National Spherical Torus eXperiment Upgrade

NSTX-U Bakeout Upgrades

NSTX-U-RQMT-RD-015-01

1/25/18

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References

[1] NSTX-U-RQMT-GRD-001-00, NSTX-U General Requirements Document
[2] NSTX-U-RQMT-SRD-005-00, NSTX-U SRD - Auxiliary Systems
[3] NSTX-CRIT-0001-02, NSTX Structural Design Criteria
[4] ES-MECH-15, Pressure Systems Program
[5] NSTX-U-RQMT-RD-010, NSTX-U Magnetic Permeability Requirements
[6] NSTX-U-RQMT-SRD-004-00, NSTX-U SRD - Vacuum Vessel and Internal Hardware
[7] NSTX-U-RQMT-RD-003, NSTX-U Disruption Analysis Requirements

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Change Record

Revision	Date	Description of Change
0	1/3/18	Initial Release
1	1/25/18	Add MTWS Requirements in Section 6
		Added requirements on bonding jumpers in the lower vessel polar regions in section 7.
		Added reference 7.
		Added 4.1f for interface to the heat transfer plates

1. Scope

a. This document describes particular requirements for the Recovery Project work related to the bakeout systems. The particular scope items are:

- Helium piping upgrades (Section 3)
- Flow control and instrumentation (Section 4)
- He feedthrough redesign (Section 5)
- Medium Temperature Water updates (MTWS) updates. (Section 6)
- DC power to the top of NSTX-U (Section 7)

b. This document augments the requirements provided in Refs. [1,2]

2. Common Requirements

a. All components in the helium pressure loop shall be designed for the simultaneous maximum temperature (450 C) and MWAP (300 PSIG) of the helium bakeout skid.

b. All mechanical design shall be governed by Ref. [3].

c. All pressure systems shall comply with Ref. [4].

d. Permeability of materials shall be as per Ref. [5].

3. Piping Insulation Upgrade

a. All lengths of piping shall be covered with insulation, except for potentially small gaps at flanges or other features. Localized gaps in insulation shall be inaccessible to unprotected personnel and shall not impose a flammability hazard.

b. Surface temperature on outside of insulation shall be less than 160 F[1].

c. Insulation shall be installed so that the insulation is not compressed.

d. Insulation shall be jacketed where possible.

[1] ASTM C1055

4. Flow Control and Instrumentation

The addition flow control and instrumentation shall meet the following requirements:

4.1 Throttling valves

a. Throttling valves shall be installed at each He load connection (i.e. vessel feedthroughs, feedthroughs to the horizontal target heating plates, etc.).

b. Throttling valves should be designed to regulate from zero flow to full open through a variable orifice.

c. Provision shall be made to adjust the throttling valves while the systems is in bakeout operation at full rated temperature and pressure.

d. Absolute position of the valve shall be measurable and reproducible with granularity of at least 1 part in 8 of the mechanical travel.

e. The setup/teardown of throttling valve remote operator assemblies to transition between plasma and bakeout operational modes shall take a crew of 2 individuals no more than 1 shift to complete.

f. Interface to the CS heating/cooling features (i.e. heat transfer plates) shall be at the vessel side of the manifold supply valves

4.2 Flow Measurements

a. Flow measurements shall be made on the piping feeding the two ring manifolds.

b. Flow measurement instrumentation shall be able to be isolated from NSTX-U with electrical isolation consistent with the GRD (2 kV RMS AV hipot requirement) during plasma operations

c. Measurements shall measure flow rates up to 200 CFM, with an accuracy of 5 CFM.

d. The typical response time of sensors shall be equal to or less than 10 seconds.

e. All flow measurements shall be available for remote display, for instance via the HMI of the bakeout PLC or EPICs. Values shall be updated at less than or equal to two second intervals.

4.3 Temperature Measurements

a. Temperature measurements shall be installed on the piping feeding the two ring manifolds.

b. Temperature measurements shall be installed at the inlet and outlet of each He load connection.

c. Temperature measurements shall measure from 10 to 500 C, with an accuracy of 5 C.

d. The typical response time of sensors shall be equal to or less than 10 seconds.

e. All temperature measurement shall be available for remote display, for instance via the HMI of the bakeout PLC or EPICs. Values shall be updated at less than or equal to two second intervals.

f. Temperature sensor and signal processing electronics design shall permit hipot of the NSTX-U vacuum vessel as per the GRD [1] (2 kV RMS AC hipot).

