# SPALLATION NEUTRON SOURCE TARGET TEST FACILITY: PROGRESS AND ACCOMPLISHMENTS IN MERCURY OPERATIONS AND REMOTE HANDLING*

P. T. Spampinato, T. W. Burgess, V. B. Graves, T. L. Ray, S. L. Schrock
Robotics and Process Systems Division
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6304
(865)576-5267

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# SPALLATION NEUTRON SOURCE TARGET TEST FACILITY: PROGRESS AND ACCOMPLISHMENTS IN MERCURY OPERATIONS AND REMOTE HANDLING

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Oak Ridge National Laboratory, P.O. Box 2008
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## ABSTRACT

The Target Test Facility (TTF) is a full-scale replica of the mercury-target flow loop and target hot cell for the Spallation Neutron Source (SNS). The TTF is a dual-purpose facility, which is used to study thermal-hydraulic characteristics of the flow loop, to gain experience operating a large-scale mercury system, and to develop and demonstrate remote-handling operations for replacing target system components. Tests are underway to verify codes used for heat-transfer coefficients and thermal profiles, to verify calculated pressure drop and flow patterns, and to assess the use of remote maintenance procedures and tools, manipulator access to components, remote viewing, and maintenance downtime. Pump curves have already been developed, and remote handling tests so far have focused on using hydraulic and air-driven tools and various seal-leak tests. Upcoming tests will include, among others, target module remote handling and remote pump replacement. In addition, equipment upgrades are underway to incorporate prototypical components: a welded-tube heat exchanger, an electro-magnetic flow meter, and a hydraulically prototypic target, to name several.

## I. INTRODUCTION

The TTF is a full-scale replica of the SNS Target Station.[1] It is being used to investigate and assess the thermal-hydraulic characteristics of the mercury-target flow loop, to gain experience in operating the full-size mercury system, and develop and demonstrate remote-handling operations on key target system components. The TTF contains 1400 L of mercury for flow testing and has a containment enclosure[2] to meet environmental, safety, and health requirements. The enclosure was designed to match the size of the actual SNS target cell. Figure 1 is a photo of the TTF and the enclosure installed in a high bay test facility at Oak Ridge National Laboratory.

## II. BACKGROUND

Early in the SNS Project, it was recognized that research and development would be required to address mercury-flow, remote-handling, and component-maintenance issues. The TTF was therefore designed as a dual-purpose facility, which is being used to verify computer codes for heat- transfer coefficients and thermal profiles: verify the calculated pressure drop and flow patterns of the mercury target material: assess the use of remote maintenance tools, manipulator access to components, and remote viewing: and quantify the time needed to replace critical components.

Figure 1. The SNS TTF is a full-scale replica of the mercury-flow loop system.

The flow loop[3] includes a mock-up target, a 75-hp centrifugal pump, a newly installed heat exchanger, the storage tank for 1.4 $m^3$ of mercury,[4] the "shielded" target module interface, numerous pipes, couplings, valves, and various process and diagnostic sensors. [The mock-up target will be replaced with a prototypic target in early calendar year (CY) 2001.] Since there is no radioactivity

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in the TTF, shielding, where it is required to assess remote-handling constraints, will be simulated in geometry only. Remote-handling testing is being performed to verify that optimal arrangements have been configured for the various components and that all components can be replaced within the time allotted for maintenance operations. Figure 2 shows the arrangement of the flow loop and the major components.

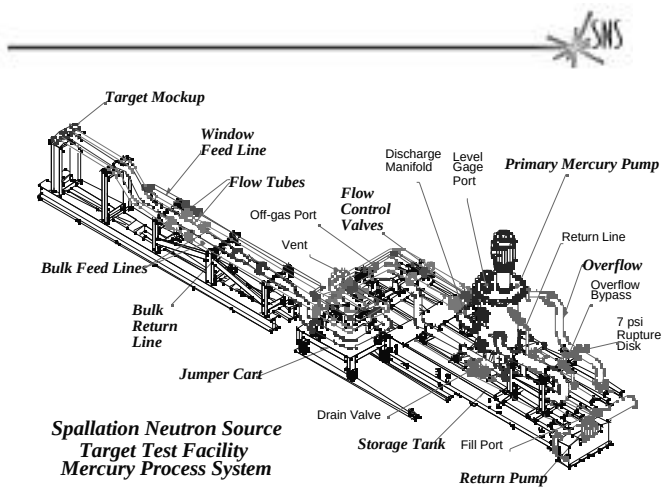


Figure 2. Mercury flow loop equipment in the TTF.

