of castings shall be cleaned by sandblasting, shot blasting, chemical cleaning, or any other standard method

- Use of chaplets in pressure castings shall be minimized. Chaplets shall be clean, corrosion-free (plating permitted), and of a composition compatible with the casting. Chaplets shall not be used in impeller castings.
- Ferrous pressure boundary and impeller castings shall not be repaired by welding, peening, plugging, or coating, except as follows:
- Weldable steel castings may be repaired by welding with a qualified welding procedure based on the requirements of ASME BPVC Section VIII, Div. 1 and Section IX
- Iron castings may be repaired by plugging within the limits of the applicable ASTM standards.

5.2.2. Welding

- Welding and weld repairs of piping, pressure-containing parts, and wetted parts shall be performed and inspected by operators and procedures qualified in accordance with the referenced standards on Section 3.1
- Welding expected to reach high hardness have to be hardness tested. If hardness obtained is 200 Brinnell or bigger, the component shall be stress relieved by thermal treatment.
- All repairs and repair welds shall be reviewed by the manufacturer to ensure that they are properly heat treated and nondestructively examined for soundness and compliance with the applicable qualified procedures. Repair welds shall be non-destructively tested by the same method used to originally qualify the part.
- If approved by the purchaser, weld repairs may be made to cast iron casings using the supplier's proven weld procedures. Welding repairs shall be part of final documentation. The procedure and qualification reports shall be submitted with the proposal of repairing.
- Any that cannot be repaired according the standard codes will create a "Deviation report" which will describe the deviation proposed and the applicable solution. Customer will reserve the right to accept or refuse any deviation. No deviation can progress without the Customer approval

5.2.3. Nameplates and Rotation Arrows

- A stainless steel nameplate shall be securely attached at a readily visible location on the pump and on any other major piece of auxiliary equipment.
- Rotation arrows shall be cast or attached to each major item of rotating equipment at a readily visible location.
- As a minimum, pump nameplate content shall be as follows:
- Manufacturer,

- Size and type.
- Purchaser's pump item
- Manufacturer serial Number.
- Rated Flow m3/h (gpm)
- Rated differential height m (ft)
- Rotation Speed. r.p.m.
- Casing design pressure barg (psig)
- Design Temperature ºC (ºF)
- Hydrostatic test pressure barg (ºF)

5.2.4. Cleaning and surface protection

- Cleaning, painting and surface protection for the external parts of every component above the soleplate shall be prepared and painted in a manner appropriate to the ambient conditions of services and for shipment in order to prevent all types of corrosion. Paint level according to ISO 12944, for more than 30 years and Annex 9.
- Carbon steel, bearing housings, and oil system components shall be coated with a suitable oil soluble preventative.
- Stainless steel will be free of harmful contaminants such as chlorides and low melting point metals. This includes, but is not limited to, paint and other coatings, tape, marking ink, and packing materials.
- The manufacturer shall prepare for each particular case a specific cleaning and surface protection procedure and shall summit it for purchaser's approval.
- Equipment shall be adequately supported for shipment. All loose parts shall be crated and/or boxed for shipment. Each box shall be appropriately marked for identification purposes

5.2.5. Insulation

Every part of the equipment/system to be insulated in accordance with data sheet requirements will be prepared in a suitable manner. The supply will include every accessory (clips, anchors, etc.) required for the correct execution of the insulation by others.

6. INSPECTION AND TESTING

6.1. GENERAL

- Supplier shall be responsible for conducting all the required tests and inspections and shall furnish to the purchaser with test results, material and inspection certificates, to demonstrate the compliance with this specification
- Supplier shall issue records of all tests, and examinations such as material certification, test results, repairs and heat treatment records,

dimensional control and all related results to verify that the requirements of the specification have been met. Supplier shall keep records available at least 5 years.

- Supplier shall issue an Inspection Program Point including at least every inspection and test to be performed according to requirements herein included
- Purchaser/Owner participation in the inspection and testing shall be conform to Annex 4.
- As far as applicable Supplier shall notify to sub suppliers of the purchaser's inspection requirements
- Unless otherwise agreed, notification of an inspection or test shall be submitted to the purchaser in advance with at least 10 working days.
- If inspection and testing at workshop have been specified, purchaser and supplier shall coordinate manufacturing hold points and inspector's visits. Equipment required for the specified inspections and tests shall be provided by the manufacturer.
- Pressure retaining parts shall not be painted until final inspections and testing are complete.

