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Title:

READINESS ASSESSMENT FOR THE INSTALLMENT OF AN INDUCTION FURNACE INTO A GLOVEBOX

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Abstract: An induction furnace for melting contaminated metal parts is ready to be moved into one of the glovebox lines at the TA-55 Plutonium Facility at Los Alamos National Laboratory (LANL) after a successful completion of cold acceptance tests. The equipment qualification tests showed that the design of the furnace met the LANL Nuclear Materials Technology Division's safety requirements. A fused silica crucible with one graphite susceptor on the bottom of the crucible was quite successful for melting aluminum (Al) and stainless steel parts. The repeatability of the melting parameters was demonstrated. Al and stainless steel were melted at least three times with the same melt parameters for each material and it was shown that the same melting parameter resulted in complete melting of the materials. A number of interlocks to help ensure safety of the system were tested satisfactorily.

INTRODUCTION

A furnace for melting metal components that have been contaminated with actinide materials has been designed and fabricated at Los Alamos National Laboratory (LANL). The furnace operates on the principles of induction heating. Induction heating provides a clean, economical, and safe environment for processing materials at elevated temperatures.

The induction furnace was designed and fabricated by Engineering Sciences and Applications-Energy and Process Engineering (ESA-EPE) and will be transferred to one of the Advanced Recovery and Integrated Extraction System (ARIES) glovebox lines at NMT's Technical Area (TA)-55 Plutonium Facility after successful completion of cold acceptance tests. The furnace will be used to melt metal parts made of aluminum (Al), stainless steel, and beryllium at TA-55.

All the cold acceptance tests were conducted at the Induction Heating Laboratory at TA-46. A special mock-up glovebox was constructed, and all tests were configured to simulate operations as they will be conducted in the glovebox line at TA-55. During the tests operational parameters were developed and established, as was total system characterization, including operator training.

INDUCTION FURNACE OPERATION

The induction furnace is operated in the "cold" test mode as follows:

1. The parts to be declassified are weighed, stacked on top of each other, and loaded by hand into the crucible along with the appropriate graphite induction current susceptors as required. The crucible cover is then installed.
2. The bell jar/furnace is raised using the lift assembly.
3. The material handling system arm is pivoted over and positioned around the loaded crucible.
4. The handling arm with the crucible attached is lifted, swiveled around to the furnace center point, and lowered to place the crucible in its location on the furnace floor.
5. The handling arm is swung out of the way and lowered to its "safe" position.
6. The bell jar/furnace is then lowered back down and the pyrometer temperature sensor mounted onto the lid and aligned such that it can read the top surface of the melt.
7. The furnace chamber is evacuated and backfilled with argon to a pressure of 400 torr.
8. After setting up safety barriers around the furnace system the induction power supply is turned on using the control system and the data acquisition system is activated.
9. Observation of both the melt temperature and induction current changes is used to determine when the melt is complete.
10. At that point the induction power is turned off and the system allowed to cool for a specified time period to assure that the product temperature is below 50^{o}C before the furnace is opened.
11. The bell jar/furnace is raised using the lift assembly.
12. The handling arm is raised, swiveled into place, and positioned around the crucible.
13. The handling arm is lifted to capture the crucible, swiveled around to the staging point, lowered to release the crucible, and then swung out of the way. The arm is then lowered to its "safe" position.
14. The crucible lid is removed and the crucible is tipped onto its side so the melt puck can be removed and separated from the graphite susceptors.

RESULTS OF COLD ACCEPTANCE TESTS

Results of Equipment Qualification Tests

In the following Equipment Qualification Tests, the requirements in the Acceptance Test Plan are written in italics followed by test results in non-italics.

5.1 Perform a preliminary mechanical lift test on the furnace/bell jar lift mechanism to verify that the design will meet NMT safety requirements. Load the furnace/bell jar to at least 25 % more than the expected operation load and verify that the lift will work properly through at least three complete lift cycles with no detrimental effects on the system.