## III. FLOW TESTS

The nominal operating parameters in the flow loop are: mercury flow rate is 1430 L/mine (380 gal/m), at 310 kilopascals (45 psi), at 38ºC. The flow tests that have been performed (Phase 1 tests) include: (a) pump characterization, (b) pump-heat input to the mercury, (c) target window-flow characteristics, and (d) induced bulk-flow imbalance characteristics. These tests have provided feedback to the SNS design team on the operating experience of the system (i.e., startup and shutdown), in addition to the data collected. Figure 3 shows the pump characterization curve for pressure drop vs flow.

Phase 2 flow tests are scheduled to begin early in CY 2001, after several equipment upgrades are completed. A hydraulically prototypic target will be installed to replace the mock-up target. The new target will contain the proper flow channels and restrictions, but not the mechanical features such as seals and bolts: hence, it will not be used for remote-handling tests. A reduced-scale, prototypic heat exchanger has already been installed and is being used to verify a double-wall, welded-tube design and to allow unlimited operating time for flow tests in the TTF. (Previously, flow operations were limited to 1 h because of the temperature rise in the mercury from the pump energy.) Other equipment to be installed includes: an electromagnetic flow meter, a prototypic drain valve, a target window-flow experiment station, and a remotely replaceable pressure sensor.

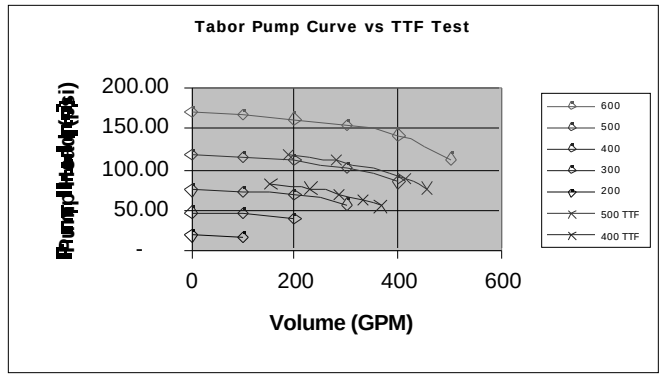


Figure 3. Pump-curve characteristics.

## IV. MANIPULATOR OPERATIONS

A pair of Central Research Laboratory (CRL) Model F manipulators mounted to a movable platform are the basis for remote-handling tests. The platform includes a simulated 1-m-thick shield window and target-cell wall for remote maintenance tests. The tests are being conducted to ensure that the designs of key components in the target cell are amenable to remote handling. Figure 4 shows the CRL manipulators installed at the east wall of the TTF enclosure for operations on the target module.

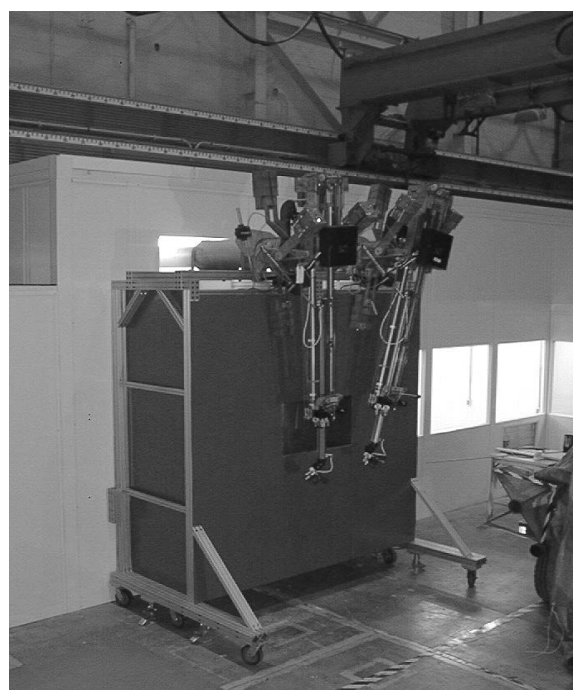

Figure 4. Through-the-wall manipulator work station.