6.2. SHOP TESTS

6.2.1. Raw Materials

- Supplier shall furnish certificate test material report (CMTR), that include chemical analysis and mechanical strength, toughness properties and heat treatment for the heats from which the material has been supplied for the following components:
- Pressure retaining castings and forgings.
- Impellers.
- Shafts
- All materials in contact with pumped fluid
- All relevant items shall be identified by permanent marking.

6.2.2. Non Destructive Testing (NDT)

NDE shall be performed in accordance with the methods and acceptance criteria standards laid down:

6.2.2.1. Methods

Methods for all NDT's conform to the relevant articles of *ASME BPVC*, Section V.

6.2.2.2. Acceptance Criteria:

- NDT's castings conform to ASME BPVC, Section VIII, div. 1, Appendix 7
- Radiography of welds conform to ASME BPVC, Section VIII, div. 1, UW-51 (for 100%) or UW-52 (for spot)
- Ultrasonic inspections of forgings conform to ASTM A-388
- Magnetic particle of welds and forgings conform to ASME BPVC, Section VIII, div. 1, Appendix 6.
- Liquid penetrant ASME BPVC, Section VIII, div. 1, Appendix 8

6.2.2.3. NDT Inspection Scope

- NDT's examination for pressure retaining parts shall be in accordance with ASME BPVC, Section VIII, div. 1, but at least radiographic examination of the circumferential butt welds (100%).
- Visual inspection of all casting surfaces in accordance with MSS-SP-055, prior to coating.
- Ultrasonic examination for shafts in the premachined surface condition

6.2.3. Dimensional control

- Supplier shall perform dimensional control for the relevant dimensions of parts and their assemblies.
- General dimensions of equipment shall be checked against approved drawings and item lists.
- Drive train alignment shall be checked before testing.

6.2.4. Testing

- Equipment required for the specified tests as well as auxiliary fluids shall be provided by the manufacturer.
- Performance and NPSH test shall be conducted in accordance with Hydraulic Inst. HI1.6.

Performance tolerances shall be according to Grade A.

- All test data and records shall be collected. Supplier shall prepare a detailed report including certified test curves and test data compared to guarantee point

6.2.4.1. Hydrostatic test

- All pressure-retaining components including seal glands, seal chambers, and welded auxiliary process fluid piping shall be hydrostatically tested with liquid at a minimum pressure of 1,5

times the design pressure.

- Tests shall be maintained for a sufficient period not less than 30 minutes to permit complete examination of parts under pressure. Test shall be considered satisfactory when neither leaks nor seepage through the casing or casing joint is observed.
- Preliminary test before witnessed tests shall not be permitted
- Casing gaskets used during test shall be of the same design as those supplied with the equipment.
- Water for hydrostatic test shall have a maximum chlorides content of 50 ppm, if wetted stainless steel parts are tested. All residual liquid shall be removed from tested parts at the conclusion of the test.

6.2.4.2. Performance test

- A performance test shall be conducted for each pump with its contract driver. Test speed shall be within 3% of the motor nominal speed, any greater change in speed requires Purchaser's approval.
- Contract seals and bearings shall be used. Acceptable level of seal leakage during testing shall be zero visible leakage. Any leakage during the pump performance test requires their disassembly and repair.
- All joints and connections shall be checked for tightness, and any leaks shall be corrected.
- Vibration values shall be recorded during the test (3 axis), these values shall not exceed the values of ISO 10816-3., zone A. Filtered values shall not be permitted.
- Sound leves shall be recorded during the test, these values shall no exceed 85 dB
- All warning, protective, and control devices used during the test shall be checked for proper operation, and adjustments shall be made as require.
- All signal to and from monitoring system shall be tested to verify internal control program
- Performance test water temperature shall be at a temperature less than 50ºC.
- All running tests and mechanical checks shall be completed before the purchaser's inspection.
- Test data, including head, capacity, and power shall be taken at a minimum of eight points. These points shall be at least shutoff (no vibration data required), minimum continuous stable flow, midway between minimum and operation flow, normal operation flow, BEP point, rated flow, midway between rated and run out and run out flow.

- Test data shall be corrected for speed, density and viscosity.
- Disassembly of the pump after the performance test for any head adjustment, like machining impeller diameter, under filling or polishing, shall be cause for retest

6.2.4.3. Isoefficiency test

- The isoefficiency test shall be performed throughout all operation speed range, in steps of 100 rpm and at the same flow rates than Performance Test, except shutoff
- BEP flow for each speed should be clearly identified.

