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AUTHOR(S): D. L. Grisham, T. S. Baldwin, E. L. Ekberg, J. E. Lambert, M. A. Madrid, and R. L. Tanner

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ABSTRACT

The Clinton P. Anderson Meson Physics Facility (LAMPF) has developed two identical remote-handling systems, Monitors I and II, that are used to repair, replace, and maintain the main proton beam line. The systems use electric master-slave manipulators to perform the required tasks using only closed-circuit television for viewing. Advances in controls and mechanical sub-assemblies have increased the efficiency of operation to a significant degree. Recent major emergency repair operations have further proven the versatility and reliability of the Monitor systems. There is now no doubt that the future maintenance of the vital beam line is assured. This technology should be extended to other toxic, hazardous, and/or dangerous work areas.

I. INTRODUCTION

Previous papers on the Monitor system[1-4] have stated that the development of two complete remote-handling systems are necessary to assure the proper and timely maintenance of the four target areas in the main proton beam line at the Clinton P. Anderson Meson Physics Facility (LAMPF). This paper will deal with the commissioning of the second unit (Monitor II) in April 1980 by accomplishing vacuum repairs in the A-5 target cell while Monitor I (the first unit) was replacing beam line components in Target Cell A-1. It also will describe the design features of Monitor II, now being applied to Monitor I. The recent operational accomplishments of the two units will be reviewed.

II. DESIGN REVIEW

As indicated in earlier papers and as shown in Figs. 1 and 2, the Monitor systems consist of a pair of electric bilateral master-slave manipulators (TeleOperator Systems Corporation, Model SM-229), mounted on a hydraulic truck loader. In operation, the hydraulic crane is placed on the edge of a 5-m by 6-m by 6-m-deep hole opened in the beam line shielding. This provides access to the main proton beam line for maintenance, repairs, or replacement of line components by the Monitor systems. Instead of dense shielding for personnel protection and lead glass windows for viewing, the Monitor systems depend on distance for shielding and closed-circuit television for viewing. The slave unit is placed on the edge of the target cell opening, while the master control trailer is positioned at a distance necessary to eliminate radiation exposure to operating personnel.

III. DESIGN IMPROVEMENTS

The original system (Monitor I) had a number of features that have continued to the present time. These features will be described and their progress to the present systems will be traced.

A. Manipulator Mounting Shoulder

As shown in Fig. 3, the manipulators are mounted on a shoulder plate at ~0.7 m center-to-center distance, which rotates around its own axis to allow the proper approach to the task at hand. The angle between the shoulder rotator and the main hydraulic crane boom can also be changed to maintain the rotator axis vertical, which is the operator's spatial orientation. The other function that the level drive performs is that of an extension of reach and/or the manipulator approach at a nonstandard angle. The shoulder rotator and level drive were originally powered by fixed-speed alternating current (ac) gear motor drives. Although the ac motors performed the rotation and leveling functions satisfactorily, the space limitation on motor and brake sizes precluded the extension function.

It was eventually concluded, since hydraulic power was already used to operate the basic crane, that the shoulder movement functions should also be hydraulic. The shoulder rotator is now powered by a commercial hydraulic motor that provides the rotation and braking capabilities in a small package. The level/extension function is accomplished with a LAMPF-designed cable-roller-chain configuration that provides the torque to perform the required functions. Both are controlled through commercial flow control valves operated by a LAMPF-designed proportional control system.

The changes in actuation method and the variable-speed controls have increased our efficiency by 20-25%.

B. Main Hydraulic Crane Controls

The main hydraulic crane was originally remotely controlled by the electromechanical movement of a normally hand-operated valve. The original system worked fairly well, but required excessive maintenance to provide even marginal reliability. The two Monitor systems now are controlled by a LAMPF-designed electrohydraulic system based on commercial proportional valve controls. The new system provides high reliability, a wide range of speed and positioning controls, and a low downtime for maintenance. The new single joystick control (with lighted pushbutton selection of function) has proven to reduce both the operator training time and operator fatigue during long operational periods.

