LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

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Gas Atomization Equipment Statement of Work and Specification for Engineering design, Fabrication, Testing, and Installation

T. Boutaleb, T. P. Pluschkell

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Disclaimer

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LAWRENCE LIVERMORE NATIONAL LABORATORY

Gas Atomization Equipment

Statement of Work and Specification for Engineering design, Fabrication, Testing, and Installation

Prepared by:

Tewfik Boutaleb, P.E.

Thomas Pluschkell

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1. Introduction

The Gas Atomization Equipment will be used to fabricate metallic powder suitable for Powder Bed Fusion additive Manufacturing material to support Lawrence Livermore National Laboratory (LLNL) research and development. The project will modernize our capabilities to develop spherical reactive, refractory, and radioactive powders in the 10-75 µm diameter size range at LLNL. ***The Gas Atomization Equipment***, hereafter referred to as the ***"Equipment"***, will be installed at LLNL Complex. The Equipment consists of modular steel structures, atomization processing equipment, piping, instrumentation, and related support equipment as detailed under the system description herein. The performance characteristics and fielding constraints define a unique set of requirements for the system. This document presents the statement of work, design, testing, and installation.

1.1. Scope

This Statement of Work (SOW) and Specification defines the requirements to perform engineering design, fabrication, system integration, testing, and installation of modular assemblies of the Equipment at LLNL Complex.

The Subcontractor **"Arcast"** shall develop the preliminary and detailed design that will meet LLNLS technical, safety, quality, and operational requirements.

The Subcontractor shall provide engineering support from procurement to installation of the equipment.

The Subcontractor shall procure all materials needed, install equipment, piping, instrumentation, related structural frame supports, and perform factory acceptance testing (FAT) of the Equipment.

The Subcontractor shall also perform any design effort necessary to integrate and resolve any design conflicts necessary to support fabrication and to complete assembly, wiring interconnect for all I/O points and functional testing.

The Subcontractor shall generate and deliver design documentation necessary to define the functional requirements of the integrated control system software and hardware. Control system integration services, consisting of Programmable Logic Controller (PLC), network servers, related hardware, software products, and software development for graphical user interface (GUI).

The Subcontractor shall provide all necessary infrastructure and services to support FAT and shall provide support and facilities to host up to 6 LLNS personnel or representatives during testing.

Scope details are summarized below:

- Plan all activities necessary to satisfy this SOW
- Prepare a Project Execution Plan
- Prepare and maintain the project schedule
- Conduct a fabrication review and provide fabrication documentation
- Procure and assemble all control system remote I/O components
- Fabricate and completely wire specified control remote I/O cabinets and enclosures
- Provide I/O instrument and control database and interlock specifications for loading into PLC
- Plan, set up, and run full-system component testing, and support troubleshooting activities

- Participate in technical interchange meetings with LLNS
- Support startup and commissioning activities at LLNL

Subcontractor shall furnish specified engineering and design services, documents, specifications, reports, project management, and any other support services required, unless otherwise specified.

1.2. System Description

The Equipment consists of requirements that are listed in ***Appendix B*** of this document.

The Subcontractor shall complete engineering design services, procurement, fabrication, installation, and startup commissioning of the equipment.

2. General Information

2.1. Definitions

Conformance	Verification that parts are manufactured according to the drawings, that assemblies are assembled according to the applicable assembly drawings and specifications.
LLNS Contract Analyst	The LLNS staff member authorized to negotiate, award, and process change orders to the subcontract. Refer to the Subcontract Article entitled “Coordination and Administration.”
Design Engineer	Engineer of Record for design of the System.
Arcast Subcontractor	Organization directly supplying product to LLNS. Corresponds to the term “supplier” in ISO 9001 “Sub” contractor follows from the relationship of LLNS as prime contractor to the US DoE for management and operations of LLNL.
Supplier	Any lower tier organization, supplying material or services to Subcontractor. Corresponds to “Subcontractor” in ISO 9001
LLNL	Lawrence Livermore National Laboratory. 7000 East Avenue, Livermore CA 94550 and affiliated facilities
LLNS	Lawrence Livermore National Security, LLC. Corresponds to “customer” in ISO 9001. LLNL is managed by Lawrence Livermore National Security, LLC (LLNS).
Contract Technical Representative(s)	Named individuals, or their designees, who have authority to discuss the technical interpretation of this SOW and Specification and referenced documents.
Acceptance	Written response from LLNS that the submittal, documentation or other action is acceptable. Acceptance must be obtained before actions described by the submittal such as manufacturing, testing, cleaning, shipping or other operations may proceed.
Information	Submittals provided to LLNS for information only and do not require a written LLNS response indicating approval. However, the Subcontractor is responsible for meeting all contract requirements related to the submittal. If a submittal provided to LLNS for information indicates that contract requirements will not be met, LLNS may reject the submittal.