The weight of the bell jar cylinder and the induction coil was 70 lbs. The weight of the bell jar lid was 19 lbs. The weight of the coaxial lead and pyrometer was approximately 5 lbs. The weight of the aluminum bracket on top of the attached to the bell jar was 5 lbs. The volume of water held inside the feed through, bell jar cylinder, and induction coil was 2.18 gallons (18.3 lbs). Therefore, by adding these numbers, the total weight of the bell jar assembly was approximately

117.3 lbs. Twenty-five percent of the assembly weight equals 29.3 lbs (117.3 x 0.25 = 29.3 lbs). The bell jar assembly was loaded with an additional 30 lbs of material. After loading, the assembly was lifted and lowered four separate times. All connectors (pyrometer cable, waterlines, and coaxial leads) were moved up and down without any problem, performing according to expectations and subsequently passing this phase of testing.

5.2 Verify and document that the crucible handling and transfer arm fixture operates properly and can safely handle the crucible and its melt load through at least three complete cycles with the crucible loaded to at least 25 % more than the expected operational load.
5.2.1 Verify and document that the handling and transfer system can be attached to the crucible, can lift the crucible, swivel it through the designed travel path, and release it.
5.2.2 Verify and document that safety limit switches are operational and prevent lowering or raising of the furnace/bell jar without the handling and transfer system arm being stowed in the proper location.

The weight of the fused silica crucible was 22 lbs. The weight of the fused silica lid was 3 lbs. It was expected that a maximum of two graphite susceptors would be needed for melt tests: one graphite susceptor with a hole in the center on the top portion of the crucible and one graphite susceptor without a hole in the center at the bottom of the crucible. The weight of the graphite susceptor with a hole in the center was 2.5 lbs. The weight of the graphite susceptor without a hole in the center was 3 lbs. The maximum weight of the metal parts that will be loaded inside of the crucible was expected to be 20 lbs. Therefore, the total weight of the crucible transfer system was 50.5 lbs (22 + 3 + 2.5 + 3 + 20 = 50.5) at most. Twenty-five percent of the total weight equals 12.6 lbs (50.5 x 0.25 = 12.6). The crucible transfer system was loaded with an additional 13 lbs of weight, creating a total load of 63.5 lbs. When the crucible transfer system was lifted to the preset position, it fell short of the position by 1/8 inch with the motor still running. It made a humming noise, signifying to the observers that there was not enough power to manage the increased operational load. Because of this, the crucible transfer system did not pass this particular test.

At a later point, the current limit of the crucible transfer system was increased. The crucible transfer system was once again loaded with 13 lbs of additional weight (63.5 lbs total) as in the previous test. With the increase in the current limit, the crucible transfer system lifted, swiveled, and released the crucible without any problems. This test operation was performed satisfactorily three times in succession, and the crucible transfer system passed this phase of testing.

5.3 Verify and document that the vacuum and backfill system operates properly through at least three cycles of the following tests:
5.3.1 Pump down the bell jar and verify that the system maintains a vacuum of less than 10 torr for 20 minutes. Then backfill the bell jar with argon to a pressure of 400 torr and make sure the system can maintain that pressure (within ± 50 torr) for a minimum of 20 minutes. (Static vacuum/backfill test)

The furnace/bell jar assembly was pumped down to 1.0 torr. The change of vacuum level was recorded. After 42 minutes the vacuum level was changed to 2.0 torr. Then the assembly was filled with argon to a pressure of 400.0 torr. The change of vacuum level was recorded. After 20 minutes the vacuum level was changed to 399.7 torr. These results indicated that the assembly maintained pressure well, passing this phase of testing.

5.3.2 Operate the bell jar with a declass load at a temperature of (to be determined) *and backfill the system to a pressure of 400 torr with argon. Make sure the system can maintain a pressure level of 400 torr (within ± 50 torr) for at least 20 minutes. (Dynamic vacuum/backfill test)*

The bell jar was loaded with seven Al parts and the temperature was raised to 900˚C. The bell jar was backfilled with argon to a pressure of 400 torr. At 9:01 AM the vacuum level was 417 torr and at 9:21 AM the vacuum level was 399 torr. Thus the system maintained a pressure level of 400 ± 50 torr for 20 minutes. In another test, the bell jar was loaded with 15 stainless steel parts and the temperature was maintained at 1400˚C. The bell jar was backfilled with argon to a pressure of 400 torr. At 9:18 AM the vacuum level was 413 torr and after 20 minutes the vacuum level was 424 torr. Thus the system maintained a pressure level of 400 ± 50 torr for at least 20 minutes.