C. Viewing System

Another significant development from the original Monitor I scheme has been the continuing refinement of the television-viewing system for the optimum coverage during remote operations. The first system had two cameras with pan-tilt and zoom capability for close-in work viewing. The other cameras were fixed and used for a single purpose. The viewing setup in the control trailer provided one large and two small monitors for the manipulator operator and six small monitors for the joint use of the camera and hydraulic crane operators.

The development of the viewing system has progressed through the use of color, an abortive attempt at servo pan-tilt controls, and pneumatic and hydraulic cylinders for positioning to the present system that has the following features:

1. All black and white 525 line television cameras with zoom lenses.
2. Center-of-gravity dc motor-driven pan-tilt units.
3. Proportional speed pan-tilt controls.
4. Large screen monitors (5) for the manipulator operator.
5. Small-sized monitors (4 to 6) for the camera operator.
6. Very small monitors (3 to 6) for the hydraulic crane operator.

Figure 3 shows the camera (boom) that is attached to the shoulder plate and provides a close-in view of the task being performed. Figure 4 shows the other close-in view camera (stem) that is mounted on an extensible boom that traverses the entire width of the Monitor slave unit. This provides another view of the task being performed from an angle that is different from the boom camera. This system is also shown in Figs. 1 and 2. Two cameras, mounted on the boom of the hydraulic crane, are shown in Figs. 2 and 5. This pair of cameras provides a complete overall view of the operation of the hydraulic crane, as well as other views of the work area. Normally two other cameras are mounted on tripods placed on the edge of the work hole for additional overall viewing.

This development and camera placement have resulted in a viewing system that provides the capability of properly viewing the tremendous variety of scenes required to accomplish the beam line maintenance task.

The result of the above improvements, linked with increased operator skills and experience, has decreased the average operational times for comparable tasks by about a factor of two.

D. Control Station

Figures 6-8 provide overall views of the control station operating area. The normal operating crew consists of three people: the manipulator operator (as crew chief), a dedicated camera operator, and a dedicated crane and auxiliary functions operator (placed as shown in Fig. 7). Figure 8 shows the manipulator operator in his working position with the television monitors directly in front of him.

III. RECENT OPERATIONAL ACCOMPLISHMENTS

Accomplishments A and B, below, were successfully completed during April-June 1980. Item C was an emergency repair that was performed from September 14-18, 1980.

A. In Target Cell A-1

1. Replaced a beam control jaws in a secondary (meson) beam line that required the removal and replacement of a large vacuum flange, water-cooling lines, and power and instrumentation leads.
2. Repaired a water leak in copper tubing welded to a stainless steel vacuum chamber by removing the leaking section and replacing with a new tube.
3. Removed and replaced a 14,500 kg main line triplet quadrupole magnet that required totally remote rigging and the replacement and removal of water lines, dc power leads, and instrumentation cables.

B. Simultaneously in Target Cell A-5

1. Removed and replaced water-cooled shielding pieces.
2. Successfully fixed a leak in a wedge-type vacuum clamp.
3. Removed and replaced a beam line diagnostic instrument.

C. Target Cell A-2

1. Leak-tested all vacuum joints in Target Cell A-2.
2. Successfully repaired leaks in two wedge-type vacuum clamps.
3. Tightened two additional vacuum clamps to prevent possible future leaks.
4. Repaired a cooling-water leak on the target chamber (by soldering).

IV. CONCLUSION

The LAMPF Monitor systems, as now developed, provide a dual capability for time-effective maintenance, modification, and replacement of vital experimental proton beam line components. We are confident with the present system that the widely used basic research facility can continue to operate as scheduled. Because of the additional Monitor unit and the aforementioned improvements, we are able to perform major maintenance operations and emergency repairs with a minimal loss of facility operating time.