2.2. Acronyms

ARO After Receipt of Order

COTS Commercial Off-the-Shelf

DR Deviation Request

FAT Factory Acceptance Testing

GFE Government Furnished Equipment

GUI Graphical User Interface

LLNL Lawrence Livermore National Laboratory

LLNS Lawrence Livermore National Security

PLC Programmable Logic Controller

P&ID Piping and Instrument Diagram

PFD Process Flow Diagram

RFI Request for Information

SOW Statement of Work

NCR Non-Conformance Request

2.3. Communication with LLNS

All communication from Subcontractor to LLNL shall be directed to the Contract Analyst and the Technical Representative (others may be cc'd on electronic mail) as appropriate. The LLNS Contract Analyst and Technical Representative will redirect questions to the appropriate LLNS personnel as required. Any communication resulting in a change to work scope, delivery requirements, or pricing shall be provided exclusively by the LLNS Contract Analyst. In no case shall any communication with, or documents received from, any person other than the LLNS Contract Analyst be taken by Subcontractor as direction or modification of work scope, delivery requirements, or pricing.

2.3.1. Deviation Request (DR)

A deviation is any planned departure from Subcontractor requirements. The Subcontractor shall submit a DR for any planned deviation from any subcontract requirement. LLNS will give a written disposition before any deviation may proceed.

2.3.2. Non-Conformance Report (NCR)

A non-conformance is any violation of the subcontract requirements that has already occurred. The Subcontractor shall submit a NCR for any non-conformance from any subcontract requirement. LLNS will review the NCR and give a written disposition

2.3.3. Requests for Information (RFI)

Clarification and interpretation of requirements that are not deviations or non-conformances may be necessary. The Subcontractor shall submit a RFI via the form (See Article 1 of Purchase Order to download forms) stating the question or issue for LLNS review and response.

2.3.4. Tracking Exchanges of Information

The Subcontractor shall sequentially number each deviation request, non-conformance report, and request for information submitted. The format for each form shall be:

- Deviation Request DR-XXX
- Non-conformance Report NCR-XXX
- Request for Information RFI-XXX

In all cases, "XXX" is the sequential iteration (e.g., RFI-004). The request/report number shall be unique and non-repeating. Requests/Reports that relate to earlier reports shall have their own unique identifier. The Subcontractor shall maintain logs of DRs, NCRs, and RFIs.

2.3.5. Forms

The Subcontractor will submit DR, NCR, and RFI forms in Microsoft Word format. See Article 1 of Purchase Order to download forms.

3. Referenced Documents

3.1. Industry Standards and Specifications for Fabrication, Assembly and Construction

The following industry standard(s) are applicable to the extent referenced herein and in other referenced documents.

Code	Title
ASME B16.5	Code for Steel Pipe Flanges, Flanged Valves and Fittings
ASME B31.3	Code for Piping, Chemical Plant and Petroleum Refinery Piping
ASME Sect. VIII, Div. 1	Boiler and Pressure Vessels Code, Pressure Vessels, Rules of Construction of Pressure Vessels
AWS	American Welding Society
CBC	2016 California Building Code
NEC	National Electric Code. Class II Division 1 wiring, fixtures, process equipment and instrumentation
NRTL	Nationally Recognized Testing Laboratory
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration

4. Fabrication Requirements

4.1. Project Objective

The objective of the fabrication effort is to minimize on-site effort necessary to deploy and commission the System. To the extent practical, the System shall be preassembled, interconnected in a temporary configuration where required, and then operated to verify function and performance. Testing shall be performed according to the test plan developed by the Design Engineer and the test procedures developed by the Subcontractor. Any necessary troubleshooting to bring system operability to specified requirements shall be performed and performance re-verified. Fabrication scope of work includes those system elements which can be pre-assembled, and standalone components that are necessary to support testing of the preassemblies.

Standalone system elements (***e.g., Glove Box, future equipment, etc.***), which need not be integrated into system testing are not included in the contract scope and will not be provided to the Subcontractor. Following the completion of fabrication and testing, the system shall be match-marked (to facilitate re-assembly), disassembled, packaged in accordance with the approved packaging plan for shipment, and delivered as stipulated in contract documents.

