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A STANDARD EXAMINATION STAGE FOR THE FUELS AND MATERIALS EXAMINATION FACILITY

MASTER

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FOR THE
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23 Pages
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STANDARD EXAMINATION STAGE

FOR FMEF

ABSTRACT

A Standard Examination Stage (SES) has been designed, fabricated, and tested for use in the Fuel and Materials Examination Facility (FMEF) at the Hanford Reservation near Richland, WA. The SES will perform multiple functions in a variety of nuclear fuel, absorber, and blanket pin handling, positioning, and examination operations in 11 of 22 work stations in the FMEF Nondestructive Examination (NDE) cell. Preprogrammable, automated, closed loop computer control provides precision positioning in the X, Y and Z directions and in pin rotational positioning. Modular construction of both the mechanical hardware and the electrical and control system has been used to facilitate in-cell maintainability.

INTRODUCTION

The Fuels and Materials Examination Facility (FMEF), now under construction, is located on the U.S. Department of Energy (DOE) Hanford Reservation approximately 19 km (12 miles) northwest of Richland, WA. The FMEF will be used to perform postirradiation examination of fuels and materials that have been irradiated in the Fast Flux Test Facility (FFTF) and other breeder reactors.[1]

Both destructive and nondestructive examinations will be performed in the FMEF.[2] The nondestructive examinations will be performed in the Nondestructive Examination (NDE) cell--a large, shielded, alpha-tight hot cell approximately 12.2 m wide by 30.5 m long (40 x 100 ft.).

Several standard irradiated fuel pin handling and positioning operations will be routinely performed at 11 of the 22 stations in the NDE cell (Figure 1). At some of these stations (e.g., gamma scan, profilometry, surface examination, and eddy current) certain other types of controlled motions of the pin are also required.

An evaluation of these functional requirements established the feasibility, practicality, and desirability of standardizing on a single machine design to perform all functions at the 11 stations of interest. Such a machine, supported by appropriate fixtures, tooling, NDE sensors, and computer software could perform both the relatively simple pin handling functions as well as the more sophisticated functions required for pin examination. The resulting machine is the Standard Examination Stage (SES), shown in Figure 2.