As a result of LAMPF's success with the Monitor systems, other dangerous and/or toxic tasks can be effectively performed by direct application of Monitor hardware and operating techniques. With minimal modifications, the Monitor system can be utilized in many industries and/or activities that may potentially compromise the health and safety of workers or operating personnel.

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FIGURE CAPTIONS

Fig. 1. Overall view of Monitor.

Fig. 2. Front view of Monitor.

Fig. 3. Shoulder rotate, close-in camera, and level-drive assembly.

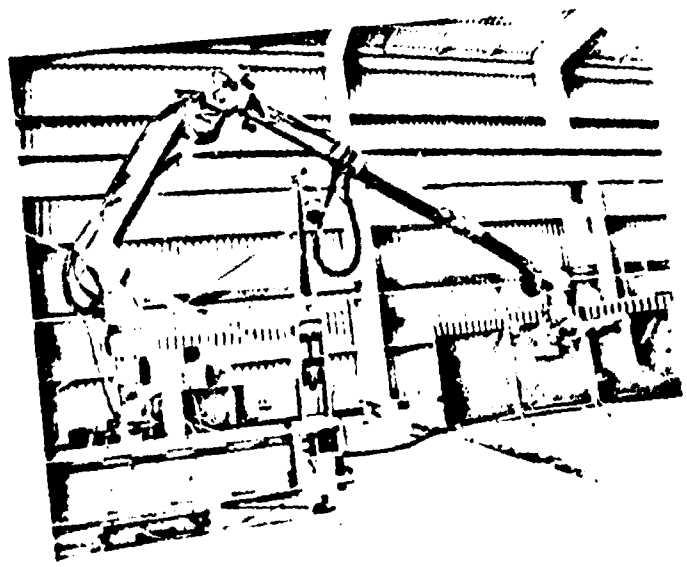
Fig. 4. Stem camera assembly.

Fig. 5. Upper boom cameras.

Fig. 6. Overall view of master control station.

Fig. 7. Close-up view of operating stations in master control station.

Fig. 8. View of manipulator operator and video monitors.



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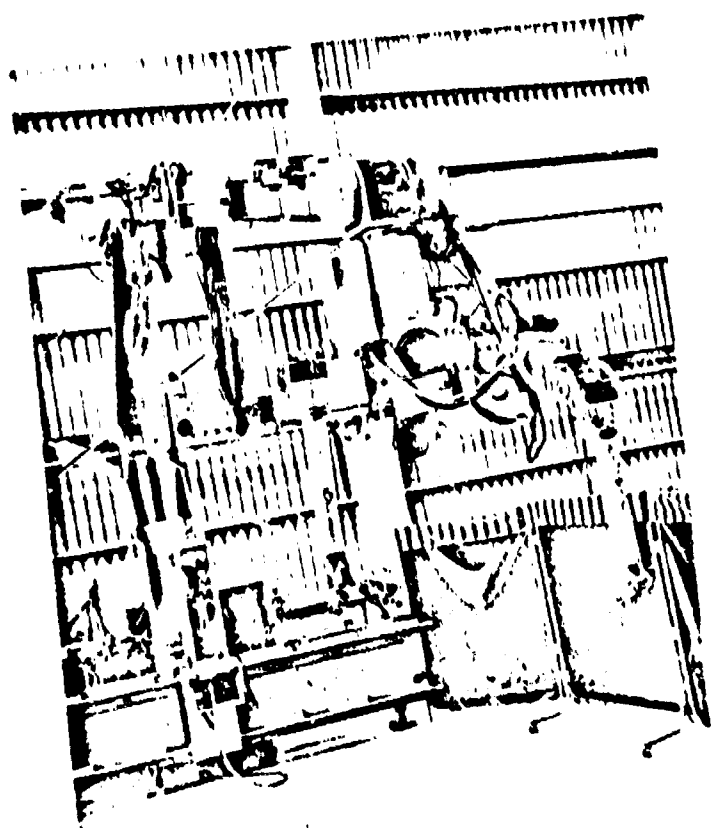


Fig. 2. Front view of Monitor.