4.2. Electrical Safety

4.2.1. Normal input power shall be 60 Hz, 208 - 520 VAC, and 3-phase power

4.2.2. The system shall include sufficient power protection to ensure that momentary interruptions of power, line transients, or line frequency fluctuations shall not cause damage to the unit or system controls

4.2.3. The system shall meet NEC, Class II, Division 1, Group E electrical safety standards

4.2.4. All specified materials shall be tested and listed, or labeled by a Nationally Recognized Testing Laboratory (NRTL), recognized by the Occupational Safety and Health Administration (OSHA) under 29 CFR 1910.7 such as, but not limited to, Underwriters Laboratories (UL).

4.2.5. All electrical equipment and installation shall meet the requirements of NFPA 70E latest version.

4.3. Structural and Seismic

Structural and nonstructural design shall meet the requirements of the 2016 California Building Code, Title 24, Part 2, Volume 1.
Site Coordinates: (LLNL) 37.681873°N, -121.768005°W
Risk Category: IV.

The structural engineering drawings and calculations shall be submitted for LLNS review and approval prior to fabrication and/or installation activities. Final drawings, specifications and calculations shall be stamped and signed by a California registered professional engineer.

4.4. Factory Assembly and Testing Requirements

4.4.1. Installation and fabrication shall be of the highest quality according to process industry standards. All components shall be new and of current manufacture.

4.4.2. Factory assembly and testing shall be performed prior to delivery of equipment to LLNL. The detailed design phase shall include plans, specifications and procedures for the independent fabrication and assembly subcontractor to build the modular equipment subsystems.

4.4.3. Testing plans and requirements shall be specified to support post-assembly testing prior to shipment to LLNL.

4.5. Pre-Installation Preparation

4.5.1. The system shall be assembled and tested prior to delivery to LLNL job site

4.5.2. All LLNL required training shall be completed prior to start of Installation

4.5.3. The detailed design phase shall include plans, specifications and how to install the Equipment at LLNL Complex

5. Work Requirements

5.1. Design Integration

The Subcontractor shall perform any design integration necessary to implement the intent of the detailed design in the fabricated and configured assemblies, and prepare and conduct acceptance testing, including but not limited to:

5.1.1. Accommodating physical installation of hardware within the modular assemblies

5.1.2. Resolving conflicts or interferences between components

5.1.3. Developing information not present in Detailed Design, but necessary for installation

5.1.4. Developing information not present in Detailed Design, but necessary for system integration

5.1.5. Engineering components or systems not part of delivered assemblies, but necessary to support acceptance testing

5.1.6. Preparation of shop drawings and submittals for review and approval of the Design Engineer

5.1.7. Review and approval of equipment and component submittals for non-GFE items

5.1.8. Review and approval of subcontractor submittals

5.2. Fabricated System Elements

The Subcontractor is responsible for the fabrication, testing and delivery of the items identified below.

5.2.1. Gas Atomizing Equipment

A structural steel frame, not to exceed 25'L x 25'W x 25'H, the stair assembly, the melt chamber, atomization chamber, atomization chamber lower cone, isolation valves, collection hopper, atomizer exhaust to cyclone, cyclone, interconnecting pipe, and instrumentation and controls (I&C) as laid out on the P&IDs.

5.3. Structural Design and Fabrication

5.3.1. The Subcontractor shall fabricate structural steel modular elements (modular frames and stairway) in accordance with the design documents. The frames shall incorporate all equipment, instrument and piping supports as detailed in the design and shall comply with the ***California Building Code (CBC)*** seismic design requirements. LLNL facility is to be classified as Risk Category IV with a seismic importance factor of 1.5. A licensed CA Professional Engineer shall sign and seal all deliverables. All structural modules and stair components shall be carbon steel, primed and epoxy painted (two coats) prior to the mounting of any equipment, instruments, panels, etc.

5.4. Component Installation

5.4.1. The Subcontractor shall install equipment, piping and instrumentation, and controls as detailed in the design documents. Any material, instrument, or equipment component not herein identified as GFE shall be procured by the Subcontractor. Installation shall be performed in accordance with supplier requirements, where provided

5.4.2. Installation and fabrication shall be of the highest quality according to process industry standards. All components shall be new and of current manufacture

5.4.3. Where possible and to the extent practical, installation shall include verification of function of the component prior to proceeding to system integration and functional testing

5.4.4. Installation tolerance shall be in accordance with AISC standards

5.4.5. Rigging of equipment components and structural steel members will be handled by LLNS crew with Subcontractor guidance

5.4.6. LLNS will perform rigging, post installed anchor bolts, and external tie-in points with the Equipment

5.4.7. Subcontractor shall make all internal connections within the Equipment system

5.4.8. Subcontractor will not be able to operate any LLNL Installation equipment

5.4.9. Subcontractor must rent its own fork lifts and scissor lifts to be used at the LLNL facility

5.5. Fabrication Documentation

5.5.1. The Subcontractor shall maintain and provide for LLNS review all fabrication records including but not limited to.