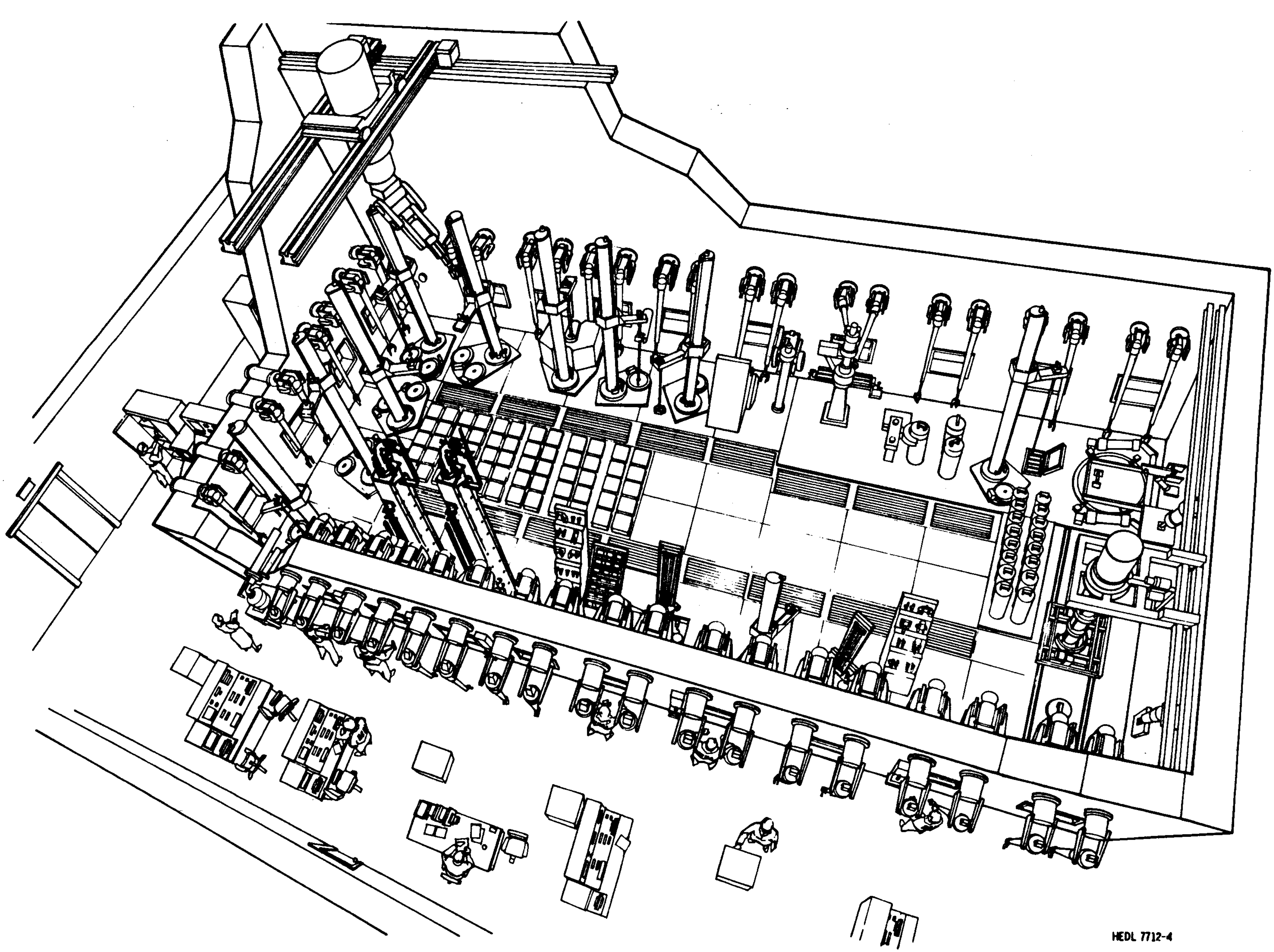

Fig Figure 1. FMEF Nondestructive Examination Cell

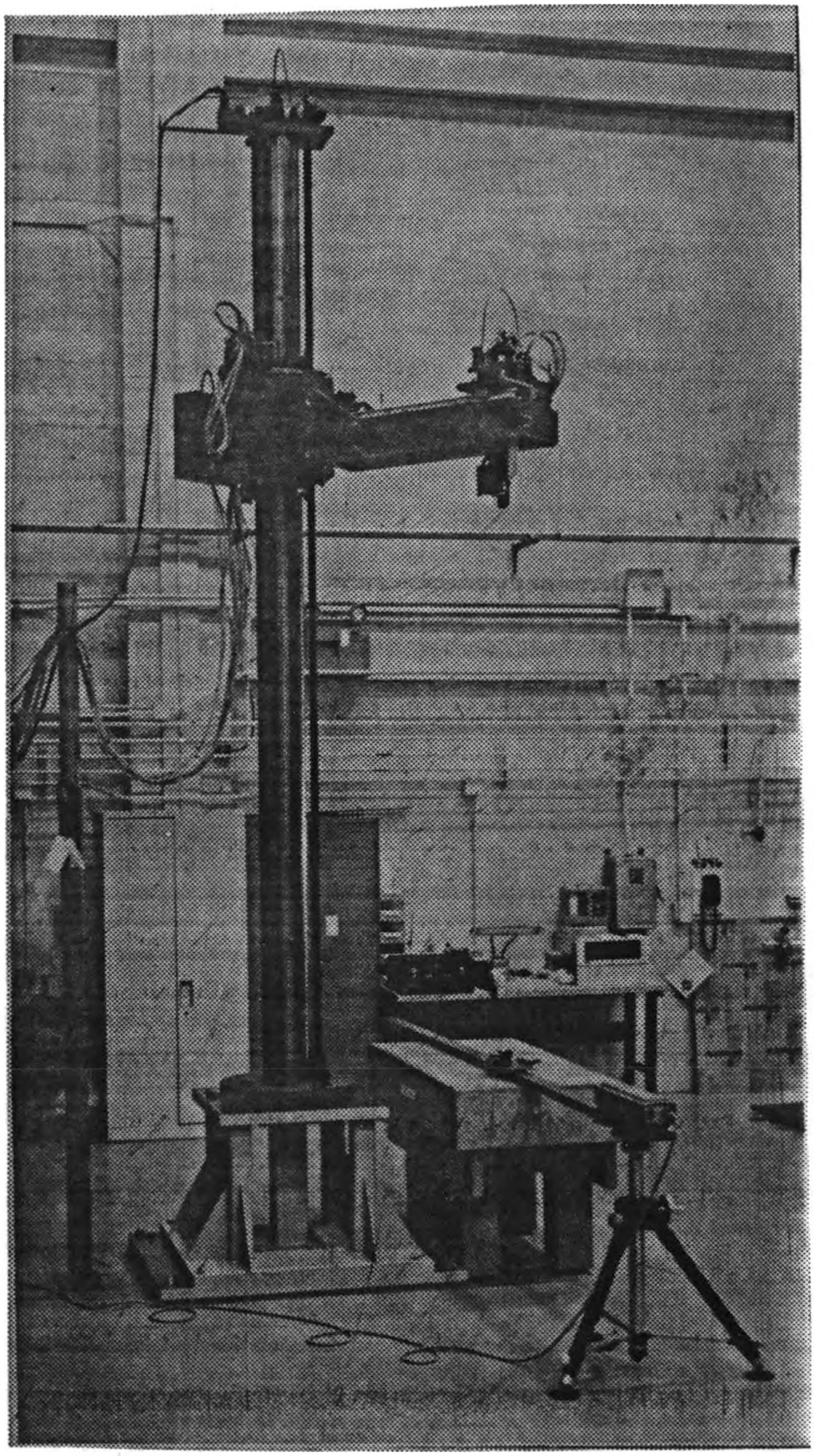

Figure 2. FMEF Standard Examination Stage

This paper describes the design basis, functional and performance requirements, and significant technical features of the SES. Emphasis will be on the mechanical design.

In mid-1977, a performance-based specification for an end item machine was prepared and, in March 1978, a contract was awarded to Sundstrand Energy Systems* to design and fabricate the first, or Testbed Standard Examination Stage (TSES), with an option for 11 plant SES's to be procured, based upon demonstration of satisfactory performance of the TSES. The TSES was delivered to the Hanford Engineering Development Laboratory (HEDL) in late October 1979, and has been undergoing acceptance testing since November 1979. The first plant SES is scheduled for shipment in February 1981.

PERFORMANCE REQUIREMENTS

Key performance requirements for the SES are summarized in Table 1. In addition to those requirements, the SES design was also based on the following ground rules and guidelines:

- Function reliably up to 10 years in a dry nitrogen or argon atmosphere, in an ionizing radiation field averaging $2x10^4$ R/hr.
- Be designed for very low probability of accidentally dropping a pin. The design goal is zero-drop.
- Be designed for long mean-times-between-failures for critical machine components.