6.2.4.4. Submergence test

- A minimum submergence test shall be performed on one pump at rated and run-out flow.
- To performance this test, a shorter version of the pump will be accepted (by removing the intermediate sections of the pump).

6.2.4.5. Strip-test

- After performance and isoeficiency tests, one pump shall be dismantled to verify measures and tolerances of basic elements.
- The inspections shall be performed at least to the following components:
- Shaft (straightness, surface)
- Impellers (material wear, dynamic balance)
- Wear Rings (searing, setting)
- Sealings (deterioration, mounting)
- Bearings (deterioration, mounting).
- Measurements and tolerances control shall be performed to the following items:
- Impellers external diameters
- Wear rings
- Smooth bearings diameter measures and shaft zone measures, checking the internal set tolerances according with the assembly drawings.
- If any deviation has been encountered, the rest of the pumps shall be checked.

6.2.5. On site mechanical run test

- On site, the pump and driver assembly and their accessories systems shall be running at least during four (4) hours, at continuous operation flow rate, until stable oil temperature (minimum half hour). Test shall be performed in accordance with ASME PTC 8.2.

- During the test shall be verified aspects such as oil temperatures, vibration levels, electrical consumption, heating, protections, alarms, instrumentation, etc; in addition to the equipment performance and its auxiliary components

7. GUARANTEES, TOLERANCES AND PENALTIES

7.1. GENERAL

The contractor shall warrant that the equipment furnished is entirely suitable for the service described herein and is in complete accordance with this Specification, except where modified by specific exceptions authorized in writing by the Owner. Contractor shall submit a certificate of conformance to the Owner.

7.2. GUARANTEES

The Supplier shall guarantee that the equipment furnished is suitable for the service described herein and is in complete in accordance with this Specification, except for deviations with written approved by the purchaser.

The Supplier shall guarantee in his proposal the following parameters:

Parameter	Requirement	Tolerance	PENALTIES (P) REJECT (R)
Delivery Date	Acc. to Spec. point 4	No positive tolerance	P
Rated point (Head and Flow)	Acc. to Data Sheet	Acc. to spec. 6.2.4	R
Rated Efficiency	Acc. to Data Sheet	Acc. to spec. 6.2.4	P
Rated Power	Acc. to Data Sheet	No positive tolerance	P
Minimum Stable Continuous Point (Head and Flow)	Acc. to Data Sheet	No positive tolerance	R
Head at Run Out Flow	Acc. to Data Sheet	± 5%	P
Reverse runaway speed	Acc. to Data Sheet	Acc. to spec. 5.1.2	P
First Critical Speed	Acc. to Data Sheet	± 25%	R
Vibration	Acc. to Data Sheet	No positive tolerance	R
Noise level	Acc. to Data Sheet	No positive tolerance	R

7.3. TOOLS AND MAINTENANCE EQUIPMENT

- Pumps shall be designed to be assembled, disassembled, and maintained, preferably with standard hand tools.
- If special tools shall be used, bidder's proposal shall include a list of special tools and equipment, with unit prices, required for any part of the pump driver train.

7.4. RECOMMENDED SPARE PARTS

Bidder's proposal shall include a list of the spare parts and components for the pump driver, with unit prices, taking into account the following conditions:

- Spare parts offered shall cover two (2) years of operation.
- Spare parts to be used during erection and commissioning shall not be considered as spare parts and they shall be quoted with the main equipment.

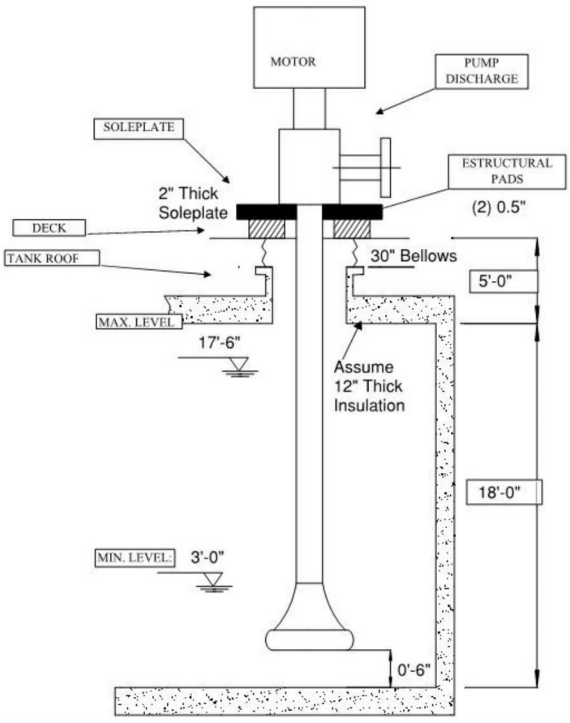
APPENDIX A – PUMP / TANK DIAGRAM

	Project	DOCUMENT
	Gen 3 Liquid-Pathway	
	DESCRIPTION	
	Salt Tanks pumps	Rev:

TECHNICAL DATA SHEET
TUBULAR CASING SALT PUMPS

PLANT IDENTIFICATION (KKS / TAG):
SUPPLIER / MANUFACTURER:
NUMBER OF PUMPS PER UNIT :
OPERATION MODE (SERIE/PARALLEL):

SKETCH OF SALT PUMPS INSTALLED INTO TANK



NOTES:
All dimensions are given above bottom of tank

APPENDIX B – PUMP DATA SHEET

See attached Excel Spreadsheet for Hot, Cold and Attemperation Pump performance criteria.

Sandia National Laboratories, Albuquerque NM				Bridgers & Paxton Consulting Engr.		
PROJECT NAME: Gen 3 Liquid-Pathway	Molten Salt Vertical Pumps VS-1A and VS-1B			Doc No: 041119_Rev A		
DATA SHEET				EQUIPMENT No: VS-1 SHEET No:	Bridgers & Paxton Consulting Engr. 1 OF 2	REV No A
TOTAL No: (2) 100%	2	WORKING No:	1	STANDBY No:	1	
AREA: Hot Salt Pumps				P&ID No:		
MANUFACTURER:		SUPPLIER:		TBC		
SIZE / TYPE:						
EQUIPMENT TITLE:	Hot Salt Pumps VS-1A & VS-1B	SPEC No:				
Fluid Data and Site Conditions						
Chloride Salts	40 $MgCl_2$ / 20 NaCl / 40 KCl					
Max. Operating Temperature	740 °C					
S.G.	1.471					
Vapor Pressure	21.9 Pa					
Viscosity	0.002503 N-S / M>2					
Location	Outdoors					
Service	Intermittent					
Operating Conditions 1 ~ Full Tank, Max Level 17.6 ft about tank bottom						
Operating Flow	30.0 m>3 / hr (110 gpm)					
Min. Stable Continuous Flow	14.7 m>3 / hr (54 gpm)					
Total Dynamic Head	27.4 m (90 ft)					
NPSHa	6.58 m (21.6 ft.) (min)					
Operating Conditions 2 ~ Empty Tank, Min. Level 3 ft above tank bottom						
Operating Flow	30.0 m>3 / hr (110 gpm)					
Min. Stable Continuous Flow	14.7 m>3 / hr (54 gpm)					
Total Dynamic Head	27.4 m (90 ft)					
NPSHa	6.58 m (21.6 ft.) (min)					
Pump Data Required from Vendors						
Characteristic curve						
First Critcal Speed						
Rated Power						
Normal Operating Efficiency						
NPSHr						
Impeller open/closed						
Sealing system: Mechanical / Packing						
Materials of Construction:						
Impeller open/closed						
Volute						
Column						
Shaft						
Mounting Plate						
Tank to Pump Seal						
Weights of:						
Bare Pump						
Base plate						
Motor						
Coupling and Guards						
Tank to Pump Seal						
Motor:						
Type						
Manufacturer						
Data Sheet						
Normal Power						
Variable Speed Drive:						
Type						
Manufacturer						
Model/Size						
Speed Max/Min						

Sandia National Laboratories, Albuquerque NM

Bridgers & Paxton Consulting Engr.

Doc No: 041119_Rev A

PROJECT NAME: Gen 3 Liquid-Pathway	Molten Salt Vertical Pumps VS-2					
DATA SHEET				EQUIPMENT No: VS-2	Bridgers & Paxton Consulting Engr.	REV No A
				SHEET No:	1 OF 2	
TOTAL No: (2) 100%	1	WORKING No:	1	STANDBY No:	1	1
AREA: Hot Salt Pumps				P&ID No:		2
MANUFACTURER:		SUPPLIER:		TBC		3
SIZE / TYPE:						4
EQUIPMENT TITLE:	Receiver Salt Pump VS-2	SPEC No:				5

Fluid Data and Site Conditions

Chloride Salts	40 $MgCl_2$ / 20 NaCl / 40 KCl		6
Max. Operating Temperature	500 °C		7
S.G.	1.568		8
Vapor Pressure	0.0288 Pa		9
Viscosity	0.004818 N-S / M>2		10
Location	Outdoors		11
Service	Intermitent		12