Results of Furnace Operation and Endurance Tests

There are two modes of vacuum pump down cycle in the control panel: Manual Mode and Auto Mode. These two modes were selected randomly to establish a vacuum. No significant difference was noticed with these modes except that the Auto Mode was more convenient to use than the Manual Mode. A vacuum level of 400 torr was established throughout the Al and stainless steel melt tests. There are two transformer taps to be selected in the control panel: 300 Volt Tap and 400 Volt Tap. The 400 Volt Tap was selected for all the Al and stainless steel melt tests. The temperature range for the pyrometer used in the furnace was 650-1800˚C.

A fused silica crucible was used for all the melt tests and miscellaneous tests. A fused silica lid was placed on top of the fused silica crucible for all the tests. There was a hole in the center of the lid. The purpose of the hole was so the pyrometer could measure the temperature of the bottom of the crucible through the hole.

A disk type graphite susceptor was used for the Al and stainless steel melt tests for better coupling in the induction field. Two types of graphite susceptors were used: susceptors with and without a hole. When the graphite susceptor was placed at the top portion of the crucible, a graphite susceptor with a hole in the center was used. The purpose of the hole was so the pyrometer could measure the temperature at the bottom of the crucible through the hole. Two wire hangers were placed on top of the fused silica crucible and then the graphite susceptor was placed on top of the wire hangers. When the graphite susceptor was placed at the bottom of the crucible, a graphite susceptor without a hole was used.

For all the tests, important test data for the PSF was collected through a data acquisition system connected to a computer. The data included time, pyrometer temperature, pressure inside of the bell jar, % voltage, % ampere, % kilowatts, cooling water flow rates (bell jar, coil/coax, heat station, and base plate), and cooling water temperatures (bell jar, coil/coax, heat station, and base plate). In this document data for only one stainless steel test are included.

After the melt test, photos of the ingots were taken for most of tests. In this document one photo for stainless steel melt tests is included.

Results of Stainless Steel Melt Tests

A total of ten stainless steel melt tests, from SS-1 to SS-10, were performed during the cold acceptance tests. The first few tests were performed in order to obtain the optimum processing parameters to melt stainless steel parts. After these parameters were obtained, the last three tests (SS-8, SS-9, and SS-10) were performed to demonstrate the repeatability of the chosen parameters.

For SS-8, a new fused silica crucible was employed. A graphite susceptor was placed in the bottom of the crucible and eight stainless steel parts were loaded into the crucible on top of the susceptor. The PID set-point temperature was 1400˚C and the process over temperature set point was 1450˚C. Automatic Heat Mode was chosen with timer set up of: Timer 1 for 100 sec @ 40 % voltage, Timer 2 for 100 sec @ 70 % voltage, and Timer 3 for 300 sec @ 90 % voltage. At 8:40 AM the power was turned on. At 8:47 AM the pyrometer started to read the temperature. At 8:49 AM the PID set point was activated. At 8:59 AM the pyrometer temperature reached 1400˚C. At 9:18 AM (38 minutes after the power was turned on) the power was turned off. At 3:00 PM the bell jar was opened. The stainless steel was completely melted.

After the melt tests, a detailed visual inspection of each ingot was performed. Detailed visual inspections showed that all the parts originally inserted into the PSF were melted and that no classified geometries or sections were visible on the surface of the ingots. Photos of the ingots were taken and are shown in Figures 1-2.

Figure 1. Front side of SS ingot after SS Melt Test #8. The graphite susceptor is seen between the two SS ingots.

Figure 2. Reverse side of SS ingot after SS Melt Test #8.

In addition to the visual inspection, cross sections of the ingots were examined. The ingots were bisected and cross sections were examined visually. No classified geometries or sections were visible on the cross sections. A photo of the cross section was taken and is shown in Figure 3.

Figure 3. Cross section of SS ingot after SS Melt Test #8.