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* Sundstrand Energy Systems, Rockford, IL

TABLE I

STANDARD EXAMINATION STAGE PERFORMANCE

	Horizontal	Vertical	Rotational
Accuracy and Repeatability			
Position a pin at a specific location in the operating range (accuracy)	± 0.762 mm ± (0.030 in.)	± 0.254 mm ± (0.010 in.)	$\pm \pi/360$ rad ± (0.5 deg.)
Return a pin to a previously established location (repeatability)	± 0.381 mm ± (0.015 in.)	± 0.127 mm ± (0.005 in.)	$\pm \pi/720$ rad ± (0.25 deg.)
Velocity and Acceleration			
Gripper translation and rotation velocity (range)	1.5 to 152.4 cm/min (0.6 to 60 in./min)	2.5 to 304.8 cm/min (1.0 to 120 in./min)	$\frac{\pi}{600}$ to $\frac{\pi}{6}$ rad/sec
Gripper acceleration (maximum)	98 cm/sec (0.1 g)	98 cm/sec (0.1 g)	
Travel Limits	76.2 cm (30 in.) 45.7 cm (18 inches) to 121.9 cm (48 inches) from centerline of column	358 cm (141 in.)	Arm 3.84 rad (220°) Gripper continuous (both CW & CCW)

- Be remotely maintainable, using an in-cell crane and electromechanical (EMM) or master/slave manipulator (MSM).
- Provide capability for manual, mechanical override of critical functions such as gripper latch/delatch or vertical drive of the horizontal arm using in-cell EMM's or MSM's.
- Design to minimize development and maximize use of state-of-the-art components, techniques, and proven industrial experience and know-how.
- Use standard commercial practices and components to the maximum practicable extent.

SYSTEM DESCRIPTION

General

The SES is an electromechanical, remotely-operated, computer-controlled pin handling and positioning system, physically similar to a tall radial drill. Overall height of the machine is $\sim$ 485 cm (16 ft.); it weighs $\sim$ 1815 kg (4000 lb). The SES combines the mechanical and control system capabilities and the operator interfaces required to provide a reliable method of positioning, sorting and nondestructively examining irradiated fueled and nonfueled pins at various stations in the NDE cell. Although specific functions vary from station to station, the SES is, generically, a "pick-and-place" machine.

The SES is a 5-axis machine (see Figure 3). The three spatial axes--vertical (Z) axis, gripper radial (R) axis and horizontal arm rotational (θ) axis--position the pin vertically and horizontally. The

