

Portable Manipulator Systems for Remote Maintenance at the ORNL Spallation Neutron Source Project

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Abstract – Early in calendar year 2004, TPG Applied Technology will deliver two manipulator systems to the Spallation Neutron Source (SNS) project in Oak Ridge, Tennessee, for use as remote maintenance systems when the SNS becomes operational in 2006. One of these manipulator systems will be a boom system mounted on a pedestal with a dual-arm dexterous manipulator mounted on the end of the stick. The other manipulator system will be a modified mini excavator with a single-arm dexterous manipulator mounted on the end of the stick. This paper describes in detail the design of the two systems and the remote maintenance tasks for which they are intended. The SNS is an accelerator-based neutron-scattering facility that will provide the world's most powerful neutron beams for conducting material science research.

I. INTRODUCTION

The SNS project, located at Oak Ridge National Laboratory in Oak Ridge, Tennessee, is a partnership involving six U.S. Department of Energy (DOE) national laboratories in the design and construction of the most powerful spallation source in the world for neutron-scattering research and development. The accelerator system consists of an ion source, a linear accelerator (linac), and an accumulator ring, which combine to produce short, powerful pulses of protons. These proton pulses are fired onto a mercury target which expels neutrons through a spallation nuclear process. These neutrons are collected into a beam that is aimed upon the material target. The instruments at the SNS, such as neutron spectrometers, will be used to determine the positions, or arrangements, of atoms in crystals, ceramics, superconductors, and proteins within the target material.

To minimize the exposure of personnel to radiation, routine maintenance will be performed with remote handling equipment. TPG Applied Technology was contracted to develop two manipulator systems for such a purpose. One of these, the pedestal-mounted boom system, will be mounted above the target cell area; and the second, the mobile system, will be portable within the facility. Through the utilization of these two systems, SNS maintenance staff will perform maintenance tasks in restricted radiation areas without risk to personnel.

II. SYSTEM DESCRIPTIONS

II.A. Pedestal-Mounted Boom System

The SNS requires a boom system that can reach out from floor level and down into the target vessel region (Figure 1) for performing remote maintenance and repair of equipment in this radiation environment. The reach of the system is approximately 20 ft horizontal, and 10 ft below floor level. Also critical is the lift capacity and rigidity of the system when the boom is fully extended.

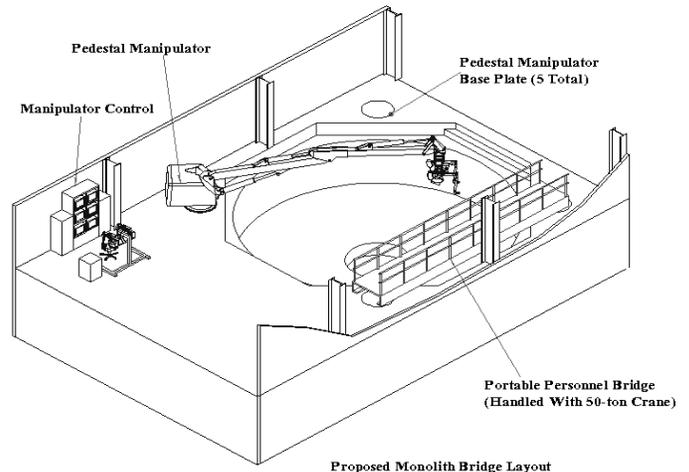


Fig. 1. Target vessel pit.

