REMOTEX AND SERVOMANIPULATOR NEEDS IN NUCLEAR FUEL REPROCESSING PLANTS

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Presentation

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ABSTRACT

Work on the conceptual design of a pilot-scale plant for reprocessing breeder reactor fuels is being performed at Oak Ridge National Laboratory. The plant design will meet all current federal regulations for reprocessing plants and will serve as prototype for future production plants. A unique future of the concept is the incorporation of totally remote operation and maintenance of the process equipment within a large barn-like hot cell. This approach, called Remotex, utilizes servomanipulators coupled with television viewing to extend man's capabilities into the hostile cell environment. The Remotex concept provides significant improvements for fuel reprocessing plants and other nuclear facilities in the areas of safeguarding nuclear materials, reducing radiation exposure, improving plant availability, recovering from unplanned events, and plant decommissioning.

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INTRODUCTION

The Consolidated Fuel Reprocessing Program (CFRP) at the Oak Ridge National Laboratory (ORNL) has a major objective of developing technology for nuclear fuel reprocessing to a point from which scale-up to production operation can be made with a reasonable assurance of success. While this program includes development work for the advanced converter reactors and thorium fuel cycles, the main efforts are in support of the uranium-plutonium breeder reactors. All development tasks are included in the program, ranging from basic laboratory and hot-cell testing through component and systems development to the conceptual design of a pilot-scale reprocessing facility designated as the Hot Experimental Facility (HEF).

The reevaluation of an original HEF design resulted in the development of the total remotely operated and maintained approach called the Remotex. This concept is essentially an optimized design solution that responds to a number of plant design criteria that include licensability, safeguards, environmental effects, waste materials, design life, radiation exposure, prototype equipment and decommissioning, none of which can be treated separately. The application of the Remotex concept to a fuel reprocessing pilot-plant is the subject of this presentation.

The Basis for Servomanipulator in Remotex

The success of the Remotex concept is probably most dependent on the performance of the remote manipulation, viewing, and maintenance system. A review of experiences at other facilities indicates that using more versatile manipulation will result in decreased complexity (and cost) of in-cell equipment and the downtime associated with maintenance. This indication can be substantiated in a number of ways. Equipment to be maintained by contact means is less expensive to design and build than remotely maintained equipment because of the inherent dexterity of the operator. When equipment is to be maintained remotely by mechanical master slave manipulators in front of a window, it becomes somewhat more complex because of the lessened dexterity of the manipulators. As the types of manipulation used for remote maintenance becomes less dexterous, such as a power (nonforce reflecting) manipulator or a crane, the complexity of equipment design increases even more. The types of manipulators that have been used in reprocessing facilities are shown in Fig. 1 in order of increasing versatility. For example, the crane system is the least versatile, and the suited man is the most versatile of the systems shown.

A number of studies and tests have been performed and documented to determine the time required to perform a set of work tasks using different types of remote manipulators. The general results of these studies are shown in Fig. 2. In each case, an unsuited man (assumed with two arms) was selected as the reference and assigned a value of 1 when performing a specific task. The same task was then performed by different types of manipulation systems, and the increased time required was determined. The numbers shown are multiplying factors, that is, it takes eight times longer to do the same task using mechanical master slave manipulators than it does using human hands. Further, it takes 60 to 100 times longer to do the same task using electromechanical manipulators (EMM). The results of these studies clearly show that manipulators with force reflection (the ability to feel) can perform tasks in far less time than nonforce-reflecting manipulators. It is also obvious that none of the manipulators are comparable to man.