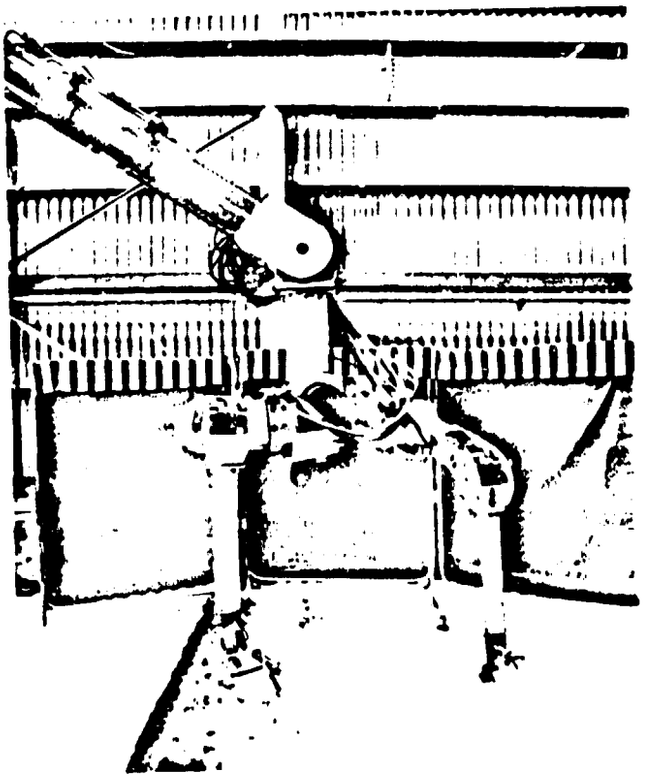


Fig. 3. Shoulder rotate, close-in camera, and level-drive assembly.

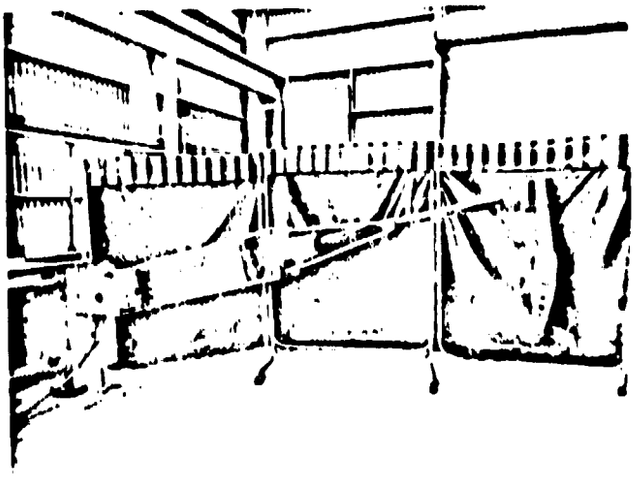
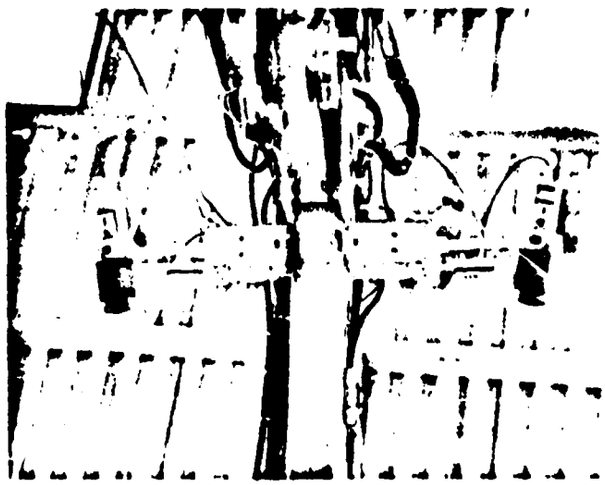


Fig. 4. Stem camera assembly.



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