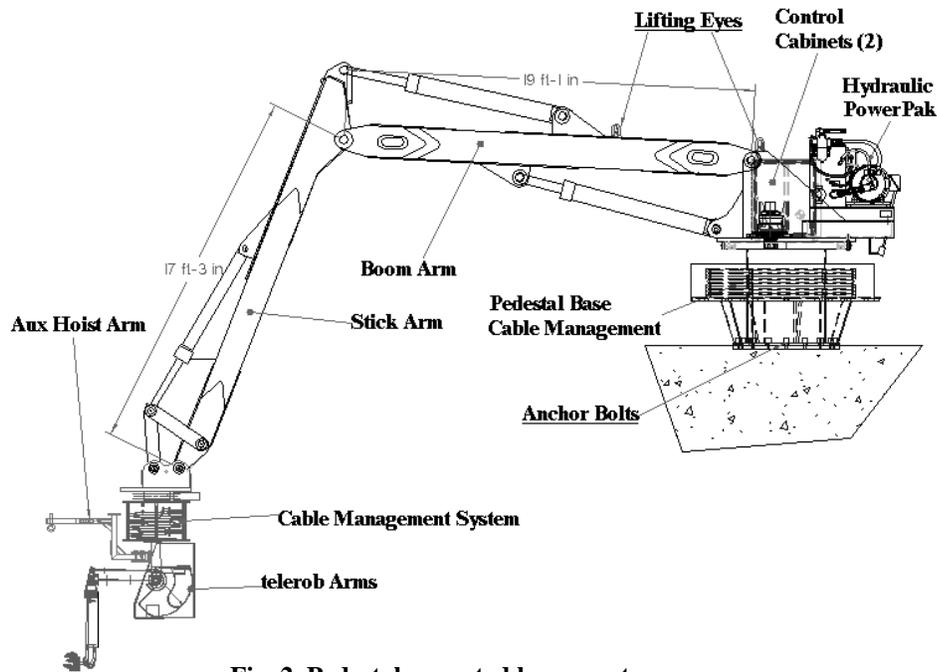


Fig. 2. Pedestal-mounted boom system.

The boom arm must be stiff—that is, noncompliant—and free from backlash so as to remain still during maintenance activities. Compliance or backlash requires the operator to slow down to avoid exciting the boom tip motion, which would make remote operations difficult.

The basic operating parameters for the system are as follows:

Boom capacity w/ hoist	1500 lb
Boom tip travel speed	variable (0.25–5 ips)
Horizontal extension	340 in.
Vertical extension	200 in. above floor
Vertical extension	110 in. below floor
Interface joint pitch	variable (0.5–5°/s)
Turret rotation	variable ($\pm 150^\circ$)
Turret slew rate	variable (0.5–5°/s)

To meet the reach and lift capacity requirements, TPG selected a conventional boom system offered by Allied Construction Products, Inc., and modified the design to include a multifunctional pedestal base, radio remote control, and a tethered hand controller. The pedestal incorporates the hydraulic power system, the hydraulic reservoir and spill pan, power distribution and control cabinets, and the tether/cable management system (Figure 2). Because the target area must be kept clear of hydraulic fluids, TPG worked with Allied to redesign the spill pan. To further minimize the risk, Quintolubric 888, an environmentally safe hydraulic fluid, is utilized in system operations. The pedestal-mounted boom system includes four degrees of freedom, pedestal rotation, boom

pitch, stick pitch, and tool plate pitch. This movement allows proper gross positioning of the servomanipulators near the work area.

II.A.1. Cable Management

The design of the pedestal system offered two unique challenges as relates to cable management. The first issue was managing cable through the base, since the typical options were not valid when combined with the 300° of rotation and the vast number of control signal cables required for the servomanipulators. Also, the boom system is designed so that the entire pedestal-mounted assembly can be moved to any of five installation points in the high bay area using an overhead bridge crane: four around the target vessel region and one in a maintenance position. Cable management is achieved through modification to an existing cable-management flexible tray system provided by KabelSchlepp to both properly manage the cable flex and protect the cable from damage. The keys to the selection of the KabelSchlepp system were its ability to manage the flex in both directions through a unique hinge design and mounting the track for operation in a rotating orientation. A support mechanism was added to the pedestal base along with a shroud cover and guide channel for protection and management of the cable track movement. Figure 3 shows the pedestal base and cable track system.

The second area of concern was the boom tip, as this unit also has a 300° freedom of rotation. This rotation is defined as a yaw motion and required that the entire

interface package be capable of this movement. Because of the large number and relative size of the control cables required for the servomanipulators, along with the auxiliary hoist, lighting, the camera, and a dedicated tooling circuit, TPG designed a cable management device to accommodate the number of cables while minimizing binding and allowing for adequate rotation. Also part of the design is the structural requirement that the servomanipulator arms and associated auxiliary equipment be supported from this device. Due to the many positions the system can operate, detailed engineering was required to assure that the system would be fully functional in all positions. A servomotor with worm drive system provides both positioning resolution and required torque. Figure 4 shows the cable housing area of the boom tip management system. This cable housing mounts directly below the TPG-designed interface package that attaches to the boom arm tool plate.

