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ABSTRACT

This paper will update the status, improvements, and accomplishments of the Monitor remote-handling system previously reported.[1] It will also outline the goals for the future to improve the efficiency and speed of remote-maintenance operations at the Clinton P. Anderson Meson Physics Facility (LAMPF).

The Monitor remote-handling system consists of a hydraulic truck loader used as a transportation and positioning device to place the selected manipulators at the work site. Viewing is completely by television and shielding for the operators in the master station is by distance alone. The use of a rate-controlled manipulator and a unilateral hydraulic servomanipulator for remote beam maintenance was reported in Ref. 1.

Since the radiation levels exceed 10^5 R/h in the beam stop area and approach that level in the three LAMPF target areas, it is increasingly imperative that the remote-handling system be capable of maintenance, repair, and replacement of all the components in those areas. The LAMPF system, Monitor, based on the use of force-reflecting manipulators and viewing only by television, has accomplished that goal, although significant improvements have been conceived and will be integrated into the system in the coming months and years. The effort to design proper tooling to assure the maximum utilization of the remote-handling system has gone in parallel with the development of the system itself.

DESCRIPTION

The present system uses the basic hydraulic truck loader as the transport and support mechanism, which moves the manipulators to the actual work site. The primary manipulators now used are a pair of Tele-Operator Systems (TOS) Model SM-229 bilateral electric master/slave servomanipulators, 10-kg capacity, mounted on the end of the boom of the hydraulic crane. As shown in Fig. 1, the manipulators are mounted on a shoulder that can be rotated about its vertical axis. Also available to be mounted on the shoulder for special uses are a unilateral hydraulic master/slave servomanipulator built by Remotion Company and a PAR-3000 electromechanical manipulator.

The shoulder is connected to the boom by a leveling drive that operates automatically to maintain the shoulder axis vertical. This allows the operators to maintain a spatial orientation at various boom angles. The leveling drive also serves as a means of extending the crane boom when required.

One of the six television cameras normally employed during a remote operation is shown as well. This particular boom camera has pan-tilt capability, with a 10 to 1 zoom lens, and an incandescent light with intensity control.

In actual operation, the Monitor hydraulic crane is placed on the edge of a hole opened in the shielding to expose the proton beam line. The operation takes place in a 5-m by 6-m hole with the beam line 6 m below the level where Monitor is positioned. Television cameras are placed at the edge of the hole and on the hydraulic crane boom to provide an overall view of the work area. Another camera similarly equipped to the boom camera is taken to the work area by a lightweight extendable mast (Stem). The present master station arrangement is shown in Fig. 2. It contains, starting from the left:

1. The masters of the TOS servomanipulator system.

2. A television monitor and the TOS servomanipulator master controls and power supplies.

3. Six television monitors, television camera and light controls, and television camera power supplies.

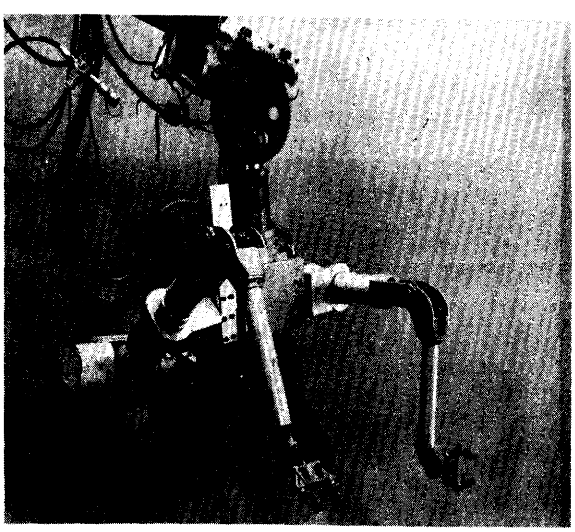

Fig. 1. Monitor operating end.

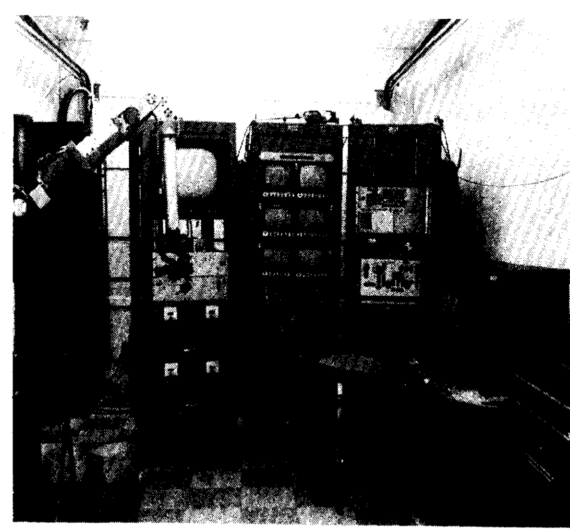

Fig. 2. Monitor master station.

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4. Master interphone speaker (slave end is normally mounted between the slave manipulators), the Stem controls, the hydraulic crane controls, tool air or electric power controls, and slide switch controls for the PAR-3000 electromechanical manipulator.

5. A television monitor and video tape recorder.

The master is contained in a 6-m-long trailer specifically designed for that purpose. Early placement of the master station in the LAMPF main experimental hall proved to be unacceptable in terms of noise, lighting, and traffic. The trailer provides a quiet, properly lighted work place that is conducive to the patience and perserverance necessary, on the operator's part, to successfully perform difficult remote-handling tasks.

