Specification No. 203-HJT-~~9000R0~~9000R1a

Specification for a Pump System for the High Power Mercury-Jet Target Experiment

~~August 24~~Nov 1, 2005

SPECIFICATION FOR A PUMP SYSTEM FOR THE HIGH POWER MERCURY-JET TARGET EXPERIMENT

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1.0 Scope

This procurement specification is issued on behalf of Brookhaven National Laboratory (BNL), hereafter referred to as the Company, and contains the requirements for the design, fabrication, and assembly of a pump system consisting of a syringe pump and a hydraulic power unit (HPU). The HPU provides the power to drive the syringe pump; the combination of these will be used to produce a jet of mercury within a containment barrier. Acceptance tests at the Seller's site shall use water in lieu of mercury in the syringe pump. *The Seller will not deal with nor handle mercury in any way, and the containment barrier and sump tank shown in Fig. 2 are not part of this procurement*. Upon completion of successful testing, the equipment shall be delivered to Oak Ridge National Laboratory (ORNL) in Oak Ridge, TN.

Under the provisions of this subcontract the Seller shall provide the following:

- Syringe pump
    - hydraulic cylinders,
    - cylinder tie beam
    - base support structure, and
    - ~~instruments~~position sensors.
- HPU
    - pump, motor, reservoir,
    - motor controller,
    - sensors and gauges,
    - hoses and fittings,
    - hydraulic fluid, and
    - mobile cart to support the HPU.
- Electrical power and system controls
- Detailed design documentation
- System integration and testing

~~*Two configurations are being considered for this system. In Configuration A, the syringe pump cylinders will be located within a magnetic field, so the cylinders and tie-beam must be fabricated from SS304L or SS316L. In Configuration B, the syringe pump cylinders are outside the magnetic field, so standard cylinders will suffice. Those requirements that are affected by these dual configurations are noted in this document. The Seller shall provide cost information for both configurations, and the Company will use that information in conjunction with other operational requirements to select the desired configuration.*~~

Figure 1 shows the syringe pump; the two outer hydraulic cylinders drive a center cylinder that will produce a jet of mercury at the Company's testing site.