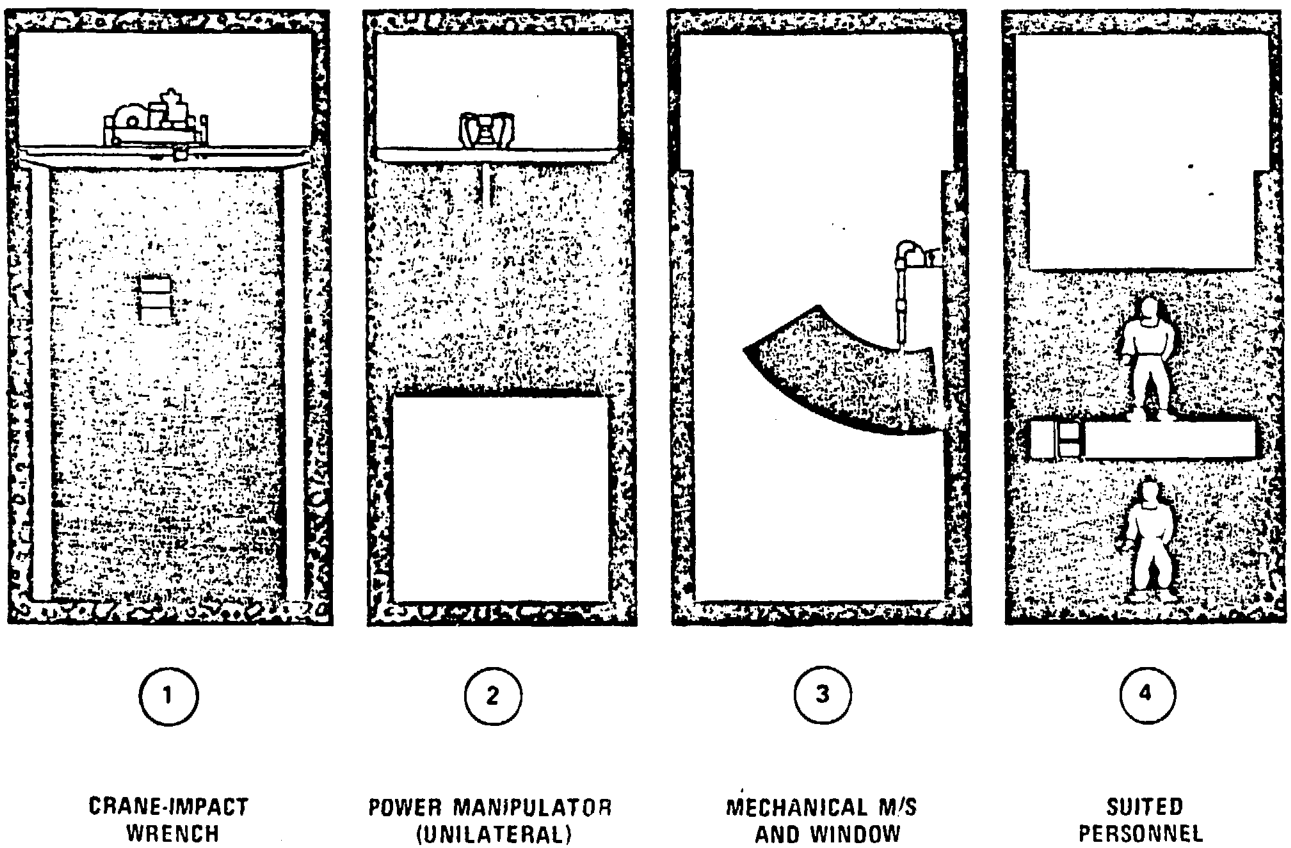

Fig. 1. Conventional manipulator-maintenance systems.

Fig. 2

TIME COMPARISON TO PERFORM TYPICAL TASKS

	LASL	MIT	NASA	MBA	CEA
TWO ARMED MAN (UNSUITED)	1	1	1	1	1
TWO ARMED MAN (SUITED)				8	
TWO-ARM MECHANICAL M/S	8	8-10	8	8	2-8
ONE-ARM MECHANICAL M/S	16		16		
ONE-ARM EMM (POSITION CONTROL)	80	40-50	64	55	10-30
ONE-ARM EMM (SWITCH CONTROL)	480	80-100	640		50-100
CRANE (IMPACT WRENCH)	>500	>100	>600	>500	>100

Being revised

The use of personnel in future reprocessing plants to maintain equipment by contact means will be significantly less than has been allowed in the past. The HEF concept is to minimize contact maintenance and to seek a replacement for man. The closest, currently existing substitute for man is the electric master slave manipulator, or servo-manipulator. An example of a currently available industrial standard system is shown in Fig. 3. The system has the same capabilities as the mechanical master slave except that the master and slave arms can be physically separated. Hence, full-volume coverage of the interior of a cell is possible with a single manipulator system. The servomanipulator was developed during the early 1950's and is commercially available from at least four sources. Widespread application has not occurred because of the relatively high cost, the concern about reliability of these units, and the fact that mechanical master slave manipulators, coupled with windows and overhead nonforce-reflecting manipulators, could be used to do the work. The experiences at three facilities where servomanipulators are used have been favorable.

For a large barn-type cell, such as in the HEF, the servomanipulator is ideal because of its dexterity and large-volume coverage. The plan for HEF is to use servomanipulators as a replacement for man for repair operations. For example, the manipulators will be mounted on a transporter that will move them to the repair area. They will then be used to turn valves, loosen bolts, and disconnect lines. A tool box containing the power and manual tools needed to perform work will be carried on the transporter. Television cameras will be mounted on the transporter, the manipulators, the overhead crane, and at other locations for close-up viewing of the repair operation.