The pyrometer temperature vs. time during the test is shown in Figure 4. The pressure inside of the bell jar vs. time during the test is shown in Figure 5. The power supply indicators vs. time during the test is shown in Figure 6. The temperatures inside of the bell jar at various locations vs.

time during the test is shown in Figure 7. The cooling water flow rate (gallons/minute) inside of the bell jar at various locations vs. time during the test is shown in Figure 8.

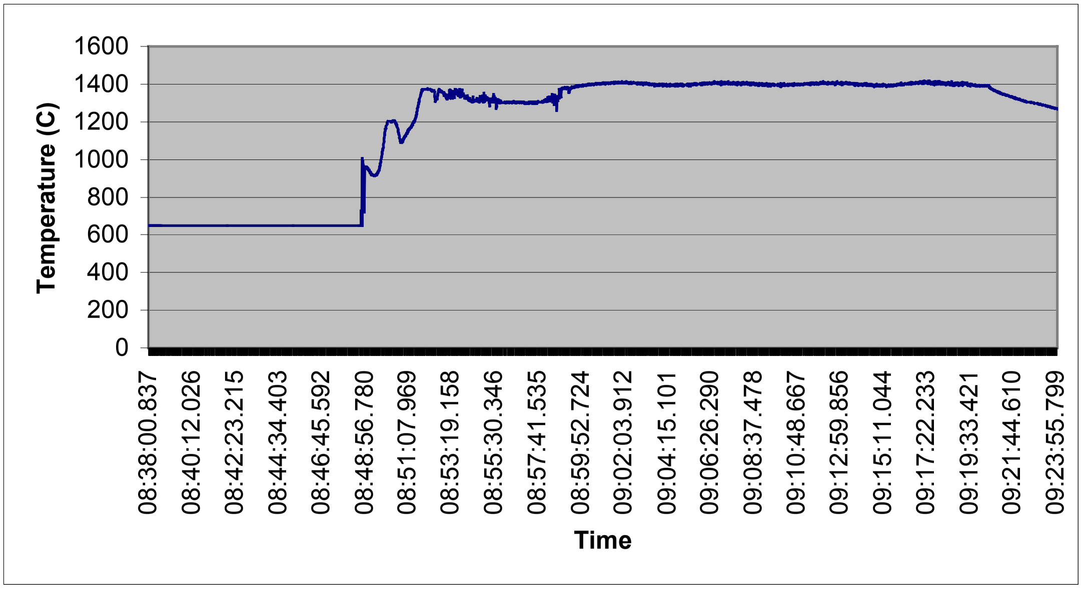

Figure 4. The pyrometer temperature vs. time for SS-8.

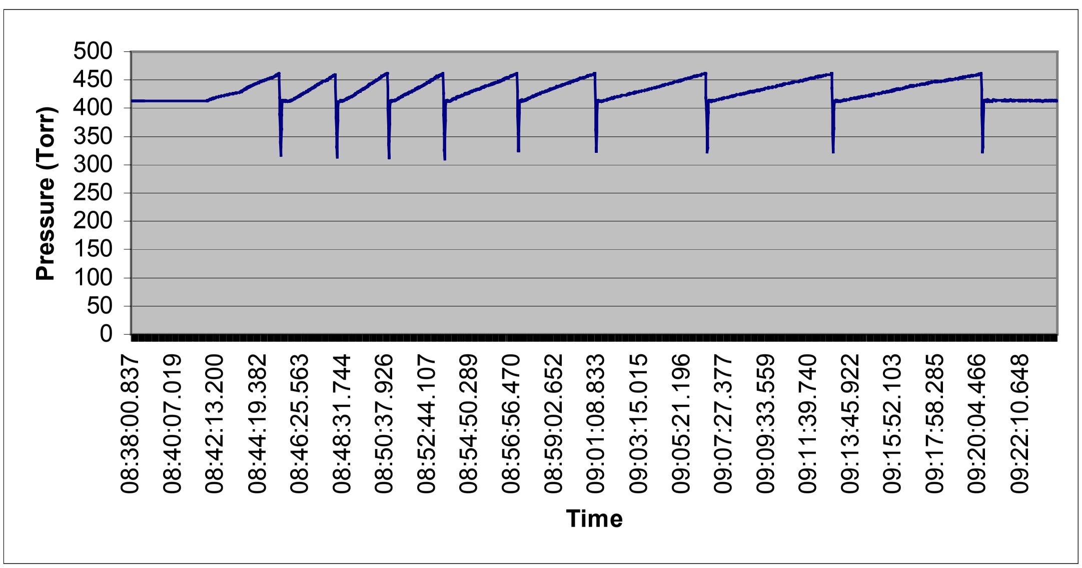

Figure 5. Pressure inside of the bell jar vs. time for SS-8.