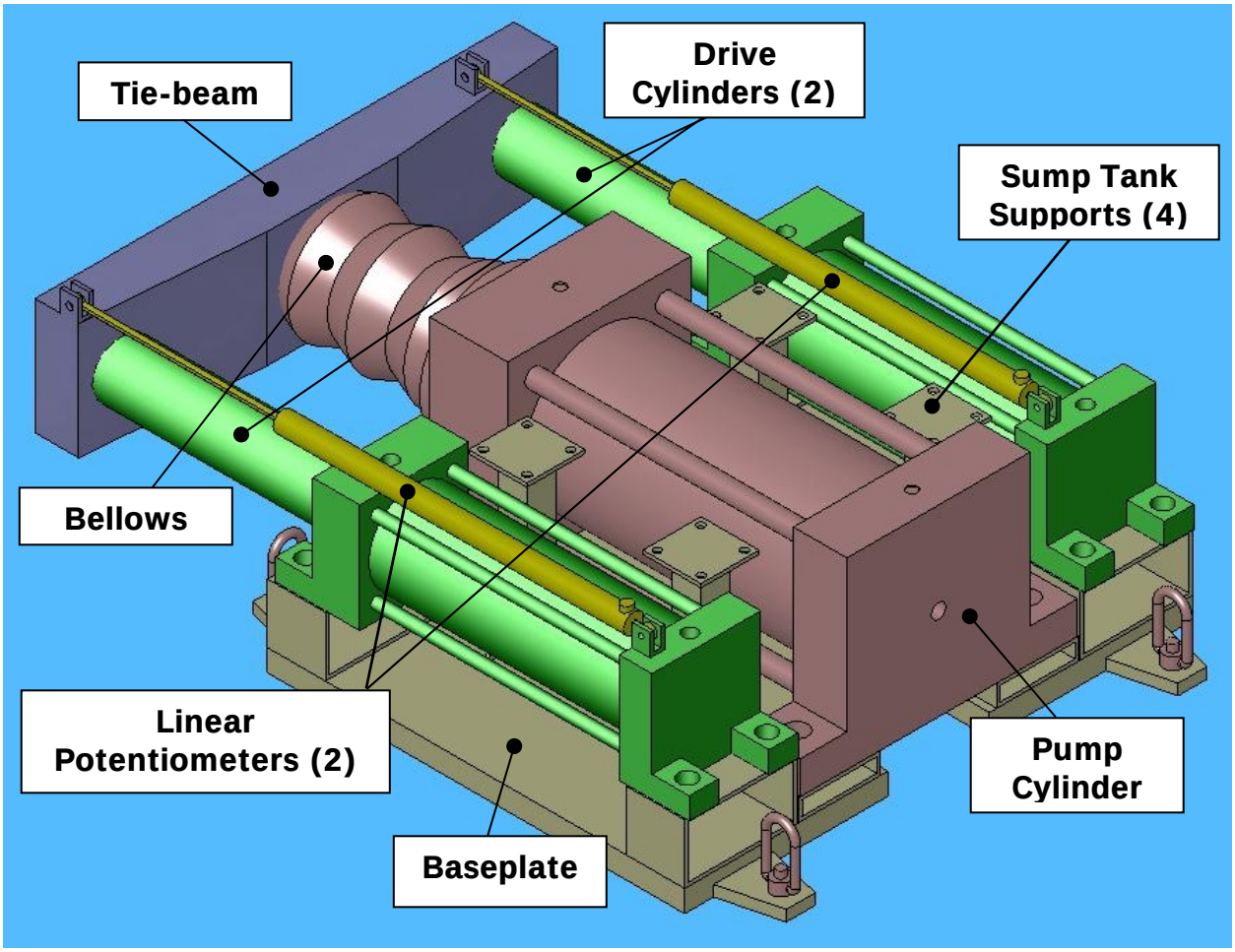

Figure 1. Syringe pump subsystem.

Figure 2 shows the syringe pump installed in a secondary containment box along with a mercury sump tank and a mercury delivery nozzle. The secondary containment, sump tank, and nozzle are shown for reference and are not part of this specification. Figure 3 shows the HPU.

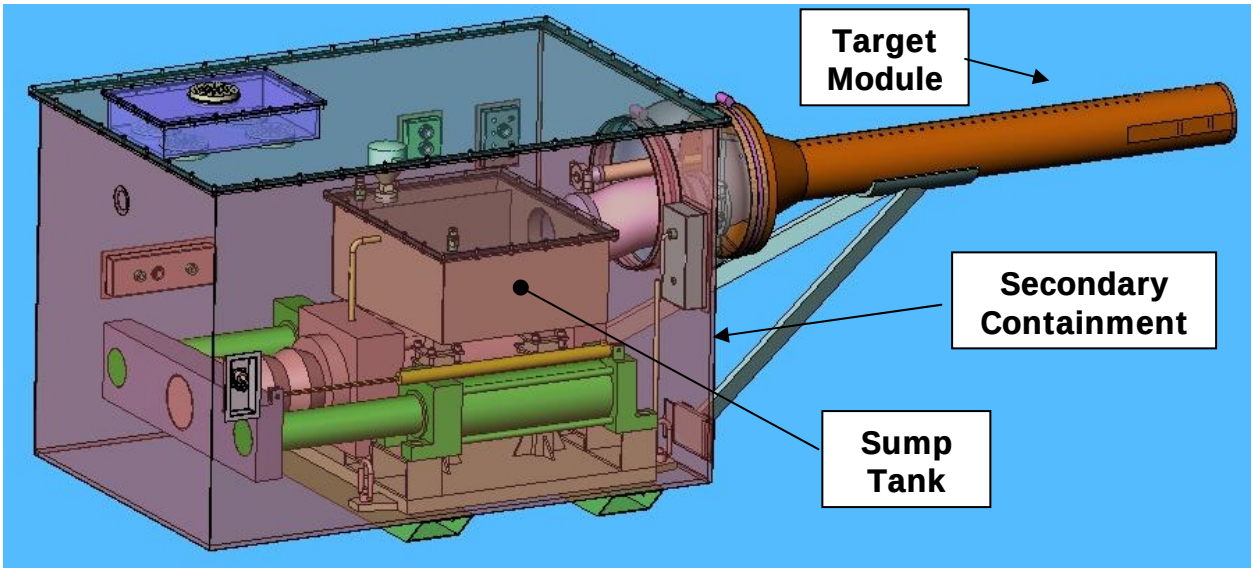

Figure 2. Syringe pump subsystem shown inside secondary containment.