- Inspection records
- Test reports
- Equipment installation and maintenance manuals

5.5.2. The Subcontractor shall submit all above documentation to LLNS as stipulated in Section 7.1.

5.6. Controls System Fabrication and Installation

The Subcontractor shall provide, install, and verify all control elements (device, wiring, remote I/O modules) up to and including the I/O cabinet within their hardware scope of supply. The Subcontractor shall also develop and provide design documentation including, but not limited to P&IDs, I/O list, Sequence of Operation, Control System Architecture drawings, etc.

5.7. Factory Assembly, Testing and Training Requirements

The Subcontractor shall prepare and conduct acceptance testing on the assembled modules to verify function and performance.

5.7.1. Factory assembly and testing shall be performed prior to delivery of equipment to LLNL

5.7.2. The Subcontractor shall further develop the Detailed Design test plan into a specific test plan, which describes the assembly configuration and defines all steps for testing and equipment functional operation

5.7.3. The subcontractor shall provide detailed test procedures, which will be used as the basis of testing

5.7.4. Testing shall fully exercise all functions of all equipment and control elements

5.7.5. The Subcontractor shall perform all preparations and set-up necessary to configure the system for testing

5.7.6. After the successful completion of testing, the Subcontractor will provide training as required up to 6 LLNS personnel

5.7.7. Test results shall be submitted to LLNL for record

5.8. Hold Points

5.8.1. As an element of the Fabrication Plan (Section 6.1.2), the Subcontractor shall propose for LLNS approval a list of hold points within the fabrication activity. Hold points should be associated with significant or critical tests, inspections, or milestones.

5.8.2. As a minimum, the following hold points shall be identified:

- Preliminary Design Review (PDR)
- Final Design Review (FDR)
- Quality control of Steel fabrication at the shop
- Any pressure testing
- Factory Acceptance Testing
- Packaging and Shipping

5.9. Preliminary Design

The Subcontractor shall prepare a preliminary design to a point where

- All sizing calculations are complete
- All major equipment is fully specified
- Equipment arrangements including all modularization are fully defined
- Utility requirements and interfaces are fully defined
- Process Flow Diagrams – PFDs as needed to describe the processes of the equipment
- Piping and Instrument Diagrams – P&IDs shall show all process equipment and instrumentation, at a level of detail such that it can be verified that the operational objectives can be met and that safety considerations can be assessed
- General Arrangement Drawings – The General Arrangement Drawings shall depict the arrangement of equipment and working space within the building envelope defined by LLNS
- Failure Modes and Effects Analysis – A FMEA shall be generated to address potential failure, accident, and mis-operation conditions that may occur over the life of the Equipment, and identify how the effects of such occurrences are mitigated through design, control action, and or procedures. It is anticipated that after initial submittal, the FMEA will be expanded collaboratively between the Subcontractor Design Group and LLNS design and safety teams to ensure that the operation hazards of the equipment are comprehensively reviewed, and mitigations addressed
- The Subcontractor will also provide to LLNS information required to support LLNS's work in delivering the facility infrastructure to be ready for Equipment component installation

5.10. Final Design

The Subcontractor shall prepare Final Design addressing any LLNS input from the Preliminary Design Review (PDR).

The Final Design package shall include as a minimum:

- Fabrication Drawings – Documentation (structural, equipment data, location, routing, e.g.) as needed to fabricate the equipment structure, install, and connect all module components.
- Facility Installation Drawings - Documentation (arrangement, routing, anchoring, and interface drawings, e.g.) necessary to install equipment in accordance with the General Arrangement
- Instrumentation and Control Documentation – Control system documentation including hardware specifications, baseline software configuration, training material and programming instructions
- Engineering Records – Comprehensive record document, including system description, code analysis, final FMEA, and any documentation such as sizing calculations, line sizing calculations, installation plans and procedures, and commissioning plans and procedures

6. Project Management

6.1. Project Execution Plan

Subcontractor shall prepare and implement a brief Project Execution Plan for the design integration, control systems integration, fabrication, test, and training of the Equipment System. The Subcontractor shall submit its Project Execution Plan within 20 days of subcontract award. LLNS will review Subcontractor's Project Execution Plan within ten days after submittal. The Project Execution Plan should adequately cover the mentioned areas, but should not be excessively lengthy. Once accepted by LLNS, the plan shall be the basis for Subcontractor's actions pertaining to this SOW and Specification. Any unplanned substantial deviations from the plan, which might affect.
Subcontractor's performance, shall be submitted, in writing, to LLNS, before implementation. Similarly, any unplanned actions or deviations from the plan, which might have a detrimental effect on schedule or quality of deliverables, shall be submitted, in writing, to LLNS, before implementation.