Operating Conditions 1 ~ Full Tank, Max Level 17.6 ft about tank bottom

Operating Flow	30.0 m>3 / hr (110 gpm)		1
Min. Stable Continuous Flow	14.7 m>3 / hr (54 gpm)		2
Total Dynamic Head	92.0 m (302 ft)		3
			4
NPSHa	6.2 m (20.4 ft.) (min)		5
			6
			7
			8
			9

Operating Conditions 2 ~ Empty Tank, Min. Level 3 ft above tank bottom

Operating Flow	30.0 m>3 / hr (110 gpm)		1
Min. Stable Continuous Flow	14.7 m>3 / hr (54 gpm)		2
Total Dynamic Head	92.0 m (302 ft)		3
			4
NPSHa	6.2 m (20.4 ft.) (min)		5
			6
			7
			8
			9

Pump Data Required from Vendors

Characteristic curve			1	
First Critical Speed			2	
Rated Power			3	
Normal Operating Efficiency			4	
NPSHr			5	
Impeller open/closed			6	
Sealing system: Mechanical / Packing			7	
Materials of Construction:				
Impeller open/closed			8	
Volute			9	
Column			10	
Shaft			11	
Mounting Plate			12	
Tank to Pump Seal			13	
			14	
Weights of:				
Bare Pump			15	
Base plate			16	
Motor			17	
Coupling and Guards			18	
Tank to Pump Seal			19	
			20	
Motor:				
Type			21	
Manufacturer			22	
Data Sheet			23	
Normal Power			24	
			25	
Variable Speed Drive:				
Type			26	
Manufacturer			27	
Model/Size			28	
Speed Max/Min			29	
			30	
			31	

Sandia National Laboratories, Albuquerque NM

Bridgers & Paxton Consulting Engr.

Doc No: 041119_Rev A

PROJECT NAME: Gen 3 Liquid-Pathway	Molten Salt Vertical Pumps VS-3					
DATA SHEET				EQUIPMENT No: VS-3	Bridgers & Paxton Consulting Engr.	REV No A
				SHEET No:	1 OF 2	
TOTAL No: (2) 100%	1	WORKING No:	1	STANDBY No:	1	
AREA: Hot Salt Pumps				P&ID No:		
MANUFACTURER:		SUPPLIER:		TBC		
SIZE / TYPE:						
EQUIPMENT TITLE:	Attemperation Salt Pump VS-3	SPEC No:				

Fluid Data and Site Conditions

Chloride Salts	40 $MgCl_2$ / 20 NaCl / 40 KCl	
Max. Operating Temperature	500 °C	
S.G.	1.568	
Vapor Pressure	0.0288 Pa	
Viscosity	0.004818 N-S / M>2	
Location	Outdoors	
Service	Intermitent	

Operating Conditions 1 ~ Full Tank, Max Level 17.6 ft about tank bottom

Operating Flow	30.0 m>3 / hr (110 gpm)	
Min. Stable Continuous Flow	14.7 m>3 / hr (54 gpm)	
Total Dynamic Head	25.3 m (83 ft)	
NPSHa	6.2 m (20.4 ft.) (min)	

Operating Conditions 2 ~ Empty Tank, Min. Level 3 ft above tank bottom

Operating Flow	30.0 m>3 / hr (110 gpm)	
Min. Stable Continuous Flow	14.7 m>3 / hr (54 gpm)	
Total Dynamic Head	25.3 m (83 ft)	
NPSHa	6.2 m (20.4 ft.) (min)	

Pump Data Required from Vendors

Characteristic curve			1	
First Critical Speed			2	
Rated Power			3	
Normal Operating Efficiency			4	
NPSHr			5	
Impeller open/closed			6	
Sealing system: Mechanical / Packing			7	
Materials of Construction:				
Impeller open/closed			8	
Volute			9	
Column			10	
Shaft			11	
Mounting Plate			12	
Tank to Pump Seal			13	
			14	
Weights of:				
Bare Pump			15	
Base plate			16	
Motor			17	
Coupling and Guards			18	
Tank to Pump Seal			19	
			20	
Motor:				
Type			21	
Manufacturer			22	
Data Sheet			23	
Normal Power			24	
			25	
Variable Speed Drive:				
Type			26	
Manufacturer			27	
Model/Size			28	
Speed Max/Min			29	
			30	
			31	