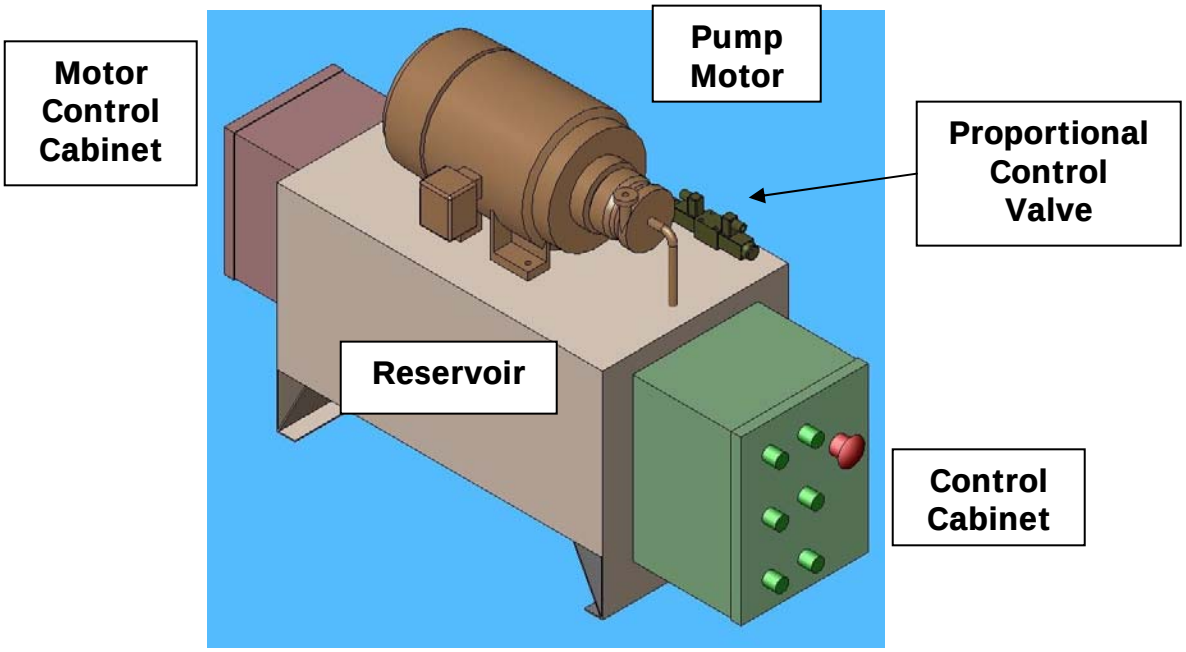

Figure 3. HPU (mobile cart not shown)

2.0 Applicable Codes and Standards

- ANSI/NFPA/JIC T.2.24.1 – 3000 psi rated cylinders
- National Electric Code latest edition – standard practices
- American Welding Society D.1 – standard practices

3.0 Design

3.1 Performance

The system shall be capable of expelling mercury from a cylinder at room temperature over a range of flow rates from 1 gpm to 30 gpm (4 – 114 liters/min) against a flow-pressure of up to ~~1000~~ 1500 psig. For the nominal flow condition of 25 gpm, jet duration shall be 12 seconds. System shall operate with angle of tilt between 0° and 5° upward.

3.2 Operating Environment

The syringe pump system shall be capable of operating in the following environment:

- temperature range of 20°C to 80°C,

The HPU shall be capable of operating in the following environment:

- temperature range of 20°C to 40°C.

3.3 Lifetime

The syringe pump and HPU shall be capable of operating for 10,000 start/stop cycles.

4.0 Design Requirements

The schematic diagram for the pump system is included at the end of the specification and is listed as Figure 5.

4.1 Hydraulic Power Unit

*4.1.1 **Pump & Motor***

The HPU pump shall have an operating pressure of 3000 psi. The motor shall be adequately sized to drive the chosen pump. The motor shall operate with 380VAC/50Hz and 480VAC/60Hz.

4.1.2 ***Reservoir***

4.1.2.1 Cart - The reservoir with integrated pump/motor and electrical system shall be mounted on a mobile cart with four lockable wheels; one pair shall be swivel wheels, one pair fixed wheels. The cart shall be steered by a handle mounted in front of the swivel wheels; if detachable, provisions shall be made to store the handle on the cart. The cart shall have a drip pan under the reservoir. The cart shall have a bracket(s) for storage of the system power cord. The cart shall be designed to allow lifting with a forktruck or an overhead crane.

4.1.2.2 Standard Maintenance Features – The reservoir shall have

- internal baffling,
- sight-gauge level indicator,
- low level fluid ~~sensor~~/ high temperature switch (140°F),
- cleanout port,
- ~~dessicant cartridge for moisture capture,~~
- N_2 purge valve,
- clean vent,
- vacuum breaker / tank relief,
- rear-mount case-drain cooler (air-to-oil)
- drain port with ball valve and cap,
- sealed fill port, and
- minimum capacity of 40 gallons.

4.1.2.3 Hydraulic Fluid – the HPU fluid shall be fire-resistant Quintolubric® 888 or equivalent. The fluid shall be pre-filtered through a filter with a $Beta_{5\mu m}>25$ before pumping into the system.

4.1.2.4 Flow control – flow shall be controlled with a proportional directional control valve with position feedback and integrated control electronics, Bosch 4WREE or equivalent.