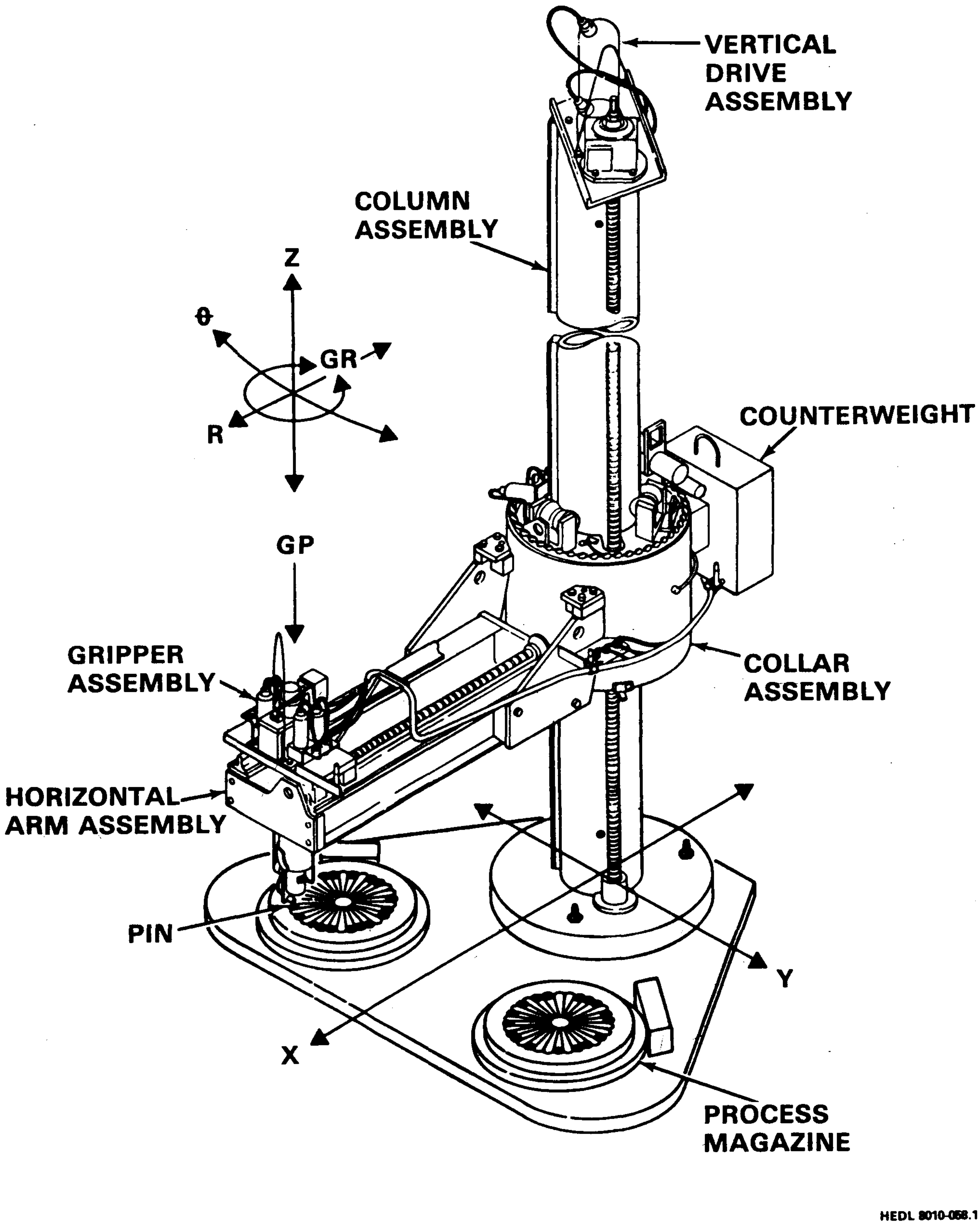

Figure 3. Standard Examination Stage Operating Coordinates

gripper rotate (GR) axis rotates the pin and positions it angularly with respect to its own longitudinal axis. Under software control, horizontal positioning may be performed by multi-axis operation of R and θ to provide straightline vectored motion in an X-Y coordinate system. Thus, gripper (i.e., pin) motion may be in X, Y, or arbitrary X-Y vectored directions, as well as in the natural machine R-θ polar coordinate system. The SES operating envelope is shown in Figure 4.

Machine motion is limited by programmable software limits, magnetically actuated electrical limit switches, and mechanical hardstops. The vertical and radial travel of the gripper is limited by the mechanical configuration. The pin can be rotated about its own (GR) axis continuously.

The gripper push (GP) "axis" is internal to the gripper and is used for gripper functions associated with installing the pin end fitting,* push testing to assure the pin is securely held, and measuring the location of the top of the pin with respect to the vertical positioning system.

Instrumentation and Control

The I & C system controls all machine motions and gripper functions of the SES. It performs these functions by means of DC servo drive motors, tachometers, absolute position encoders, and the gripper load cell, all located in-cell on the machine. The tachometers and absolute

* The pin end fitting (shown in Figure 5) is a device that is used for all pin handling operations in the NDE cell. Its purpose is to minimize the probability of dropping a pin.