The plan shall include at a minimum the following sections:

6.1.1. **Management** - The Management section shall briefly describe how the subcontract will be managed and organized, and should include:
- Listing of personnel with key technical and management responsibility;
- The level of responsibility and authority allocated to each position;
- Any other information needed to define the roles and responsibilities of key personnel.

6.1.2. **Fabrication** - The Fabrication section shall describe the manufacturing plan that the subcontractor will implement to build the Equipment. It should include:
- General procurement and fabrication plan for components
- Identification of the critical subcontractors, such as those for electrical systems

- Assembly plan
- Test plan
- Holds Points

6.1.3. **Packaging, Shipping and Installation** - The Packaging and Shipping section shall describe how the Subcontractor will package and ship the system to the LLNL site.

6.1.4. **Project Schedule** - The Subcontractor shall provide a project schedule. This schedule shall clearly identify the steps in the fabrication, integration, and testing of the Equipment System. Scheduled tasks shall be described with sufficient granularity that progress can be quantitatively tracked, reported and verified. Subcontractor's Project Schedule shall reflect, at minimum, the following milestone completion dates:

- Procurement of material
- Assembly and verification of the Equipment system
- Control System remote I/O hardware assembly and wiring
- Performance testing
- Packaging and shipping

A Project Schedule shall be provided by the Subcontractor within two weeks of initiation of the Fabrication phase. The schedule shall address all activity through testing, training, and turnover. Schedule status shall be reported to LLNS on a regular basis, at least monthly.

6.1.5. **Quality Assurance (QA)** - The Subcontractor shall have a program and perform planning and related quality assurance efforts consistent with the control and assurance elements of ANSI/ASQC C1 or an equivalent. Subcontractor shall submit a QA Plan for the Equipment System subcontract as a section of the Project Management Plan. The QA Plan shall include, but is not limited to:

- The method to implement quality control of the equipment and components:
  - Identification of selected suppliers of sensitive and critical equipment,
  - Oversight of the equipment suppliers,
  - Verifying the performance of equipment,
- Documentation of verification and test results;
- Quality assurance during fabrication, assembly and installation of the equipment system.

6.2. Monthly Project Status Reports

Subcontractor shall provide a brief written Project Status Report on a monthly basis. The Project Status Report shall include, but is not limited to:

- A narrative of work performed, tasks completed, and status of contract deliverables
- Identification of problems encountered and proposed solutions, areas of concern, outstanding action items, and acceptances or approvals pending from LLNS
- The Monthly Project Status Report is expected to be brief, in bullet list or outline form, and may be sent via e-mail to LLNS Procurement Representative
- As needed weekly phone calls to go over progress

7. Deliverables

7.1. Documentation

LLNS review and acceptance or approval of plans, data, specifications, or procedures submitted by Subcontractor does not constitute acceptance of any means, methods, materials, process, or components which do not fulfill the requirements of the specification. The schedule for submittal of documentation is given below. The Subcontractor shall furnish the following documentation for LLNS approval or information as indicated herein. Documents referenced in this SOW and Specification may specify additional documentation-submittal requirements. LLNS review and acceptance or approval of documents submitted by the Subcontractor does not relieve the Subcontractor from strict compliance with this specification, the drawings and other Subcontract documents, except where explicitly approved by LLNS in writing. In addition to the required submittals, Subcontractor generated documentation shall be available for reference and review by LLNS at the fabrication site. The Subcontractor shall submit all submittals, reports and documentation to the LLNS Contract Analyst. The Subcontractor shall submit an electronic file for each document, except when stated otherwise in this document. LLNS will review and respond to submittal information in a timely manner, generally within ten days, except when stated otherwise in this document. Re-submittal shall be required for incomplete or deficient items.