4.1.2.5 Fittings – the only allowed fittings will be SAE without specific Company approval.

4.1.2.6 Hoses – One pair of hoses shall connect to the reservoir to form the supply and return lines; these shall be split into two pairs inside the secondary containment of the mercury delivery system (see Figure 5), with each pair connecting to one of the drive cylinders. The supply and return lines shall terminate at the reservoir and the secondary containment boundary with male/female fittings, with opposite sex fittings chosen to eliminate the possibility of incorrect hookup. The supply and return hoses shall have check valve quick-disconnect ends, and be a minimum of ~~65~~ 100 ft. in length. Hoses shall incorporate OSHA-approved whip checks at the disconnects. No magnetic materials are

allowed in the hoses or in the quick-disconnects at the secondary containment; if different quick-disconnects are used at the reservoir, a mechanism shall be provided to prevent them from connecting to the secondary containment.

4.1.2.7 Contamination Control – A filter meeting the contamination control requirements of the ~~proportional directional control valve~~hydraulic pump shall be installed in the return line close to the reservoir. The filter housing shall include a bypass valve, and a local visual indicator and a panel light to indicate ~~high differential pressure across the filter~~a clogged filter condition. The HPU shall be delivered to ORNL with two spare filters.

*4.1.3 **Controls***

4.1.3.1 The HPU control system shall be housed in two cabinets, the motor control cabinet and the control cabinet. All components with voltages greater than 50V shall be housed in the motor control cabinet; the control cabinet shall contain only components that can be energized with less than 50V. All electrical components shall be UL listed or approved. The HPU shall be capable of operating with 3-phase, 480VAC/60Hz power for U.S. operation and 380VAC/50Hz power for European operation.

4.1.3.2 The control system shall be provided with 50 ft of NEC-approved power cable with a Hubble HBL26419 plug. The cable shall be stored on the mobile cart.

4.1.3.3 All wiring shall meet applicable National Electrical Code requirements. All conductors shall be installed with labels corresponding to those listed on the Seller-supplied wiring diagram.

4.1.3.4 The control system shall include a motor starter and the following controls and indicators:

- Main power disconnect
- Cabinet mounted motor start button
- Cabinet mounted motor stop button
- Cabinet mounted dial for controlling the directional control valve
- Cabinet mounted switch for local or remote control that enables/disables the control valve dial control and the motor start/stop buttons
- Cabinet mounted "system energized" indicator light
- Cabinet mounted “motor on” indicator light
- Cabinet mounted “filter dirty” indicator light
- Cabinet mounted “low reservoir fluid level” indicator light
- Cabinet mounted "high-temperature" indicator light
- Cabinet mounted push-to-test button to test indicator lights
- Cabinet mounted emergency stop button
- Pendant mounted emergency stop button

4.1.3.5 The control system shall be housed in NEMA 4 enclosures. The main power disconnect, fuses, relays, and motor starter shall be in the motor control cabinet. ~~It shall also include a step-down transformer to 110VAC and a 24VDC power supply powered by 110VAC.~~ One 110V/20A circuit with breaker for external loads shall be provided, with one quad GFI-protected receptacle mounted in/on the motor control cabinet. An on-board step-down transformer from 380V to 110V shall provide power for the 110V circuit during operations in Europe; for U.S. operations the circuit can be powered through a flanged inlet receptacle. ~~The~~ A 24VDC power supply shall be provided and sized to drive all relays and indicators and provide an additional 250W to external, Company-supplied loads.

4.1.3.6 The controls and indicator lights shall be housed in/on a separate enclosure, the control cabinet, and operated at 24VDC. The starter contactor shall operate with 24VDC. The control cabinet shall be a minimum of 24 inches tall, 20 inches wide, and 8 inches deep and shall contain full-width horizontal DIN rails attached to panel mounting brackets for mounting Seller- and Company-supplied equipment. All Seller-supplied control and sensor wiring shall connect to a terminal block mounted on one of the DIN rails. The terminal block shall provide a minimum of 48 connection points for Company-supplied wiring at a later time. The cabinet shall provide a minimum of 240 in^2 of space for Company-supplied equipment.

4.1.3.7 The control system shall have the ability for manual operation from the control cabinet with the motor start/stop buttons and the directional control valve dial when the local/remote switch is set to local control. When the local/remote switch is set to remote control, operation of the motor start/stop buttons and directional control valve shall come from a remote computer. Wiring from the remote computer interface will be installed by the Company. Signals to all indicator lights on the control cabinet shall be accessible to a remote computer through the Seller-provided terminal block. A bulkhead Ethernet connection with standard RJ45 ports on both sides shall be installed in the control cabinet by the Seller.

4.1.3.8 A push-to-test circuit shall be included. When the button is pushed, all indicator lamps should illuminate to verify their operation.

4.1.3.9 If a low-fluid-level or a high-fluid-temperature signal is received, the pump motor shall automatically be disabled.

4.1.3.10 The control system shall incorporate emergency stop features to stop the pump. The cabinet-mounted emergency stop button shall be a non-illuminated mushroom-style switch, two inches in diameter or larger. It shall be push-to-stop and remain in that position, and shall require ~~pull~~twist-to-release to allow operation of the start button.