Remote operations on components that cannot be reached by the wall manipulators require using an overhead bridge-mounted manipulator. Currently, a PaR 3000 power arm is being used. However, in January 2001, a Telemate® master-slave manipulator will be installed to replace of the power arm. Figure 5 is a photo of the Telemate® system with the control station shown in the background. Maintenance on components such as the primary mercury pump and the transfer pump shown in Figure 2 will require overhead operations.

A number of remote-handling tests with small tools and pipe connectors have already been completed.[5–7] These focused primarily on manipulator handling of hydraulic and air-driven tools, use of the tools on components in the target cell, cable management, and preliminary remote viewing studies with wall-mounted cameras. Figure 6 shows the through-the-wall manipulators handling a hydraulic wrench.

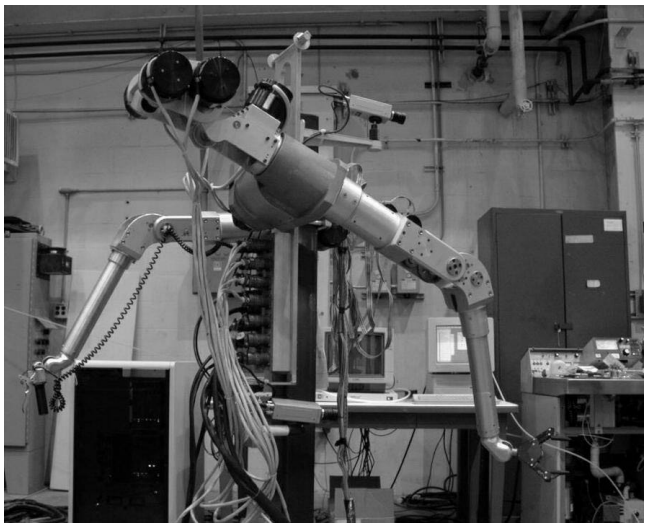

Figure 5. Telemate® master-slave manipulator system.

## V. SEAL TESTS

Several other tests were carried out over the past year that were not specific to mercury operations or remote handling, but are important enough to include. The first dealt with the original target-seal configuration. The tests were designed to assess sealing integrity of a series of non-circular, concentric metal seals and to quantify the amount of torque needed to activate the seals. Figure 7 shows the arrangement of the seals. It was determined that this design could not work because the inner seals could not be properly compressed without warping the plate structure that supported the target. Furthermore, it was shown that the vertical orientation of the seals was not amenable to remote handling.

Figure 6. Manipulator handling of a hydraulic wrench.

As a result, the target-seal interface was redesigned to be horizontally oriented and the seals were configured to be circular with smaller diameters. The tests for the new design include assessing bolt-torque values, nitrogen-gas pressurization, and helium-leakage tests. They are scheduled to begin in late November 2000. Figure 8 is a sketch of the new test fixture. (The turnbuckle is used to simulate the weight of mercury in the target module.)

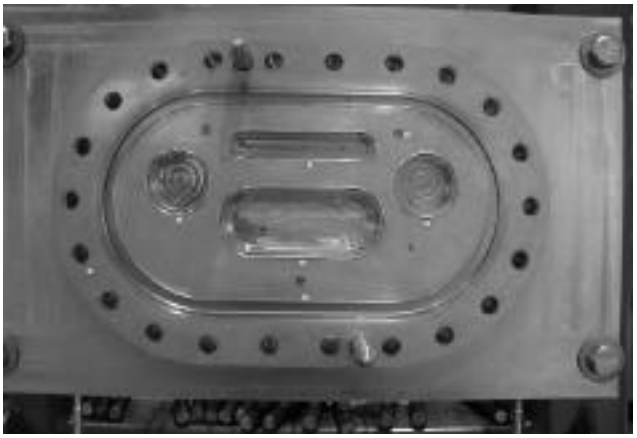

Figure 7. The original design for the target-seal test.