5. Helium Feedthrough Redesign

a. The helium feedthroughs at the following 6 vessel flanges shall be replaced with new designs: Bay A/L Upper, Bay D Upper, Bay H Upper, Bay A/L Lower, Bay D Lower, Bay H Lower.

b. The new designs at each of 6 locations shall accommodate both He inlet and outlet feedthroughs on each vessel flange.

c. The feedthroughs shall have compliant features, such as a 6” length of braided flexible tubing, where they connect to in-vessel manifolds, to accommodate various thermal and EM load cases.

d. The feedthroughs shall have compliant features, such as a 6” length of braided flexible tubing, where they connect to external manifolds, to accommodate thermal and EM load cases.

e. Each of the 6 feedthrough locations shall have additional feedthroughs ports for up to 32 thermocouples, in order to support expansion of the internal TC deployment.

6. Medium Temperature Water System Updates

a. The Medium Temperature Water System (MTWS) shall provide temperature-regulated pressurized water to the ex-VV surface manifolds.

b. The system shall be able to heat the working fluid to a maximum temperature of 155°C.

c. The system shall be able to cool the working fluid to a minimum temperature of 20°C.

d. The system pressure shall be maintained at a minimum of 125% the vapor pressure of the water at the peak system temperature in accordance with *ASHRAE Systems and Equipment Handbook* Section 14.1 (2000).

e. The system pressure shall have a head pressure provided from a source not part of the subject system (i.e. instrument air) at 125% of the vapor pressure of the water at the peak system temperature in accordance with *ASHRAE Systems and Equipment Handbook* Section 14.1 (2000).

f. Heated water volumes shall be kept at a minimum where possible.

g. The circulation pump(s) shall be redundant. If the lead pump fails to provide flow (or trips) the control system shall automatically energize the standby pump and annunciate an alarm. If both pumps fail the bakeout system shall shutdown and an alarm shall be generated.

h. The working-fluid manifolds shall have capability for automated blow-down.

i. The heating system shall be interlocked to the working fluid pressure, temperature, and flow.
    i. If the working fluid temperature exceeds 155°C the heaters shall de-energize, the bakeout system shall shutdown, and an alarm shall be generated.
    ii. If the working fluid pressure is less than the minimum 125% of the vapor pressure at temperature[2], the heaters shall de-energize and an alarm generated.
    iii. If the working fluid pressure is less than 105% of the vapor pressure at temperature, the the heaters shall de-energize, the bakeout system shall shutdown, and an alarm shall be generated.

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[2] The vapor pressure at temperature shall be determined by either the pressure at 155°C and/or as calculated by measured temperatures.

iv. If the working fluid temperature continues to exceed 155°C and/or the minimum working fluid pressure cannot be reached after the heaters are de-energized, the working fluid manifold shall be isolated and blown down by the control system, the bakeout system shall shutdown, and an alarm shall be generated.[3]

v. The heating system shall only be permitted to operate when flow is detected in the working fluid manifold.

j. The working fluid loop shall at a minimum be instrumented for pressure (0-200 PSIG) and temperature (10-200°C) at both the supply and return. The flowrate (0-125 GPM) shall be measured at a minimum of one location in the working fluid loop.

k. Instrument values shall be incorporated into the Bakeout System operator interfaces and updated at 2 second intervals so that they may be viewed from remote operator stations.

l. Representative instrument values shall be trended and archived at a minimum of 1 minute intervals.

7. DC Power to the Top of the Machine

a. The DC power supplies shall be permanently located in order to feed DC power to connections at the top of NSTX-U.

b. This activity shall include permanent reconfiguration of the control cabling, plug-connected AC power, and water cooling hoses/tubing.

c. DC current shall be supplied to the top of the machine at the three bus connections noted in Ref. [6].

d. Inner-to-outer vessel bonding jumpers shall be installed at three locations proximal to the lower polar region in order to electrically bond the lower centerstack IBDH flange to the outer vessel wall. The bonding jumpers shall link the existing CHI inner and outer flags and be rated for the individual feed point ampacities as described in 7.e & 7.f.

e. Bonding jumpers in the lower polar region shall be designed for permanent installation, and qualified for disruption loads [7].

[3] This event response addresses the condition wherein the vacuum vessel is heating the working fluid beyond the design envelope of the system.

f. Bonding jumpers in the lower polar region shall be designed with minimal loop areas.

g. At least one bonding jumper shall have a connection to the motorized ground switch, providing switchable vessel ground.

h. Total current delivered to the CS shall be up to 8 kA.

i. DC current ampacity of individual cable or bus connections to individual feed points at the top of the machine shall be 5.3 kA.[4]

j. For non-permanent portions of the installation, the time to completely ready the system with a two person crew shall be <2 shifts.

k. At minimum, all interlocks, inputs, outputs, and interfaces from the previous implementation of the DC supply systems shall be maintained. These include the interlocks specified in Ref. [2].

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[4] 5.3 kA is derived from a ⅓ split of the 8000 kA, with a factor of 2 safety factor.