4.1.3.11 A hand-held, pendant-mounted emergency stop button shall be provided that performs the same functionality as the on-board emergency stop button. The button on the pendant shall be a non-illuminated mushroom-style switch, 1-1/2 inches in diameter. It shall be push-to-stop and remain in that position, and shall require pull to release to allow operation of the start button. The pendant is to be on a 250-ft, SO-type cord that can be disconnected from the control cabinet when remote operation is not needed.

4.2 Syringe Pump

*4.2.1 **Size Constraint***

The syringe pump shall be designed to fit within the secondary containment box of the mercury delivery system as shown in Figure 4. Maximum syringe pump width is 35 inches, and the maximum syringe pump extended length is 50 inches. Maximum overall height of the syringe pump is 18 inches.

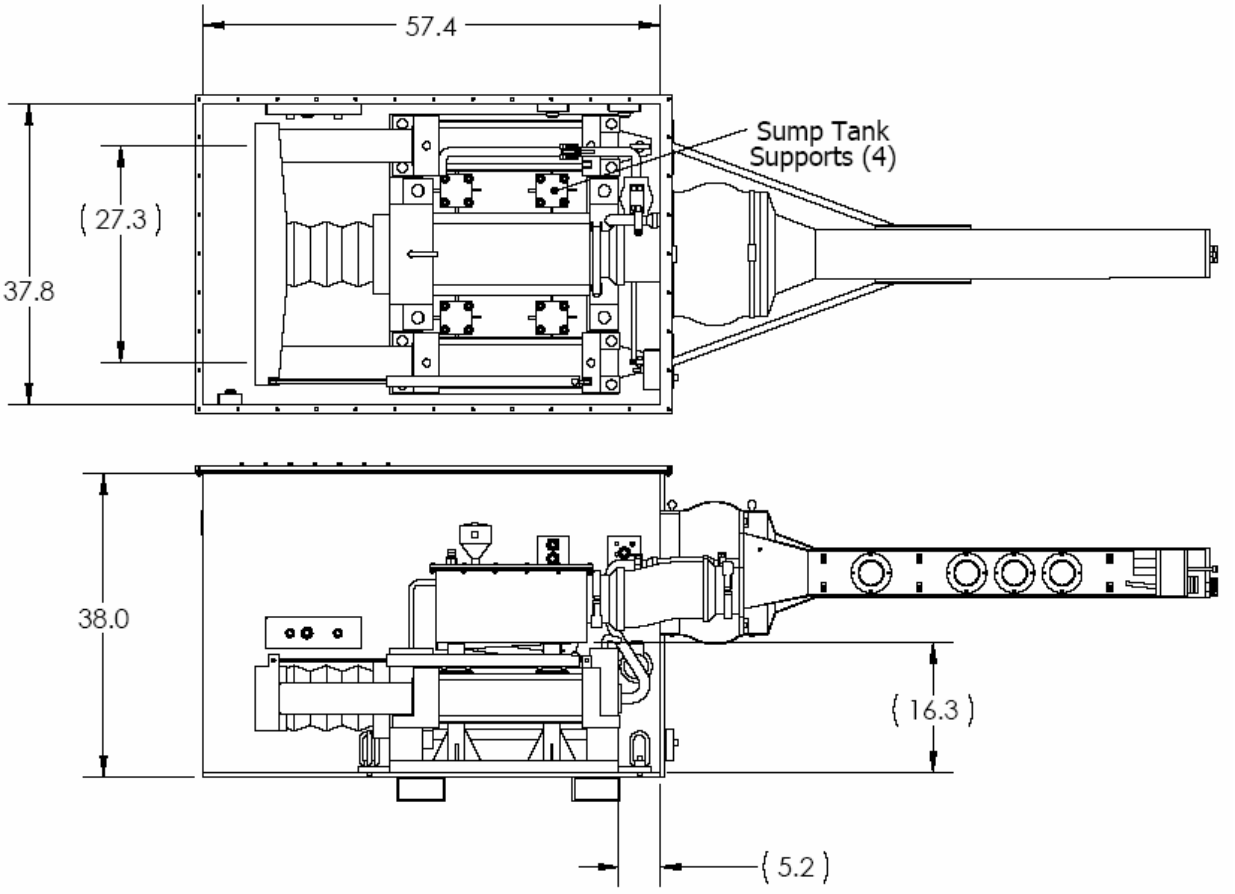

Figure 4. Syringe pump size constraints (dimensions in inches)

4.2.2 ***Pump Cylinder***

4.2.2.1 The pump cylinder shall be a NFPA Industrial Type ~~heavy-duty~~ cylinder rated for ~~3000~~ 1500 psi service with a 15-inch stroke and a 10-inch bore.

4.2.2.2 Materials for the pump cylinder assembly shall be compatible with mercury; therefore, use of bronze, brass, copper, aluminum, and similar metals, for bearings, bushings, and other miscellaneous hardware is prohibited.