Several remote-handling tests were performed in conjunction with the design of the new seal configuration. The tests used a wooden mock-up of the target-seal interface and various pipe jumpers to validate the new arrangement of bolts and to ensure that remotely operated tools could be used. Figure 9 shows the mock-up of the target-seal jumper configuration.

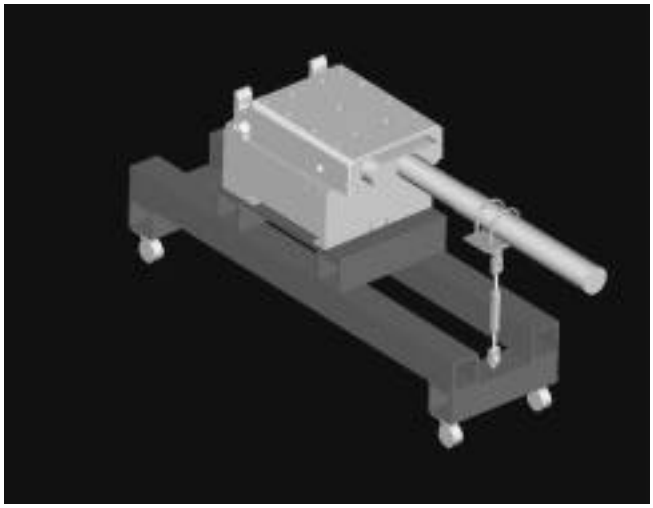

Figure 8. Target-seal test: new configuration.

Figure 9. Target-seal jumper mock-up.

## VI. NEXT STEPS

A number of tests are planned for fiscal year 2001 that go beyond the scope of the target cell and related mercury-flow equipment. These will be done on full-scale test stands outside of the TTF enclosure and they are designed to address remote handling of other-than-target components. They include: remote-handling and seal-integrity tests for the target and target jumpers, the target inflatable seal, the proton-beam-window inflatable seal, replacement of the mercury-circulation pump, and replacement of various process instrumentation. Figure 10 is a sketch of the Design Validation Test Stand, where most of these tests will be performed in the latter part of 2001.

## VII. CONCLUSIONS

A full-scale replica of the SNS Target Station is being used to study thermal-hydraulic characteristics of the flow loop, gain experience operating a large-scale mercury system, and develop and demonstrate remote-handling operations for replacing target system components. Tests are underway to verify the codes used for heat-transfer coefficients and thermal profiles, to verify calculated pressure drop and flow patterns, and to assess the use of remote maintenance procedures and tools, manipulator access to components, remote viewing, and maintenance downtime. Pump curves have already been developed, and remote handling tests so far have focused on using hydraulic and air-driven tools, and various seal leak tests. Major upcoming tests are target-module remote handling and remote pump replacement. In addition, equipment upgrades are underway to incorporate prototypical components, namely, a welded tube heat exchanger, an electromagnetic flow meter, and a hydraulically prototypic target.

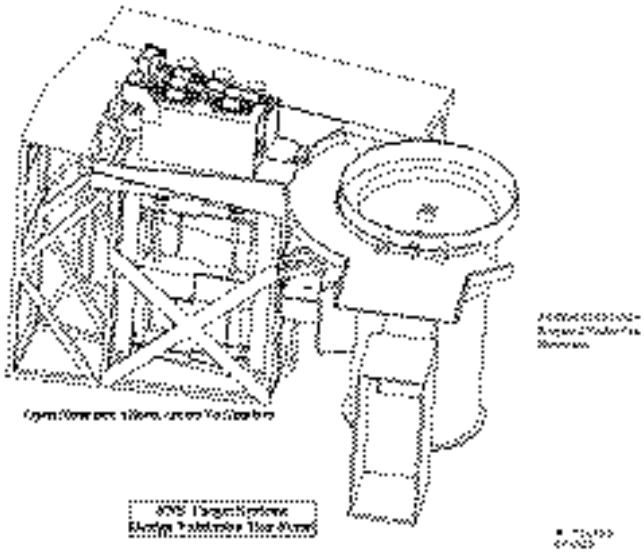

Figure 10. The design validation test stand.

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