Submittal	**Ref. Section**	Submittal Time & Frequency
Project Execution Plan	6.1	Within 20 days of subcontract award
Project Schedule	6.1.4	Within 20 days of subcontract award
Quality Assurance (QA) Program Plan	6.1.5	Within 20 days of subcontract award
Project Status Reports	6.2	Monthly
Engineering Calculations	5.3	At FDR
Preliminary Design Review		At PDR
Final Design Review		At FDR
Final Drawings		180 days prior to Equipment Shipment
Fabrication Documentation	5.5.1	Within 30 days of completion
Test Plan	5.7.2	60 days prior to implementation
Test Procedures	5.7.3	30 days prior to implementation
Test Records	5.5.2	Within 30 days of completion
Shipping Plan		30 days prior to shipment

Appendix A – LLNL – INSTALLATION SERVICES

1. **LLNL Training**
   Subcontractor is required to complete LLNL training necessary for a Work Authorization Level B (WAL B) installation. All required training needs to be completed prior to start of installation work.

2. **As-Built Drawings**
   Maintain one set of marked-up "as-built" drawings and specifications showing, in red ink, on-site changes to the installation documents.

3. **Installation**
   3.1. LLNL Division of Responsibility
   - LLNL shall operate equipment such as rigging, fork-lift, and scissor lift
   - LLNL shall perform tie-ins for gas lines, water lines, and power lines to the system
   - LLNL shall drill and install the post installed anchor bolts
   - LLNL shall provide access to Subcontractor to Room 1441 to complete installation
   - LLNL shall provide services such as power, water, toilets, and washing facility.

   3.2. Subcontractor Division of Responsibility

   - Subcontractor shall ensure that Safety rules are obeyed while doing work at LLNL
   - Subcontractor shall erect the steel structure and perform plumpness survey during installation
   - Subcontractor shall ensure the erected tolerance of structure is within the AISC "Code of Standard Practice for steel buildings and bridges".
   - Subcontractor is responsible to ensure the Atomization equipment and its components are adequately connected, supported, and functional
   - Subcontractor shall handle all material and equipment that do not require rigging

Developed by: Thomas Pluschkell

Appendix B – LLNL – Requirements

General Design

1. The system shall include a piston-driven tubular material feeder.
    1.1. The tube-feed system shall include ram and screw feeding options with a modular design for easy configuration transformation.
        1.1.1. The ram feed option shall include an indexable magazine feeder for loading pre-packaged, sealed cassettes into the system.
            1.1.1.1. The sealed cassettes shall be pre-loaded with feed material within an inert environment (a glove box).
        1.1.2. The screw feed option shall load loose feedstock material into the system by pushing the material into the hopper from a feed hopper.
2. The system melt chamber shall consist of a water cooled copper hearth that is connected to the end of the tubular material feeder. Two transfer plasma arcs shall be used to melt the feed material into a molten pool within the copper hearth.
    2.1. The copper hearth shall be designed such that as the molten pool grows, it pours over the lip of the copper hearth to form a molten stream of material.
    2.2. The transfer plasma arcs shall be developed by a tungsten electrode mounted in a tapered collet.
        2.2.1. The electrodes and tapered collets shall be mounted in a ball joint, allowing a full range of movement within the hearth area.
    2.3. The first plasma arc shall be used to melt the bulk material as it enters the copper hearth.
    2.4. The second plasma arc shall be used to add heat to the molten pool and stream as it flows from the edge of the hearth.
3. The system shall include free-fall atomization.
    3.1. The molten stream developed in the melt chamber shall pour through a free-fall gas-ring.
    3.2. The atomization gas shall be delivered via a free-fall die.
    3.3. The atomization gas shall be argon.
4. The system shall include a stainless steel, high vacuum atomization chamber.
5. The system shall include a 3 times redundant paramagnetic oxygen analyzer and gas control system to control the oxygen levels during or after atomization.
6. The system shall include a remote atomization cone opening device.
    6.1. The lower cone of the atomization chamber shall be attached by means of quick clamps to allow easy access for powder removal and cleaning.