4.2.2.3 ~~*Configuration A:*~~ The cylinder, piston and rod shall be fabricated from SS304L or SS316L. ~~*Configuration B:* The cylinder, piston, and rod shall be manufactured using Seller's standard materials. *In both configurations,* t~~The pump cylinder shall be designed for water service.

4.2.2.4 The seals in the pump cylinder shall be double-wipe Viton seals.

4.2.2.5 Ports/Fittings – Cylinder end shall have three ports: 1-inch four bolt flange center port for Hg inlet & outlet (SAE J518 Code 61); 1/2-inch straight thread O-ring top port for vent (SAE J1926-1); and 1/2-inch straight thread O-ring bottom port for Hg drain (SAE J1926-1). Rod end shall have 1/2-inch straight thread O-ring top port for vent (SAE J1926-1). Hg drain line stub shall be provided and shall include 90-deg fitting, 12 inches of 1/2" tubing, and a ~~1000~~1500-psig-rated stainless steel ball valve with end cap.

4.2.2.6 Containment - A boot (soft bellows) shall be provided to cover the extracted piston rod of the pump cylinder. The boot material and its connecting hardware must be compatible with mercury and shall serve as a vapor filter. A vent port shall be provided to allow routed-venting of the boot cover. See Fig. 5.

4.2.3 ***Drive Cylinders***

4.2.3.1 The two drive cylinders shall be NFPA Industrial Type heavy-duty cylinders rated for a minimum 3000 psi service with ~~15-inch~~suitable strokes.

4.2.3.2 ~~*Configuration A:*~~ The cylinder, piston and rod shall be fabricated from SS304L or SS316L. ~~*Configuration B:* The cylinder, piston, and rod shall be manufactured using Seller's standard materials.~~

4.2.3.3 The seals in the drive cylinders shall be double-wipe Viton seals.

4.2.3.4 Ports/Fittings – Supply and return ports shall be on the top of the drive cylinders. Ports shall be SAE J1926-1 straight-thread O-ring ports.

4.2.4 ***Base Support Structure***

4.2.4.1 The base support shall be fabricated from SS304L or SS316L.

4.2.4.2 The base support structure shall include four leg supports for a sump tank (that is not part of this procurement); the leg supports shall be designed to support 1000 lbs. at a height of two inches above the pump cylinder. See Figure 4 for interface dimensions.

4.2.4.3 Four stainless-steel swivel hoist rings shall be provided on the base support structure for vertical lifting. Locations shall be included on the design drawings approved by the Company prior to fabrication.

4.2.4.4 The base support structure shall include provisions for mechanical attachment to the floor of the secondary containment box through 4 studs welded to the secondary containment. The weld studs will be provided by the Company.

4.2.4.5 The base support structure shall support the pump cylinder at a height that allows a horizontal drain line and valve to be installed in the drain port of the cylinder.

*4.2.5 **Tie Beam***

4.2.5.1 The tie beam shall be a demountable, rigid attachment joining the drive cylinder and the pump cylinder rods so that all three move simultaneously.

4.2.5.2 The tie beam shall be fabricated from SS304L or SS316L.

4.3 Instruments

*4.3.1 **Pressure Sensors***

Pressure sensors with local display and remote output capability (4-20mA output signal) shall be located at the pump discharge and inlet ports. See Fig. 5.

*4.3.2 **Position Sensor***

~~Both of the drive cylinders~~The Pump Cylinder shall be fitted with ~~a~~ two (2) Celesco Model CLWG Linear Potentiometers or equivalent with a minimum of 10 ft. of instrument wire. ~~See Fig. 1.~~

4.4 Design Documents

The Seller shall provide the complete design for the pump system, including calculations, in accordance with this specification. A complete set of design drawings and supporting documents describing key physical aspects of the pump system shall be submitted according to the Document Submission Schedule outlined in Section 9.0. The drawings and documents provided by the Seller shall include:

- Fully dimensioned and labeled assembly drawings, fabrication drawings, and relevant Seller catalog information;

- Electronic SolidWorks®-compatible 3D CAD models (with accurate external dimensions) of the pump system design for integration into the Company's overall experiment assembly model;
- Parts List of all components;
- Calculations supporting the design;
- Maintenance Manual for routine and non-routine maintenance; and
- Operations Manual for the hydraulic system.

All materials must be identified on the Seller's drawings by specification number, by generic name, and by grade or type. Company approval of the drawings and documents wherein materials are so identified, constitutes approval of the materials. Drawings shall be dimensioned in inches.

4.5 Design Review

A Design Review covering all aspects of the system design shall be held at the Seller's location within 30 days of subcontract award. The Company shall be notified at least 10 days prior to the design review date. No system components can be ordered prior to this Design Review.

