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MASTER-SLAVE MANIPULATORS AND REMOTE MAINTENANCE AT THE OAK RIDGE NATIONAL LABORATORY*

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ABSTRACT

The volume of master-slave manipulator maintenance at Oak Ridge National Laboratory has necessitated the establishment of a repair facility and the organization of a specially trained group of craftsmen. Emphasis on cell containment requires the use of manipulator boots and the development of precise procedures for accomplishing the maintenance of 283 installed units. To provide the most economical type of preventive maintenance, a very satisfactory computer-programmed maintenance system has been established at the Laboratory.

INTRODUCTION

Master-slave manipulators were developed because a need arose for a tool that could operate in hostile environments behind barricades or through shielding walls. This tool must be capable of making all the manipulations that could be performed by the human hand. The resulting master-slave manipulators have proven to be a very useful device for research activities, particularly in the nuclear energy field. Early handling techniques included tongs, over-the-wall mechanical devices, and other simple techniques to minimize personnel radiation exposure.

Remotely operated manipulator-type work started at Oak Ridge National Laboratory in 1953 with the installation of a CRL Model 4 unit in the Solid State Division hot cells. Since that time, the number of manipulators has increased to 283 (see Table 1). To provide the necessary maintenance for this number of manipulators, the Laboratory has developed a specially trained crew of one foreman, eleven millwrights, and one electrician.

The contents of this paper will be limited to the maintenance history and the available information used at the Laboratory for procuring present-generation manipulators and manipulators' booting.

With the advent of reactor fuel recycle systems and the environmental impact of waste handling, it is conceivable that we are at the threshold of an entirely new generation of remote handling devices.

FACILITIES AND EQUIPMENT

The manipulator repair facility at ORNL has approximately 6000 square feet of floor space, which is divided into four areas of operation. Two of these areas are used for contaminated repairs, and the other two are used for clean repairs and boot fabrication.

The units weigh from 140 to 450 kilograms and are awkward to handle; so it was necessary to design and fabricate all the handling equipment for the dual purposes of cell installation or removal and transportation to and from the repair facility. The Laboratory has fabricated six portable dollies of a modified "A" frame design that incorporates a hydraulic cylinder. The dollies are designed so that they become a part of the unit for transportation purposes. When taken to the repair shop, the manipulator is placed in a glove box for cleaning or decontamination, and the dolly is then available for other service.

MANIPULATOR BOOTS

The special emphasis on cell containment at ORNL requires that all manipulators be equipped with boots to seal the cell opening for the manipulator. This requirement has enlarged the maintenance problem in that, with booted units, 50 to 60 percent of the maintenance lies in replacing worn or damaged boots. Therefore, in 1961 the Research Services Department instituted a development program to provide a material and a means of producing boots that would meet the needs of the Laboratory. This investigation resulted in a spray method of boot fabrication in which liquid urethane rubber is used.[1]

From a maintenance standpoint, the protection afforded a manipulator by the use of boots has prolonged slave-end bearing life and has considerably decreased mechanical failures.

Since the number of manipulator removals for boot changes needed to be reduced and since nearly all boot failures occurred in the gauntlet area, a two-piece boot is now in use in many hot cells at the Laboratory. This two-piece boot is fabricated so that the lower section, including gauntlet, can be remotely removed and replaced by a manipulator.(2) Also, because the activities at ORNL involve transuranium elements and because of rigid safety requirements for handling these materials, a double-layered boot is fabricated for 12 Model F manipulators in the Transuranium Processing Plant (TRU).

PROGRAMMED MAINTENANCE

Until 1961, all manipulator maintenance work was performed on an "as-needed" basis. Machines remained in operation until a failure occurred and the unit was inoperable. Experience had shown that if minor adjustments could be made from time to time, the more serious difficulties could be alleviated. To minimize cell downtime and to achieve more efficient manipulator performance, a computer programmed maintenance system was introduced. This program includes a two-week to one-month check on each installed manipulator. Tape and cable tensions are measured and adjusted, all motions are checked for possible malfunctions, and linkages are inspected for wear or out-of-tolerance conditions. A preventive maintenance program of this type has proven very satisfactory at the Laboratory, and an approximate 30% savings in maintenance costs has been realized. Prior to programmed maintenance, the average unit was taken to the manipulator repair facility twice per year for complete overhaul; after the programmed maintenance system was established, the units now average one trip per year to the maintenance facility for these extensive repairs.

In general, statistics available from the programmed maintenance activities show that annual costs of manipulator repairs will vary from $800 to $1200 per unit, excluding booting. The cell downtime due to manipulator removal and installation will vary from five to ten days per year. It should be noted, however, that the maximum time required to remove or install a unit is three hours. The five-to-ten-days figure is acquired by using an accumulation of the total time required for each service call. Another interesting statistic shown by programmed maintenance is that the right-hand manipulator requires twice as many repairs as the left-hand unit. This may indicate that when designing an in-cell system, consideration should be given to a right handed operation.

FUTURE NEEDS

Discussions with ORNL hot-cell operators reveals that the presently available manipulators are generally satisfactory for their research-type activities. Improvements could possibly be made in feedback information such as feel, temperature, etc.; but for their research, which is nonrepetitive in nature, present units provide the needed dexterity. These units are detailed in ORNL specifications 10017-N-111-X, XSP-239, and MP-200. However, for scientific personnel designing fuel recycle systems or waste handling systems, presently available manipulators are not satisfactory. It appears that programmable modules to work in conjunction with automated equipment are rapidly becoming a requirement in this remote handling area.

Unfortunately, units available on the open market are in no way adequate to be considered for these needs. Also, the criteria for such programmable units are incomplete.

CONCLUSION

As a result of the techniques and facilities described in this paper, it is felt from both the maintenance and research viewpoint that a very satisfactory manipulator maintenance program has been established at ORNL. This program will be continuing since the number of manipulators are increasing and since the demands on the functions are broadening.

TABLE 1

Master-Slave Manipulators

Type	Model	Units
MSM	4	5
MSM	7	12
MSM	8	114
MSM	A	49
MSM	D	7
MSM	E	42
MSM	F	14
MSM	G	23
MSM	H	4
MSM	L	2
Electro Mechanical		11

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