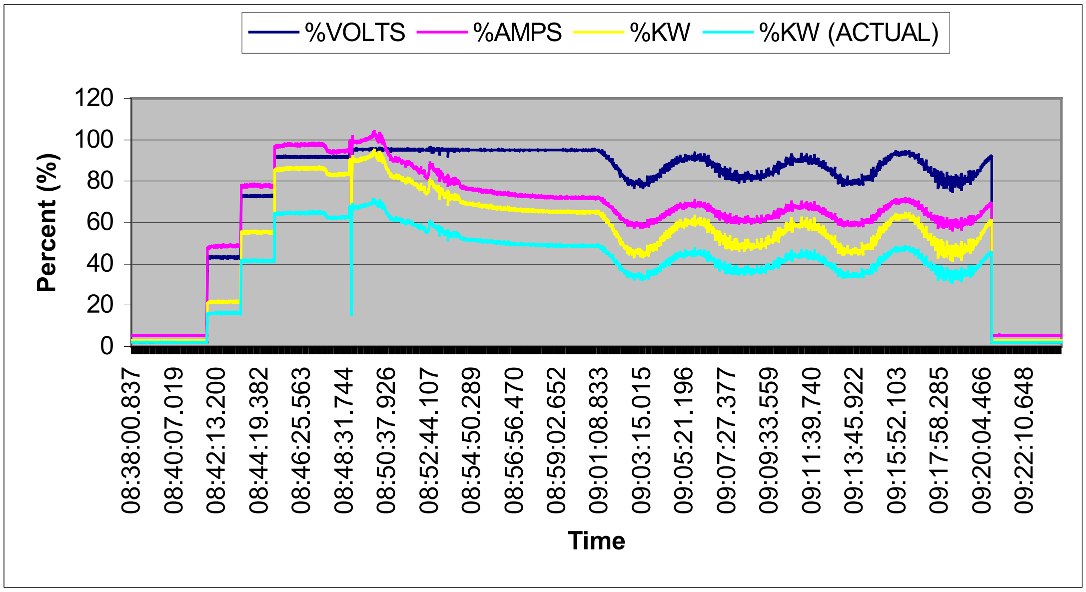

Figure 6. Power supply indicators vs. time for SS-8.