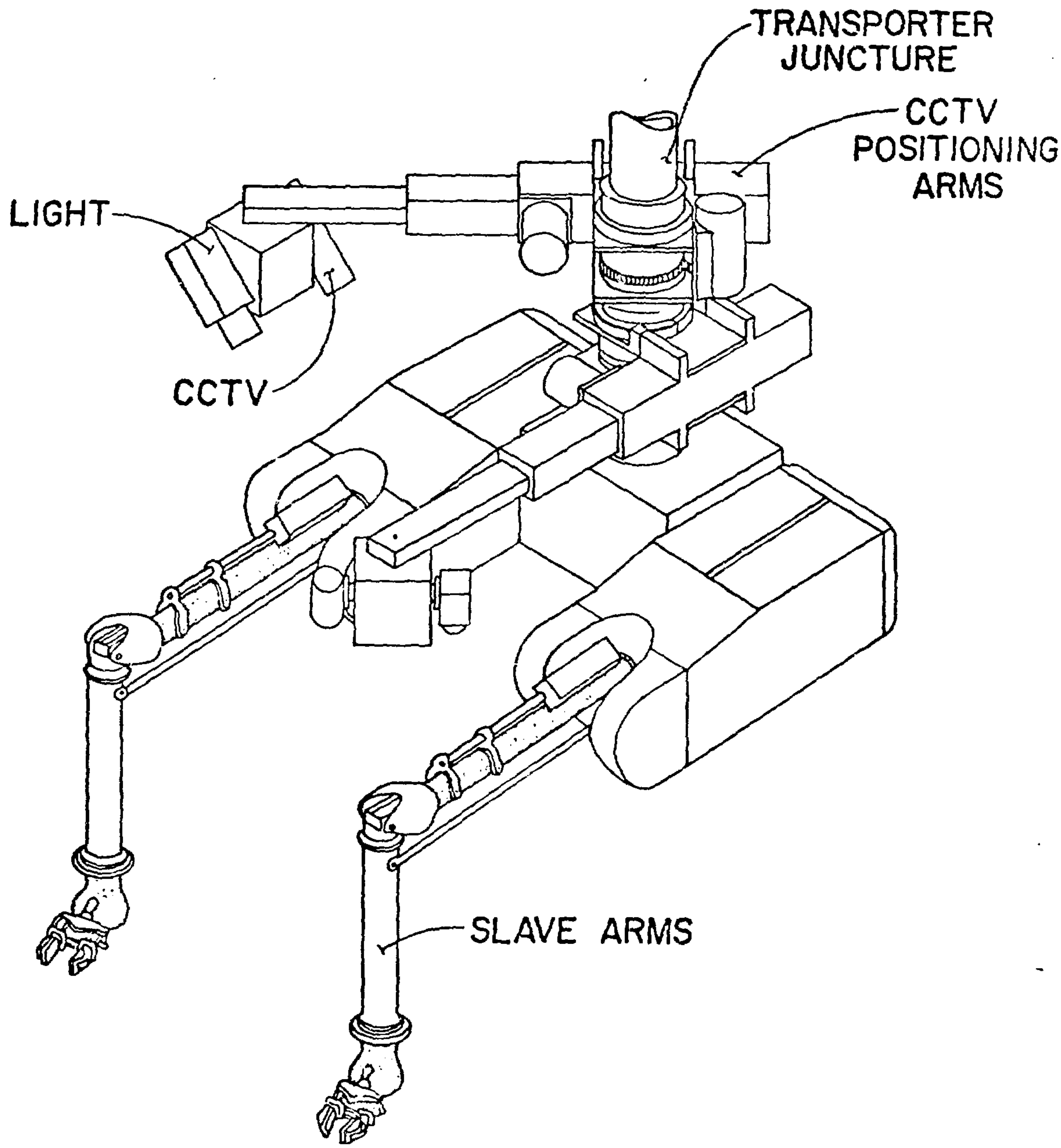

Fig. 3. Industry standard in-cell (slave) manipulator system

The features of commercially available servomanipulators appear adequate to perform repair functions in the HEF. They have not, however, been operated in large, highly radioactive and totally remote plants.

Remote Control Engineering

The Remote Control Engineering task was established at ORNL to improve the technology for remote control and manipulation systems in the radioactive environment of nuclear fuel reprocessing plants. The primary goals of the development area are to improve the currently available industrial systems and to insure their performance in large highly radioactive and totally remote plants. The development is also aimed at making the remotely controlled system more reliable, more easily maintained, and more efficient, all of which contribute to a more efficient plant. The basis of these overall objectives are requirements to achieve the "Remotex" concept.

The Fig. 4 outlines the system architecture in terms of functional elements that are required to implement "Remotex."

The remote handling system is made-up of a number of key elements located in-cell and out-of-cell. The in-cell equipment is made-up of the transporter system, viewing and lighting system and servomanipulators. The out-of-cell equipment includes the man-machine interface and miscellaneous support equipment such as power supplies and supervisor controls systems.