6.1.1. The lower cone shall be mounted on a wheeled frame that allows it to be tipped for cleaning and inspection.

7. The system shall include six explosion rated powder removal hoppers, fitted with isolation valves.
   7.1. The powder removal hoppers shall include quick clamps.
   7.2. The powder removal hoppers shall mount to a glove box, such that the powder can be transferred between the atomizer and the glove box while remaining in a fully inert atmosphere.
8. The system atomization chamber shall vent to a high efficiency cyclone separator to remove the majority of fine powder particles.
9. The system shall include a fine-filter bank to capture any ultra-fine particulates that are not contained by the cyclone separator.
   9.1. The fine-filter bank shall be contained within a vacuum-tight chamber.
10. The basic overall dimensions of the system shall not exceed 25 feet x 25 feet x 25 feet.
11. The internal cavities of the system (including the feed tube, melt chamber, atomization chamber, cyclone separator chamber, filter banks, powder removal hoppers, and ductwork) shall have the ability to be evacuated and back-filled with argon.
   11.1. The system shall be vacuum rated.
   11.2. The system shall include a high vacuum option with the addition of a high capacity diffusion pump.
      11.2.1. The system shall achieve an ultimate vacuum of ca. 5x10-5 mbar.
      11.2.2. The system shall reach its operating vacuum level in less than 1 hour, starting from a clean, dry state.
   11.3. The system shall maintain a leak rate of less than 1×10^{-6} atm/cc/s.
12. The system shall include, at a minimum, two viewports in the atomizing section and two viewports in the melting chamber to allow for visual monitoring of melting and atomizing processes.
13. The system shall include appropriate monitoring systems within the melt and atomization chambers. These systems include, but are not limited to:
   13.1. An optical pyrometer to be used to monitor melt temperature.
   13.2. Thermocouples within the melt chamber.
   13.3. An oxygen monitoring system consisting of a 3 times redundant paramagnetic oxygen analyzer and gas control system.
   13.4. A pressure monitoring system, including mechanical gauges and pressure transducers.
14. All monitoring system data shall be logged through a PLC/ HMI.
15. All components within the system shall be cleanable such that the system can atomize different materials without cross-contamination.
   15.1. Transforming the system for a new material shall be done in a safe and timely fashion.

15.2. The system shall minimize powder traps where possible by limiting piping sections to 36 inches in length and only allowing for a maximum of one 90-degree bend for any pipe section which may be exposed to powder.

15.3. Straight groove O-ring seals and hygienic seals shall be used where possible.

15.4. All internal walls shall be constructed of polished 3 series stainless steel.

15.5. Two operators shall be able to clean out the entire system and prepare for a new material feed in 3 days, assuming standard, 8-hour work days.

16. The system computer shall have the ability to connect to a network.

16.1. The system computer shall be a stand-alone system with the ability to be networked.

16.1.1. The standard control system shall use a Siemens PLC / HMI.

17. Standard operation of the system computer shall not require administrative access.

17.1. The system computer shall allow multiple users to log in / log out.

18. The system shall have a modular design, where possible, to allow components to be easily, efficiently, and safely changed or replaced.

18.1. These components include, but are not limited to:

18.1.1. The material feed system

18.1.2. The melt chamber

18.1.3. The atomization chamber

18.1.4. The cyclone separator

18.1.5. The filter bank

18.1.6. Any plumbing within the system

18.1.7. The powder removal hoppers.

18.2. The system shall be designed to be retrofittable, to accommodate new technology which The Subcontractor develops.

18.2.1. The improved free-fall atomizing nozzle shall be retrofittable into the system should LLNS and the Subcontractor agree to terms on an NDA.

Performance

19. The system shall melt and atomize a wide range of feedstock.

19.1. The system shall accept feedstock in a variety of forms including, but not limited to, pre-alloyed materials, powders, crushed materials, and bar feedstock.

19.1.1. The system shall accept feedstock with a minimum characteristic dimension of 1.5 inches.

19.2. The system shall accept a wide variety of materials, including radioactive, refractory, and reactive metals.

19.2.1. The system shall atomize depleted uranium alloys, including U6Nb (uranium – niobium alloy with 6% Niobium by weight) and similar radioactive materials.

19.2.2. The system shall atomize Tungsten and other refractory metals.

19.2.3. The system shall atomize titanium alloys and similar reactive materials.

20. The materials and installation of the system shall minimize the interaction between the process material, carbon, and oxygen.

20.1. The atomization process shall not contribute additional carbon to the atomized material.

20.2. Aside from the intentional introduction of oxygen for passivation, the atomization process shall not contribute additional oxygen to the atomized material.

20.3. The system furnace shall be constructed with water cooled copper to prevent contamination.

21. 50% of the powder yield (by weight) shall meet the following quality requirements:

21.1. The powders shall have a minimum circularity of 0.85.

21.2. The powders shall have a minimum aspect ratio of 0.85.

21.3. The powder shall have a diameter of 10 – 75 μm.

22. The system shall prevent a powder waste stream by accepting out-of-spec powder (Requirement 21) to be recycled back into the system, re-melted, and atomized.