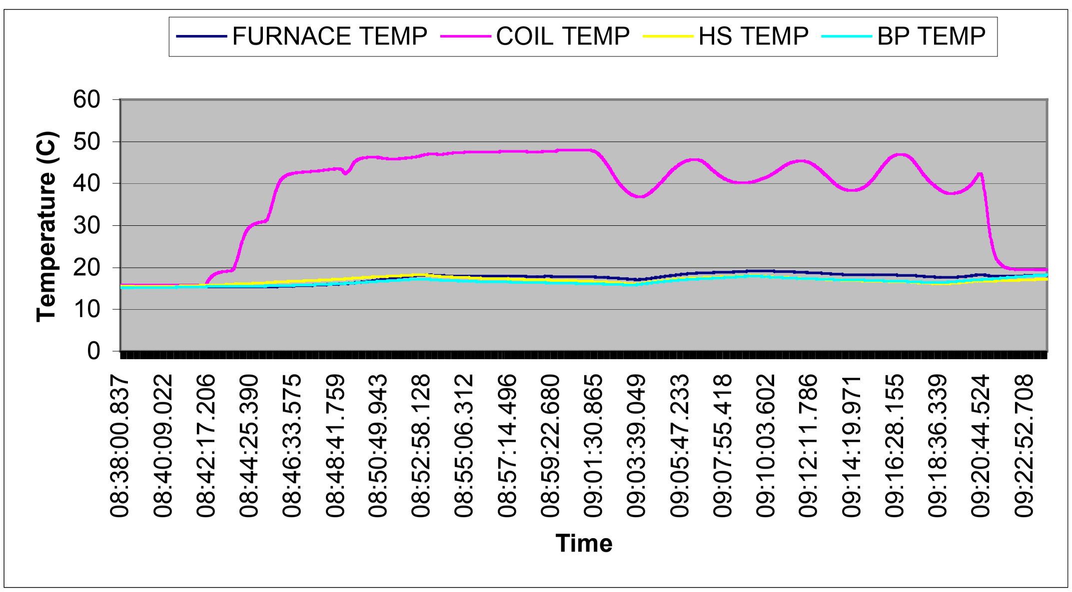

Figure 7. Temperatures inside of the bell jar at various locations vs. time for SS-8.

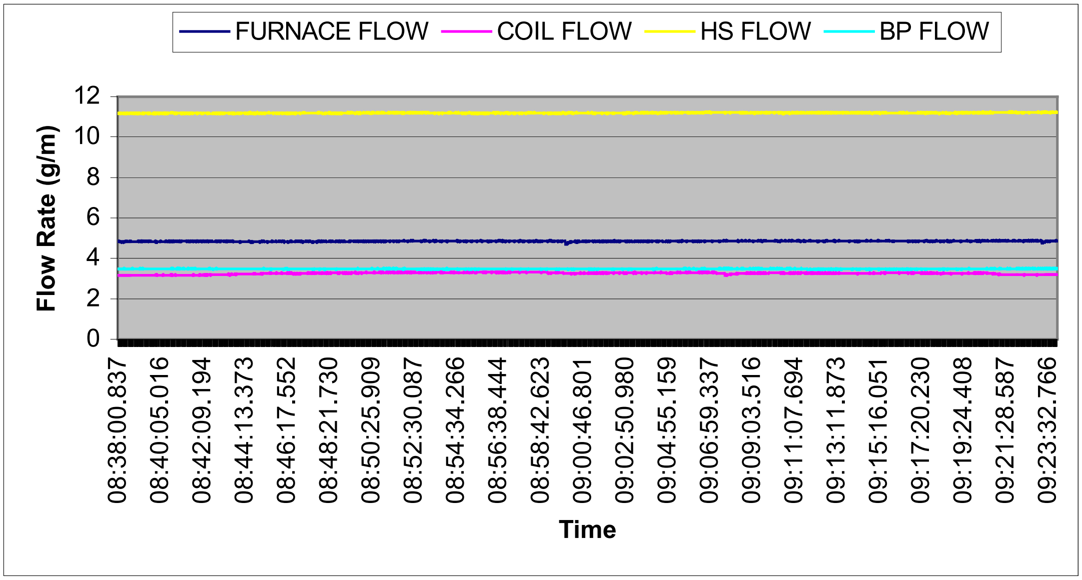

Figure 8. Cooling water flow rate (gallons/minute) inside of the bell jar at various locations vs. time for SS-8.

The same processing parameters used for SS-8 were used for SS-9 and SS-10 to show the repeatability of the chosen parameters. The results showed all the stainless steel parts were completely melted for SS-9 and SS-10. After SS-8, SS-9, and SS-10, it was concluded that the stainless steel parts could be completely melted using the following parameters: (1) Automatic Heat Mode timer set up of: Timer 1 for 100 sec @ 40 % voltage, Timer 2 for 100 sec @ 70 % voltage, and Timer 3 for 300 sec @ 90 % voltage, and (2) 38 minutes of furnace running time.

SAFETY/INTERLOCKS OF THE FURNACE

A number of interlocks are incorporated into the furnace to help ensure safety and proper operations. Some of the safety features are as follows:

If gloves are inserted into the glove box during the furnace operation, a glove sensor will be activated and the power will be shut down.

The bell jar lift mechanism will not operate: (1) if the swing arm is not in the stowed position, (2) if the bell jar is evacuated, or (3) if the crucible temperature is above 50°C.

The power supply will not operate (or shut down): (1) if the cooling water flow rate is not sufficient, (2) if the cooling water temperature is too high, (3) if there is electrical arcing or a short circuit in the system.