Our basic approach is to improve systems by using current technology and maximizing information feedback to the operator to render the overall system more efficient. For the transporter

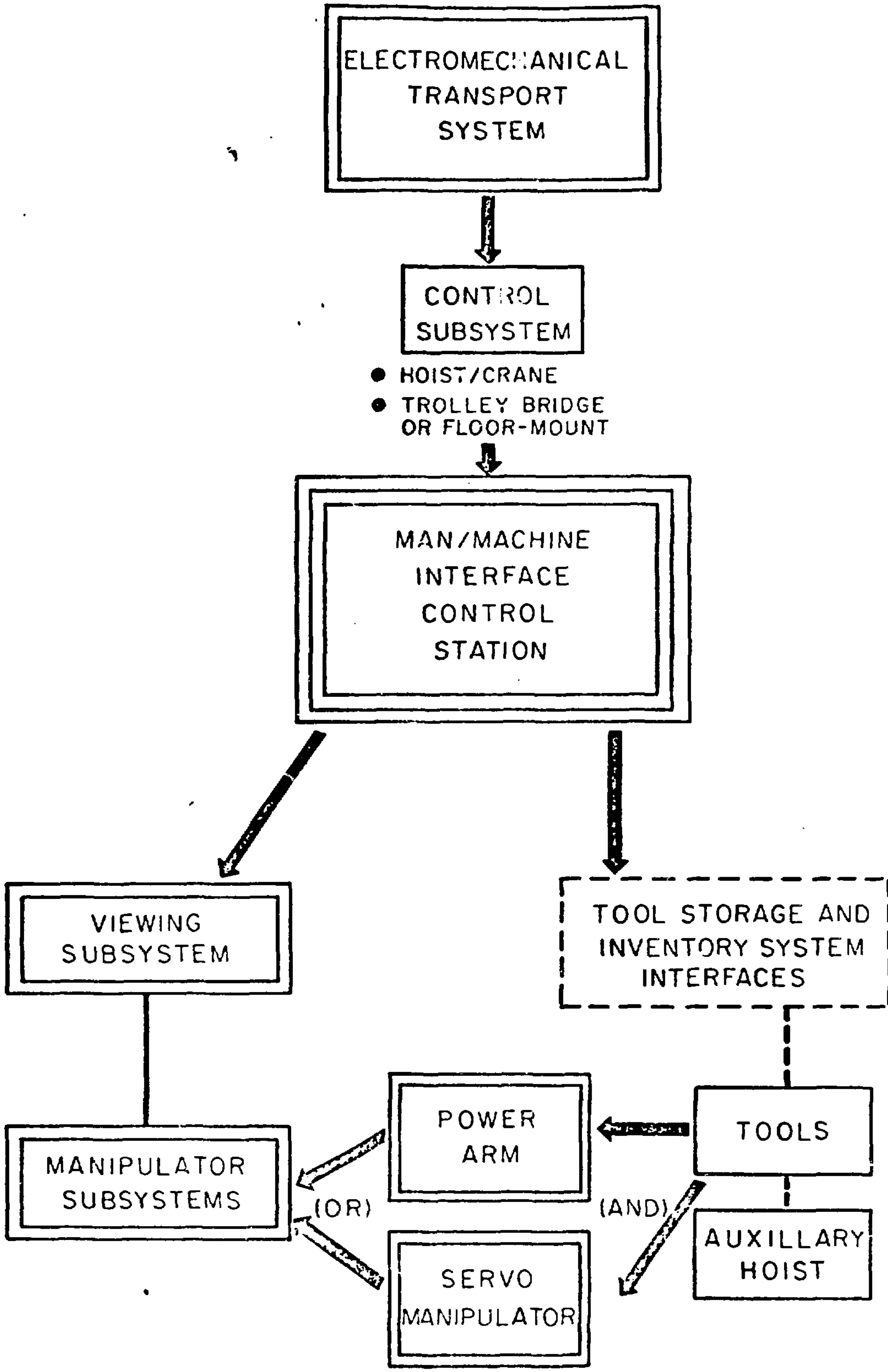

Fig. 4. Remote control engineering major task end — products

system, we are improving the methods of controls which involves better actuator/drive, modern control techniques, better data and power transmission techniques. For the viewing and lighting system, we are optimizing the system and striving to make the system as "transparent" as possible so that the operators have a sense of presence in the work situation.

The servomanipulator system is being optimized so that arm kinematics is suited for HEF tasks. The TV positioning system is compatible with the arm kinematics, decontamination and remote maintenance. The development will be demonstrated with prototypic equipment at ORNL.

Two conceptual studies will be completed in FY 1981 for an advanced servomanipulator system. One of these concepts will then be built for evaluation and demonstration in FY 1982 and 1983. As part of the HEF conceptual design, two concepts of transporters were evaluated and selected. This task will obtain a conceptual design for the transporter system in FY 1981. The final design and fabrication of this system will be completed in the following two years.