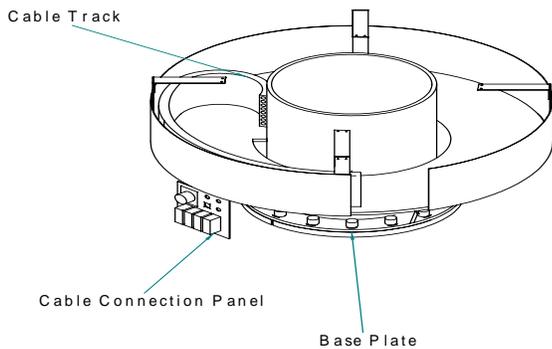


Fig. 3. Pedestal cable management system.

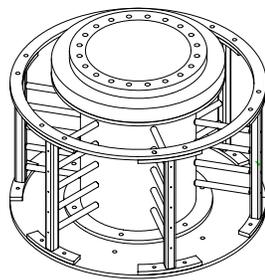


Fig. 4. Boom tip cable management.

II.A.2. Telerob Servomanipulator

A pair of Telerob EMSM 2B servomanipulator arms can be attached to the interface package as well as an auxiliary hoist, as shown in Figure 5. The boom system will be used for gross positioning of the Telerob arms. Fine positioning of the manipulator end-effector (EE) will then be achieved by using the rotation of the interface package and the range of motion inherent in the two

Telerob arms. These arms are controlled from a remotely located control room, which houses both the master control arms and the auxiliary system controls including the camera operating system.

II.A.3. System Controls

Operation of the pedestal system will involve both line-of-sight and remote operation through the use of video cameras. The overall pedestal boom system has three distinct control systems for completely operating the system: the Telerob servomanipulators, hydraulic boom positioning, and video. The Telerob servomanipulator control is virtually a stand-alone system provided with the servomanipulator arms by Telerob. For this reason, no description of the Telerob controls is provided in this document.

TPG designed the control for the hydraulic system and auxiliary components on the pedestal. Either radio remote or a hard-wired tether controls all functions, including HPU control, boom positioning, yaw joint rotation, the auxiliary hoist, the tooling circuit, and lighting. Figure 6 represents the Hetriconic radio remote control station provided for system control.

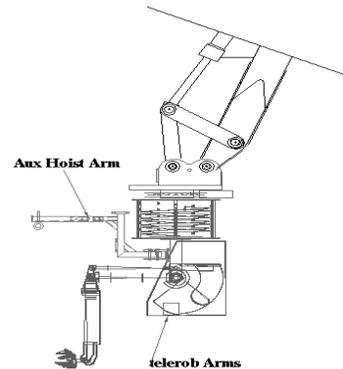


Fig. 5. Boom tip assembly.



Fig. 6. Hetriconic radio remote station.

Operators will control gross boom movement functions independent of the servomanipulators. Once the gross positioning is complete, the operator switches to the control room station for performance of maintenance

tasks. However, because there are boom tip functions required during task performance, the system control includes operator controls within the control room for functions including the servomanipulator yaw joint rotation and auxiliary component operation. TPG incorporated these functions into the camera control station (Figure 7), which is provided by IST Corporation, to minimize the number of control stations required in the equipment room.

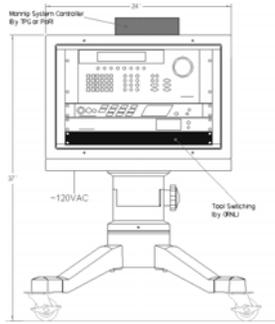


Fig. 7. IST/TPG control station.

II.A.4. Boom Tip Attachments

A “quick” disconnect device allows operators to interchange between the servomanipulator and a chain hoist EE. When using the servomanipulator arms, either a single arm or both arms can be attached. This is accompanied by an auxiliary hoist, which is used to assist in locating maintenance and/or repair equipment and material into the work location. When larger payloads are required, the servomanipulator arms can be removed and

placed on a storage stand. The operator then utilizes the chain hoist EE, which allows crane-type operations. The auxiliary hoist has a capacity of 250 lb, while the EE has a capacity of 1000 lb.