22.1. At least 50% (by weight) of atomizing feedstock for a given run shall be able to consist of out-of-spec powder (Requirement 21) from previous runs.

22.2. Powder recycling shall not require any intermediate steps, including the casting of ingots.

22.2.1. Loading the powder into pre-packaged, sealed cassettes is acceptable.

23. The system shall be capable of producing at least 200 cubic inches of quality powder per week, assuming a standard, 40-hour work week.

Safety

24. Ultra-fine powder particulate (<10 micron in diameter) shall be safely contained via a cyclone separator and fine filter bank.

25. The system shall be capable of safely passivating the powder in a controlled environment before removal of the powder from the system.

25.1. The bulk of the powder in the collection hopper shall have the ability to be isolated before the rest of the system undergoes controlled passivation.

26. The vacuum system shall be designed to prevent ultra-fine particulates and vapors from backfilling the system.

27. The system shall include engineered, mechanical safety solutions where possible.

27.1. These shall be backed up with switches and analogue interlocks as necessary to prevent any harmful exposure to the operator.

28. Any water systems shall include flow, pressure, and temperature interlocks to ensure safe operation.

28.1. The system shall include a closed-loop water cooling system with twin redundant pumps.

29. The system shall alert the operator if any unusual activity is detected.

30. Powder and other feedstock input into the system feeder shall remain fully enclosed within the system.
    30.1. The system shall not leak more than 0.5 cubic inches of powder during a day of standard operation.
31. The system shall not create an asphyxiation hazard within the room of operation.
32. The system shall meet a minimum short circuit current rating (SCCR) of 10 kA.
33. The system shall be tested and approved by the Nationally Recognized Testing Laboratory (NRTL) prior to delivery to LLNL.
34. All isolation valves shall have the ability to back purge the dead space in the valve body to help prevent ignition within the valve while actuating.
35. The system shall be rated for deflagration/pressure rise.
36. The equipment shall be designed in accordance to the guidance provided by the National Fire Protection Agency (NFPA). Assume Aluminum as the worst-case material feedstock.

Miscellaneous

37. All repairs, troubleshooting, and upgrades shall be performed at LLNL by appropriately trained LLNS employees.
    37.1. No data-storing components will be sent off the LLNL site.
38. The system shall be delivered with full operation/instruction manuals in English and the Subcontractor shall provide sufficient training at the LLNL facility so that LLNS operators and maintenance staff can effectively use and maintain the machine.
39. The Subcontractor shall submit a machine maintenance schedule.
40. The Subcontractor shall provide the following spare components in quantities sufficient for two years of standard machine operation.
    40.1. Standard seals
    40.2. Electrode parts
    40.3. Spare crucible assemblies
    40.4. Gas jet assemblies
    40.5. View ports

Acceptance Testing

41. The Subcontractor shall complete a factory acceptance runoff at their facility to demonstrate the capabilities of the machine.
    41.1. The Subcontractor shall successfully melt and atomize Copper, Titanium, and Tungsten during the first stage of acceptance testing.
        41.1.1. The powder produced shall meet the powder quality requirements specified in Requirement 21.
        41.1.2. The powder produced shall not have elevated Carbon or Oxygen contents compared to the feed material (other than a controlled passivated oxide layer).

42. The Subcontractor shall complete a second acceptance test after the installation of the machine at LLNL's facility.

    42.1. The Subcontractor shall successfully melt and atomize copper during the second stage of acceptance testing.

        42.1.1. The powder produced shall meet the powder quality requirements specified in Requirement 21.

        42.1.2. The powder produced shall not have elevated Carbon or Oxygen contents compared to the feed material (other than a controlled passivated oxide layer).

    42.2. U6Nb atomization will not be required as part of the on-site acceptance test. However, the Subcontractor will successfully clean out the equipment and prepare the system for atomization with U6Nb. The Subcontractor shall then assist LLNS with the atomization process of U6Nb.

        42.2.1. The Subcontractor shall serve a supervisory role; they shall not handle the machine, or any equipment once contaminated.

        42.2.2. A document outlining the hazards and risks will be provided to The Subcontractor prior to converting the machine over to U6Nb.

            42.2.2.1. The Subcontractor shall determine whether they want to partake in this effort after they have read through the potential risks and hazards documentation.

Additional Subcontractor Deliverables

43 Tube Feed Plasma/Arc
44 Free Fall Gas Atomizer
45 Passivation and Remote Opening for Safe Powder Handling
46 Passivation control and remote cone opening
47 Closed Loop Water Cooling System
48 NRTL Certification