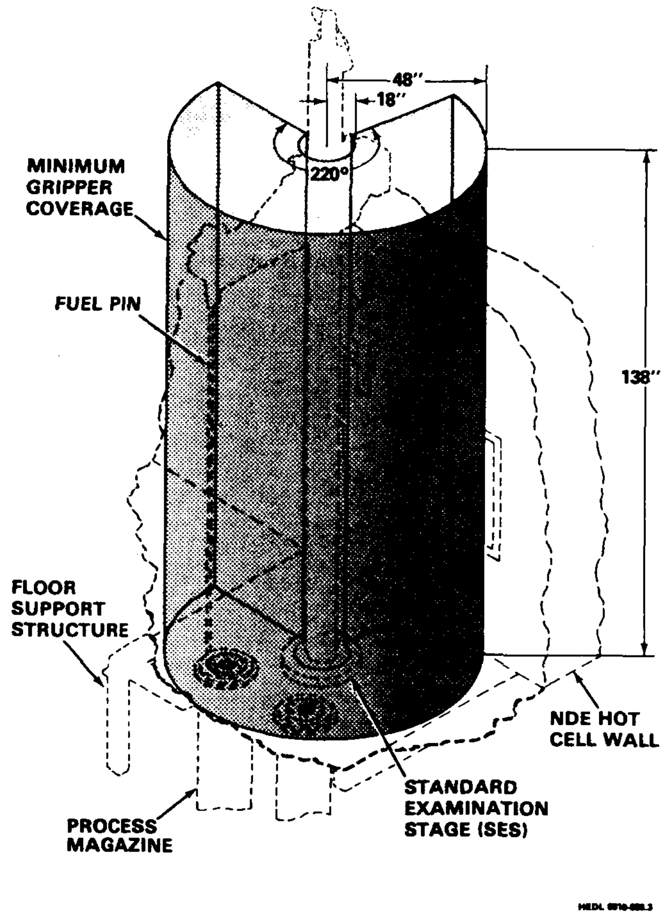

Figure 4. Standard Examination Stage Gripper Coverage Envelope.

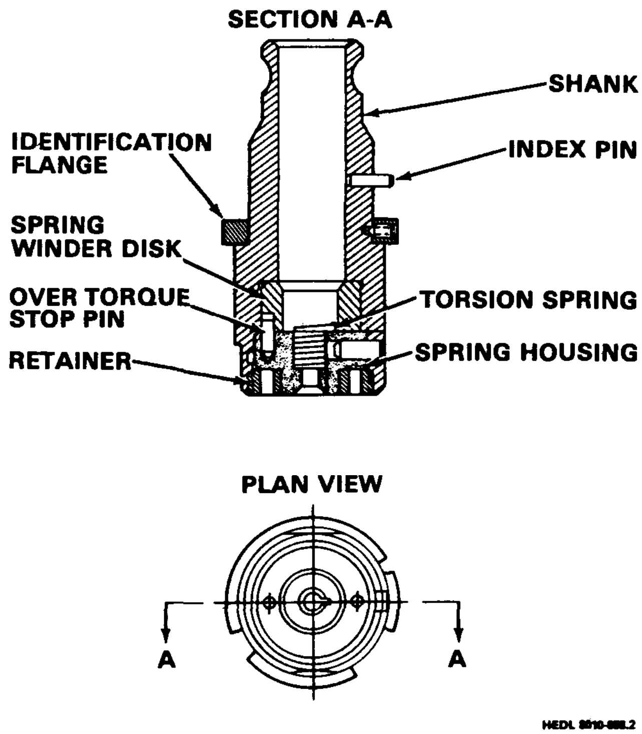

Figure 5. Pin End Fitting

position encoders monitor velocity and position in all axes and provide necessary feedback to control the machine within the performance requirements listed in Table 1.

A Digital Equipment Corporation (DEC) LSI-11/23 microcomputer-based Instrumentation and Control (I & C) system is located in the operating gallery, ex-cell, and consists of the following:

- Manual Control Panel and Computer Cabinet
- Machine Electrics Cabinet
- Operator's CRT Terminal

Necessary control and positioning data is available to the station operator at the control console CRT terminal and as LED readouts on the Manual Control Panel. Communication between the SES and the LSI-11/23 takes place through CAMAC-standardized process input/output interface and control modules.