II.B. Mobile System

A variety of remote maintenance tasks must be performed in other rooms and bay areas of the SNS target facility. A small mobile vehicle (Figure 8) with onboard manipulation capability is required to access the equipment in these areas. TPG selected a Schaeff-Terex HR-12 mini excavator as the mobility platform primarily because the tracks can be retracted for driving through doorways and then extended at the work site to form a more stable base. Another criterion that led to use of the HR-12 was its reach to weight capability. The vehicle has a boom-style arm similar to the pedestal boom system but with an overall reach of approximately 12 ft horizontally and 5 ft below floor level. The basic minimal operating parameters for the system are as follows:

Boom capacity w/ hoist	500 lb
Boom tip travel speed	Variable (0.25–5 ips)
Horizontal extension	100 in.
Vertical extension	90 in. above floor
Vertical extension	80 in. below floor
Interface joint pitch	Variable (0.5–5°/s)
Interface joint yaw	Variable (0.5–5°/s)
Turret rotation	Variable (±150°)
Turret slew rate	Variable (0.5–5°/s)
Travel speed	Variable (5–50 ft/min)
Maximum travel width	39 in.
Minimum ground clearance	6 in.

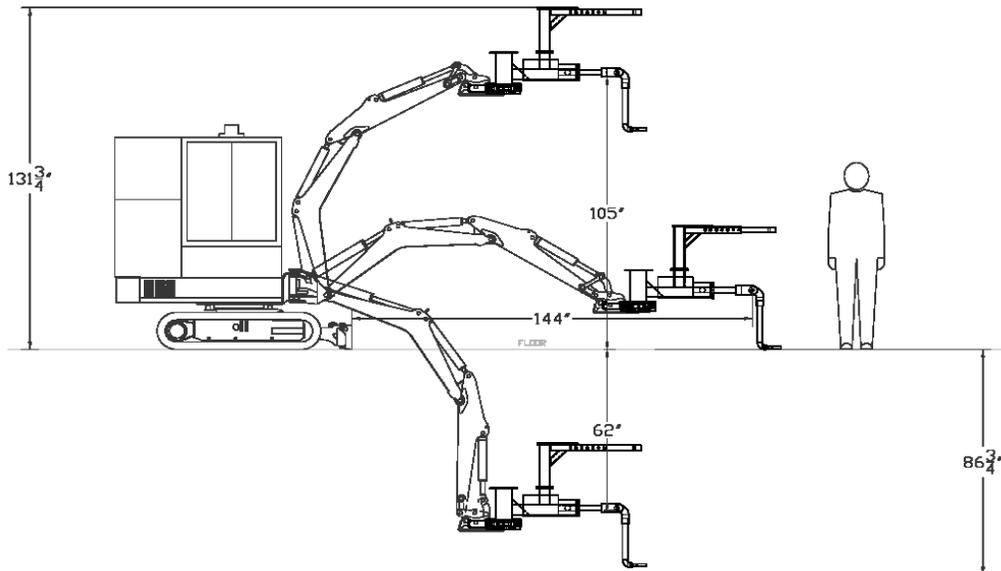


Fig. 8. Mobile system.

II.B.1 .Hydraulic Power

TPG worked with Schaeff-Terex Corporation to modify the HR-12 design to use an electrically driven motor rather than a diesel motor and then redesigned the chassis area to incorporate power and control cabinets in a compact package. This was accomplished through removal of the operator cab and hand controls. Locating this equipment on the mobile unit minimizes the number of control signals required from the off-board control interface. Also, as with the pedestal-mounted system, the spill pan was redesigned and Quintolubric 888, an environmentally safe hydraulic fluid, is utilized in system operations to minimize the spill risk.

II.B.2. Telemate Servomanipulator

ORNL is providing a single Telemate servo-manipulator arm that can be attached to the interface package, while TPG is integrating an auxiliary hoist as shown in Figure 9. The boom system will be used for gross positioning of the Telemate arm. Fine positioning of the manipulator EE will then be achieved using the rotation of the interface package and the range of motion inherent in the Telemate arm. These arms are controlled from a portable control station, which holds the master control arm, auxiliary system controls, and the camera station.

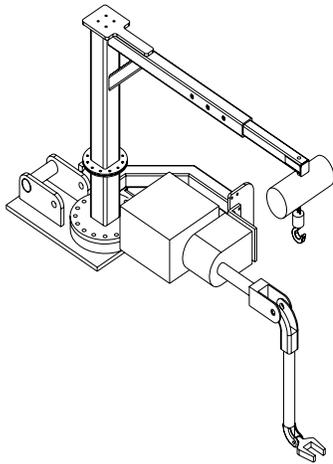


Fig. 9. Boom tip package.