5.0 Inspection and Testing

The Seller shall submit a Test and Inspection Plan for Company approval. This plan will be reviewed by the Company and returned to the Seller with hold/witness points designated. After the plan is approved, it shall constitute a part of this specification and shall be distributed to all responsible personnel involved in the manufacturing or testing of items covered by this specification. Such personnel shall be instructed to implement and carry out all provisions of the plan.

As part of the Company's quality assurance program, source surveillance activities may be conducted at the Seller's facility or any sub-tier Seller facility that the Company determines necessary to ensure that quality objectives are met. Such surveillance may include auditing and monitoring of production processes, in-process inspection and controls, chemical or physical certifications, final inspection and tests, preparation for shipment, and review of certification data. The Seller shall provide the Company representative(s) access to all data and operating areas pertinent to the contract. Source surveillance by the Company representative shall in no way relieve the Seller of the responsibility to furnish acceptable items.

5.1 Acceptance Testing

The Company shall have the right to witness final functional testing and inspection of the equipment at the Seller's site. Such testing shall be specified by the Seller to ensure full compliance of the equipment with the requirements of this specification. The Seller shall supply the Company with a Final Inspection and Testing Report. The requirement for witnessed-tests

and inspections are at the Company's discretion upon receipt of the Seller's test and inspection plan.

Final acceptance tests of the syringe pump system shall be based on the tests outlined in the Test and Inspection Plan. The test setup shall include those items shown in Figure 5 as "*Needed for Test*." Distilled water shall be used as the test fluid in the pump cylinder. At a minimum the acceptance tests shall demonstrate

- Velocity control of the pump cylinder using both local and remote control.
- Signal feedback from all sensors.
- Test fluid expulsion from the pump cylinder through a discharge pipe and nozzle. The discharge pipe shall be 1-inch dia with a minimum length of 6 ft, and the nozzle shall be approximated by a 3-inch-long section of 5" pipe followed by a 4-inch-long section of 1/2" tube or some other method of providing a prototypic back pressure.
- Gravity intake of the test fluid through the discharge pipe.
- Operation of vent and drain ports.
- One hundred cycles of the syringe pump at a water discharge rate of 25 gpm, with a cycle rate of one complete discharge every 2 minutes.

Acceptance tests shall take place at the Seller's site using the actual components, equipment, and materials that will be delivered to the Company.

5.2 Seller's Responsibilities

The Seller shall notify the Company ten (10) working days prior to the start of tests and inspections that are designated in the Test and Inspection Plan. The Company at its discretion shall have representatives witness the performance tests. Testing shall not be initiated until the Seller receives Company approval of all testing procedures to be used.

6.0 Quality Assurance

The Seller shall provide a Quality Assurance Program for Company approval. The Program shall contain the following elements; training and qualification, improvement, documents and records, process control, design, procurement, inspection and test, and assessment.

6.1 Non-Conforming Items

The Company expects to receive equipment items, components, materials, software, and documentation that conform to all codes, standards, specifications, and procedures in the Agreement. The Seller may use its own nonconformance program to identify, report, and recommend disposition of all non-conformances, but disposition that would leave any remaining nonconformity must be submitted to the Company for approval. A nonconformity request should identify the affected items(s) by name and serial number (if applicable), citing the

drawing/specification number and revision number containing the specific requirement that has not been met. The Seller or the Seller's supplier may attach a description of the cause, and a corrective action plan and schedule if pertinent.

Note: The issuance and acceptance of such a request does not limit or affect the warranty provision of the Agreement. Such a request shall not establish a precedent or obligation to accept existing or future items not conforming to all provisions of the Agreement.

6.2 Seller's Requested Deviations

The Seller may propose deviations from the specifications, drawings, or other technical requirements of this procurement. Where time is a consideration, the Seller may communicate the proposed deviations or changes directly to the Company's principal engineer or technical lead with a copy to the Company's buyer. The engineer or technical lead will evaluate the technical aspects and recommend to the buyer, who will communicate acceptance or disapproval to the Seller. The request should identify the affected items, drawing/specification number and revision number, a description of the proposed deviation, and the justification for it.

7.0 Schedule

The pump system design, fabrication, and acceptance testing shall be completed 20 weeks after subcontract award. Delivery to ORNL shall take place immediately thereafter.

8.0 Packing, Shipping and Handling

The pump system assembly(ies) shall be packed for truck shipping, and shipped via dedicated-truck transport.

8.1 Equipment Identification

Each major assembly or component shall be tagged indicating the Seller's name and address, the Seller's equipment identification information, date of manufacture, and Company information as shown below:

Seller name and address
Seller equipment identification number
Date of manufacture

UT-Battelle, LLC
ORNL, High Power Hg Target Experiment
Oak Ridge, TN 37830
Specification No.203-HJT-9000

9.0 Documentation

Seller-supplied documentation shall be provided according to the schedule shown in Table 1. Wherever feasible, all documentation shall be submitted in an electronic format acceptable to the Company, in addition to any other formats. Adobe Portable Document Format (PDF) and Microsoft Word are examples of acceptable formats.