SYSTEM INSTALLATION INTO THE GLOVEBOX

The induction furnace will be installed into a glovebox where another system already exists. The induction furnace was designed with special consideration for the space available. A schematic diagram showing the induction furnace and the glovebox is shown in Figure 9.

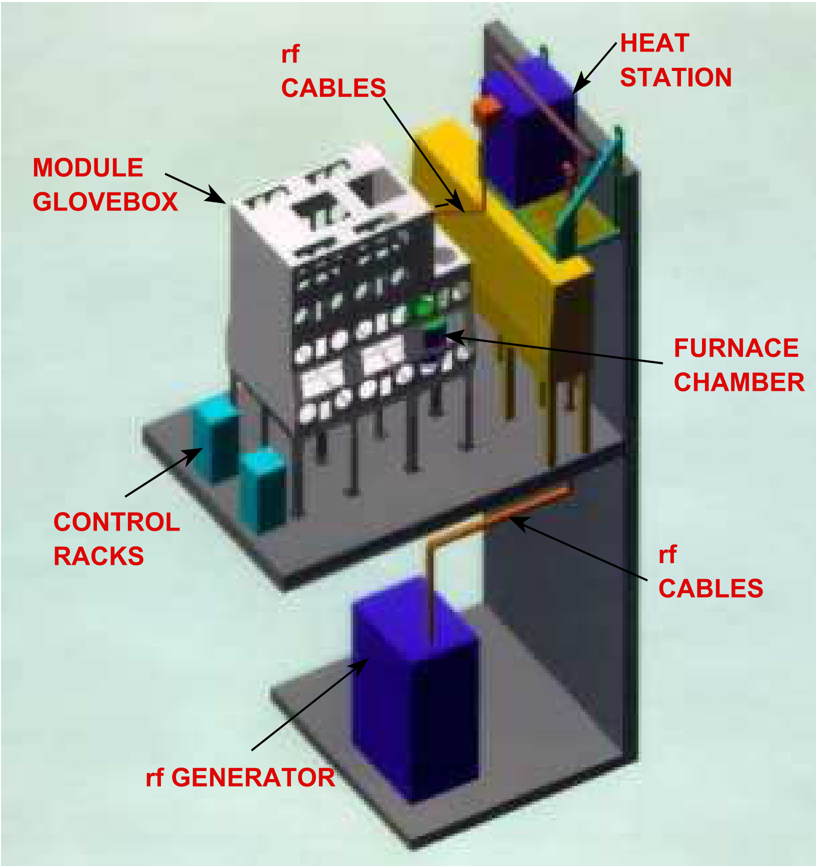

Figure 9. Schematic diagram of the induction furnace system and the glovebox.

The induction furnace system will be disassembled into many components. The disassembled components will be lowered through the openings of the glovebox. Because some of the furnace components are too large for the existing introductory port, a ceiling panel on the glovebox will be removed. A procedure for transferring the components efficiently into the glovebox will be developed with a test setup that simulates the in-plant glovebox system. Special consideration will be given for the weight and geometry of the components. A lowering mechanism will be developed and tested.

The components must be introduced as quickly as possible in order to reduce worker exposure and the spread of contamination. The glovebox must undergo special preparation. All excess items will be removed. It will be decontaminated to the lowest level possible.

The glovebox will be equipped with the appropriate utilities to operate the furnace. Power leads will be routed from the power supply in the basement to a coaxial feed through on the glovebox. Service panels on the glovebox are modified to accommodate the necessary power and signal requirements.

SUMMARY

An induction furnace for melting contaminated metal parts is ready to be moved into one of the glovebox lines at the TA-55 Plutonium Facility at Los Alamos National Laboratory (LANL) after a successful completion of cold acceptance tests. The equipment qualification tests showed that the design of the furnace met the LANL Nuclear Materials Technology Division's safety requirements. The results of equipment installation and endurance test showed that the furnace can melt Al and stainless steel parts repeatedly with chosen melt parameters. A number of interlocks to help ensure safety of the system were tested satisfactorily. A detailed plan to successfully install the furnace in to the glovebox is currently under development.