II.B.3. System Controls

As with the pedestal boom system, the mobile system has three distinct control systems for completely operating the overall pedestal-mounted boom system: the Telemate servomanipulators, vehicle positioning, and the camera. The video camera and manipulator control cables

will be connected to a rolling control station that allows the operator to be up to 150 ft from the vehicle. The Telemate control system is a self-contained system which effectively operates independently of the vehicle and camera systems. The vehicle has full functional control through use of a tethered control station, as shown in Figure 10.

The tethered station controls all functions, including HPU control, vehicle movement, and boom positioning. The vehicle motion includes right track forward/reverse, left track forward/reverse, track base retraction/extension, turret rotate, plow blade up/down, boom pitch, stick pitch and tool plate pitch.

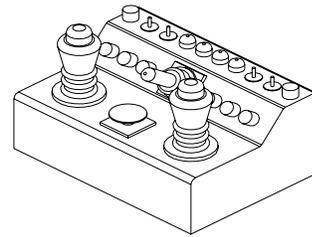


Fig. 10. Tethered control station.

II.B.4. Boom Tip Attachments

An interface package similar to the pedestal-mounted system was designed to attach to the tool plate that provides a rotational degree of freedom, the tether management system, and an auxiliary hoist. A single Telemate servomanipulator arm can be attached to this interface package. The auxiliary hoist can also be utilized to hold tools or other equipment to perform activities such as maintaining the filter, as shown in Figure 11. Since there is only one arm on this vehicle, it will be limited in

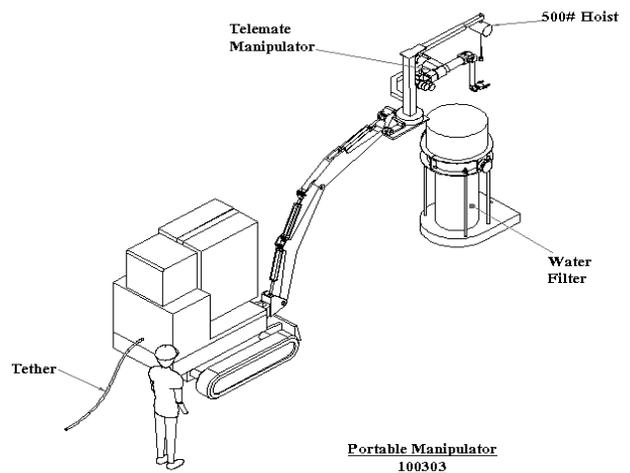


Fig. 11. Mobile system.

the tasks it can perform; however, this system will be able to do many tasks that will reduce the exposure of maintenance crews to radiation. A “quick disconnect” device allows the interface package to be removed and placed on a storage stand.

III. STATUS

As of the writing of this document the project system status is as follows.

- The pedestal-mounted boom system design is complete and has been approved by the SNS review committee. Allied Construction is currently fabricating the boom structure, with an expected completion date of early February. TPG will then send representatives to the Allied factory in Cleveland, Ohio, for factory performance testing. The expected shipping date from factory to TPG is late February. Once the system arrives at the TPG facility, TPG will oversee the final integration of the Telerob servomanipulators arms and auxiliary equipment, with final testing expected by mid-March. The completed system will be ready for use by SNS in the late March to April timeframe.
- The design for the mobile system is complete and also has been approved by the SNS review committee. The Schaeff-Terex HR12 unit has been fully constructed, with TPG integrating basic control

functions and performance testing at the Schaeff-Terex facility in Rothenburg, Germany. The unit has been shipped and is expected at the TPG facility in late January. Once at the TPG facility, TPG will oversee the final integration of the Telemate servomanipulator and auxiliary equipment, with final testing expected in late February. The completed system will be ready for use by SNS in the mid-March timeframe.

IV. ACKNOWLEDGMENTS

TPG Applied Technology would like to thank the following organizations for their participation in this project:

PaR Systems Inc. for providing the Telerob servomanipulator system

Oak Ridge National Laboratory for providing the Telemate servomanipulator and video for the mobile system

Imaging & Sensing Technology Corporation (IST) for providing the video for the pedestal system

Allied Construction Products, LLC, for assisting in the redesign and fabrication of the pedestal boom

Schaeff-Terex GmbH & Company for assisting in the redesign and fabrication of the mini-excavator