Table 1. Document Submission Schedule

Item Description	Specification Paragraph	Seller's Submittal Date	No. of Copies*	Company Approval Required
Assembly & Fabrication Dwgs, Seller Catalog Info	4.4	30 days after award	2	Yes
Parts List & Calculations	4.4	30 days after award	2	Yes
Quality Assurance Program	6.0	30 days after award	1	Yes
Test and Inspection Plan	5.0	30 days after award	1	Yes
Operating, and Maintenance Manual	4.4	Prior to shipment	3	No
Final Inspection and Test Reports	5.1	Prior to shipment	1	No

*Multiple copies not required if documents submitted electronically

10.0 Hydraulic Schematic

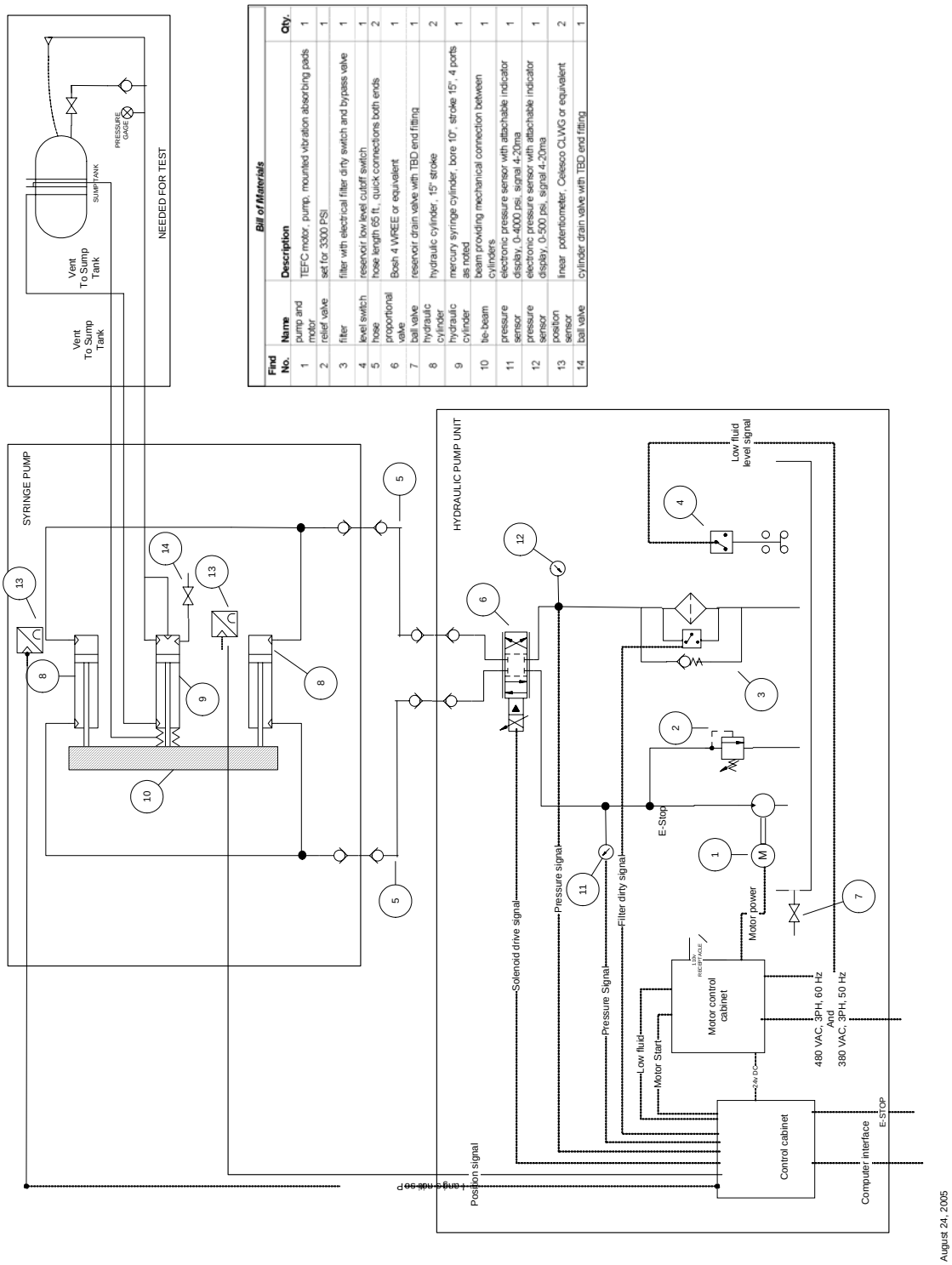

Fig. 5. Syringe Pump Schematic