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MONITOR 1981*

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Summary

The experimental proton beam line at the Clinton P. Anderson Meson Physics Facility (LAMPF) is maintained remotely (because of high radiation levels) by a specially designed remote handling system called Monitor. The prototype Monitor unit was placed in service in 1976 to repair highly activated components in the LAMPF beam stop. Since that time, the Monitor system has been continually improved to keep pace with more complex maintenance tasks and ever-increasing radiation levels in the experimental areas. To ensure that the facility can be maintained on a timely basis, a second Monitor unit was commissioned in 1980. The improvements in the Monitor system and components have increased the efficiency of LAMPF's remote-maintenance operations by a factor of two. The technology developed has advanced to the state where it can be directly applied to other applications or industries that may potentially compromise health and/or safety of workers.

Introduction

Previous papers on the Monitor system[1-5] 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 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 and major beam line improvements performed in Target Cells A-5 and A-6 during November 1980-February 1981. 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.

Design Review

As indicated in earlier papers and as shown in Figs. 1 and 2, the Monitor systems consist of a pair of electrical bilateral master-slave manipulators (Tele-Operator Systems Corporation, Model SM-229), mounted on a hydraulic truck loader. In operation, the hydraulic crane is placed on the edge of a 5- by 6- 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.

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.

Manipulator Mounting Shoulder

As shown in Fig. 2, 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

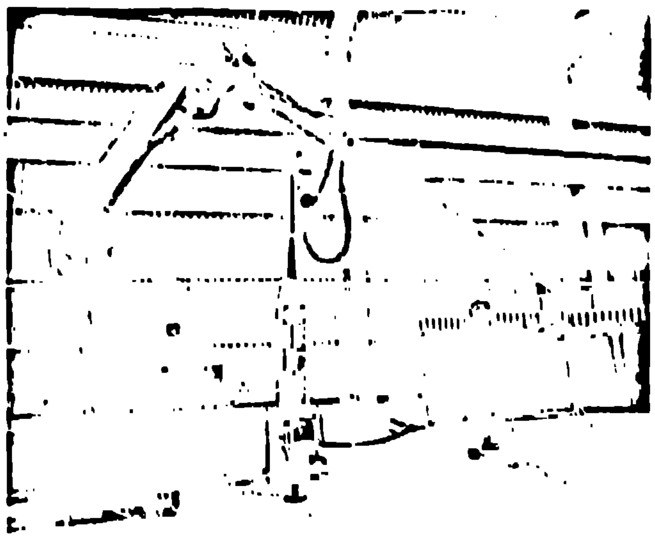

Fig. 1. Overall view of Monitor.

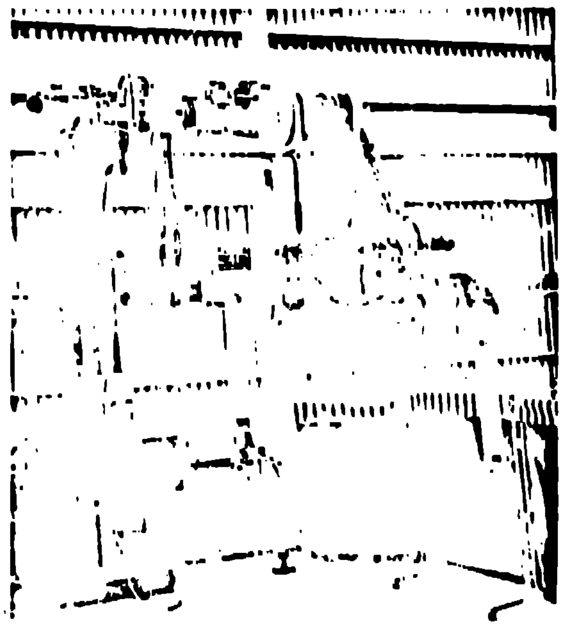

Fig. 2. Front view of Monitor.

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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%.

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 are now controlled by a LAMPF-designed electro-hydraulic 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 proved to reduce both the operator training time and operator fatigue during long operational periods.

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 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 2 shows the camera (boom) that is attached to the shoulder plate and provides a close-in view of the task being performed. Figure 2 also 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. Two cameras, mounted on the boom of the hydraulic crane, are shown in Figs. 1 and 2. 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.

Control Station

Figure 3 provides 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.

Recent Operational Accomplishments

Accomplishments 1 and 2, below, were successfully completed during April-June 1980. Item 3 was an emergency repair that was performed from September 14-18, 1980. Items 4 and 5 are major improvements made to the beam line during the December 1980-February 1981 maintenance period.

1. In Target Cell A-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 instrumentation leads.

Fig. 3. Overall view of master control station.

-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.

-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.

2. Simultaneously in Target Cell A-5

-Removed and replaced water-cooled shielding pieces.

-Successfully fixed a leak in a wedge-type vacuum clamp.

-Removed and replaced a beam line diagnostic instrument.

3. Target Cell A-2

-Leak-tested all vacuum joints in Target Cell A-2.

-Successfully repaired leaks in two wedge-type vacuum clamps.

-Tightened two additional vacuum clamps to prevent possible future leaks.

-Repaired a cooling-water leak on the target chamber.

4. Target Cell A-6

-Removed and replaced beam stop (~100 000 R/h).

-Installed a beam degrader (to enhance neutrino production). This operation included remote welding with a MIG torch.

-Removed and replaced vacuum window.

-Replaced two cooling water distribution manifolds and related plumbing.

-Repaired 9 water leaks by silver soldering, using an air-acetylene torch.

-Removed and replaced beam line diagnostic instrumentation.

5. Target Cell A-5

-Performed major modifications to cooling water distribution system. Work included remote tube cutting, silver soldering, routing of new tubing, and filling installation.

-Removed and replaced beam line diagnostic instrumentation.

-Added additional thermocouples using remotely operated stud welder.

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 that, with the present system, 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 minimum loss of facility operating time.

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