The connection between the master and slave stations in the Monitor system consists of several multiple conductor cables, totaling about 400 conductors, including coaxial cables.

ACCOMPLISHMENTS

Since the original remote operation that was reported on in Ref. 1, the following remote operations have been performed:

1. Repaired a vacuum leak on the third target box, added a water-cooled shield to reduce the heat load on the downstream vacuum clamp, and installed an air-cooling line for that clamp in September and October 1977. This was the first use of a TOS arm, and involved operations as follows:

a. Added a hardened washer containing a thermocouple to the vacuum flange clamp bolt and tightened the bolt.

b. Routed and properly aimed an air-cooling line to the above clamp to limit the temperature cycling.

c. Installed the 40-lb water-cooled shield under another overhanging shield and connected its cooling lines to the existing water system.

2. Replaced the failed beam exit window and collimator in the beam stop area (also done during September and October 1977). This involved operations as follows:

a. Disconnected the water-cooling lines to the collimator and removed the collimator.

b. Disconnected the water-cooling lines from the window assembly, disconnected the vacuum clamp to the main beam line, and removed the collimator.

c. Installed a new water circuit to the window to isolate it from other water-cooled items.

d. Reinstalled the window and hooked up cooling lines.

e. Remade the vacuum connection and leak-checked remotely.

f. Reinstalled the collimator and hooked up cooling lines.

3. Various attempt to fix heat-dependent vacuum leaks in the third target cell during January and March 1978; this involved tightening vacuum clamp bolts and bolted vacuum joints as well as leak checking.

4. After the unsuccessful attempt to repair the vacuum leaks in the third target cell, a newly designed target box was installed during April and May 1978. Operations were as follows:

a. Disconnected water and vacuum connectors, removed surrounding shielding, and extracted the extremely radioactive (>1000 R/h) target box.

b. Rerouted cooling water lines to the target box and shielding.

c. Installed the new target box, connected cooling water and vacuum joints, and installed improved target cell shielding.

5. During September and October 1978, water leaks on the second target box and in the beam stop area were repaired or isolated. The following work items were accomplished:

a. Removed and capped copper lines with unrepairable leaks, and added a drip-cooling system as a replacement.

b. Removed a leaking copper line by cutting with a reciprocating saw and loosening a swagelock fitting. After wire brushing, a new solder joint was made and the swagelock was tightened.

c. Moved the main beam stop to a new position after the inoperative drive was disassembled.

6. January and February 1979 were spent in replacing a magnet-protection collimator in the second target cell. The following operations were performed:

a. Repaired a vacuum clamp by drilling out the broken bolt and replacing it with a toggle-type bolt.

b. Cut and resoldered copper water lines.

c. Removed and replaced thermocouples.

d. Removed and replaced vacuum clamps and seals.

e. Vacuum-leak checked.

In conjunction with the development of the remote-handling equipment, a parallel effort in the development of remote tooling has been accomplished. These tools range from hand tools for a single purpose (i.e., a hook to hold up a vacuum clamp while the bolt is fastened) to powered saws, grinders, drills, wrenches, and hammers. About half the powered tools are commercial items adapted for remote use, while the rest are specifically designed for LAMPF's purpose.

Tools should be considered the logical adjunct to the manipulators, just as a man's arm requires tools for most useful endeavors.

FUTURE PLANS

The plans for the near term are as follows:

1. Completion of the Monitor II slave unit with a second-generation leveling drive, shoulder, camera mounts, Stem positioning unit, and hydraulic crane joint position indicators.

2. Completion of the Monitor II master control station, which will include new placement of television monitors and controls, and fully adjustable master manipulator mounts.

3. Intensify the training of operators through realistic mockups of the actual hardware configuration in the target cells.

4. Improve the television-viewing capability by possible use of stereo, servocontrolled pan and tilt units, and further investigate other commercial television equipment. Fiber-optic systems will be tested to extend the television-viewing capability.

5. Acquisition of another pair of advanced manipulators.

6. Further develop remote-soldering techniques and develop remote-welding capability.

7. Continue the development of pertinent tooling.

Long-term plans include:

1. Development of more advanced master/slave systems with a lower threshold of force-reflection and increased capacity to 25-30 kg. Experiments at LAMPF last summer proved that the force-reflection threshold of a one-degree-of-freedom hydraulic manipulator can be decreased by an order of magnitude. This is accomplished by measuring the slave force with strain gages and applying that force to the master. Similar experiments have been conducted by TOS and Remotion Company.

2. Fully implement servocontrol of cameras to allow head-aimed or other more advanced camera-control schemes.

3. Automate the hydraulic crane to place the manipulators at the work station in the shortest possible time.

CONCLUSIONS

The LAMPF remote-handling system, Monitor, has been developed into a system that can perform remote-maintenance, repair, and replacement of highly radioactive components by using only television as the viewing medium. This technology can and should be extended to other areas where dexterity and speed can increase the efficiency of operation and decrease the radiation exposure to personnel. Interest has now been generated in fusion reactor experiments and in fuel processing to use advanced remote-handling systems similar to Monitor. It seems that an advanced remote-handling system could profitably be applied to nuclear power reactor repair and nuclear waste handling.

REFERENCE

J. J. Burgerjon, E. L. Ekberg, D. L. Grisham, R. A. Horne, R. E. Meyer, C. R. Flatau, and K. B. Wilson, "A Solution for Remote Handling in Accelerator Installations," IEEE Trans. Nucl. Sci., Vol. NS-24, No. 3 (June 1977).