The ex-cell I & C system communicates with the in-cell machine and instrumentation via an electrical umbilical cable, through special sealed and shielded feedthrough assemblies that penetrate the four-foot-thick concrete NDE cell shield walls. All in-cell cables to the machine are terminated at each end with MS 3100-A series connectors, and may be disconnected at the machine and at an in-cell junction panel for in-cell replacement.

Machine functions are always controlled by the computer, whether operation is from the CRT or the Manual Panel. However, end-location position commands can only be entered from the CRT. When operating from the CRT, the operator communicates with the LSI-11/23 control computer using a conversational-type command language (e.g., "DRIVE," "LATCH," "STATUS") for controlling individual machine motions or requesting status information. In Manual Panel operation, machine moves are made using a jog switch and the operator positions the pin by jogging to desired locations that are displayed on the Manual Panel.

In the event of computer failure, or for maintenance functions where single axis operation is desired, the Z-, R-, θ-, and GR-axes can be driven from a special maintenance panel in the machine electrics cabinet. From this panel the axis motors are driven directly, without feedback control; i.e., the computer is completely by-passed. Speed is controlled by setting a potentiometer that limits axis velocities to the range of 0% to 100% of full speed. In this mode of operation, only one axis can be energized at a time; i.e., multi-axis moves are not possible.

MACHINE DESCRIPTION

The SES is of modular design so that necessary maintenance or repair can be accomplished remotely. It consists of the following four basic functional subassemblies:

- Vertical Support Column Assembly
- Rotating Collar Assembly
- Horizontal Positioning Arm Assembly
- Gripper Assembly

The following sections describe the design and functions of individual machine modules:

Column Assembly

The column assembly is the SES primary structural support member. It supports the vertical drive assembly and the rotating collar/horizontal arm/gripper assemblies, and provides the means for securing the machine to the cell floor and for aligning the column vertically, using adjusting screws in the base.

The vertical drive assembly consists of a DC servo motor and integral tachometer that drives a vertical ball screw and nut assembly through a right angle gearbox. The motor incorporates an integral brake that is energized to release. Removing power from the motor engages the brake to stop motor/ball screw rotation, thus providing fail safe operation.

Rotating Collar and Horizontal Arm Assemblies

The horizontal positioning arm is attached to the support column through the rotating collar assembly. The collar assembly is supported from the ballscrew by the ball nut which is attached to the lower plate of the inner, non-rotating collar. The collar and horizontal arm assembly are guided and stabilized during vertical travel by three equally-spaced sets of rollers mounted on the upper and lower plates of the inner collar. A counterweight, designed to balance out component bending moments on the column and to minimize moment loads on the vertical guide rollers, is attached to the outer collar opposite the horizontal arm assembly.

A precision Helicon gear, mounted on the outer collar, is driven by a DC servo gearmotor and matched Helicon pinion to produce rotational (θ-axis) motion of the horizontal arm. The gear motor is mounted on the upper plate of the inner collar.

The horizontal arm assembly is located on the collar by three pins and secured with captive screws. This attachment method permits remote removal and replacement of the horizontal arm. The gripper mounting plate is supported on a pair of guide rails on the arm and driven in the radial direction (R-axis) by a DC servo gearmotor mounted at the inboard end of the arm.

Gripper Assembly

The gripper assembly (shown schematically in Figure 6) is the module most critical to SES performance. It bolts directly to the gripper mounting plate on the horizontal arm, and is accurately positioned with alignment pins and secured with captive bolts, which permit remote removal and replacement using an EMM. Gripper functions which may be performed under direct manual or programmed control are discussed below:

- Gripper Latch/Unlatch - A sliding sleeve, ball-collet latch secures the pin end fitting (Figure 5) in the gripper. To unlatch and release the end fitting, a solenoid is energized to raise the sleeve from the latched position shown in Figure 6. Gravity and a spring maintain the sleeve in the latched position when the solenoid is deenergized, providing fail safe operation.

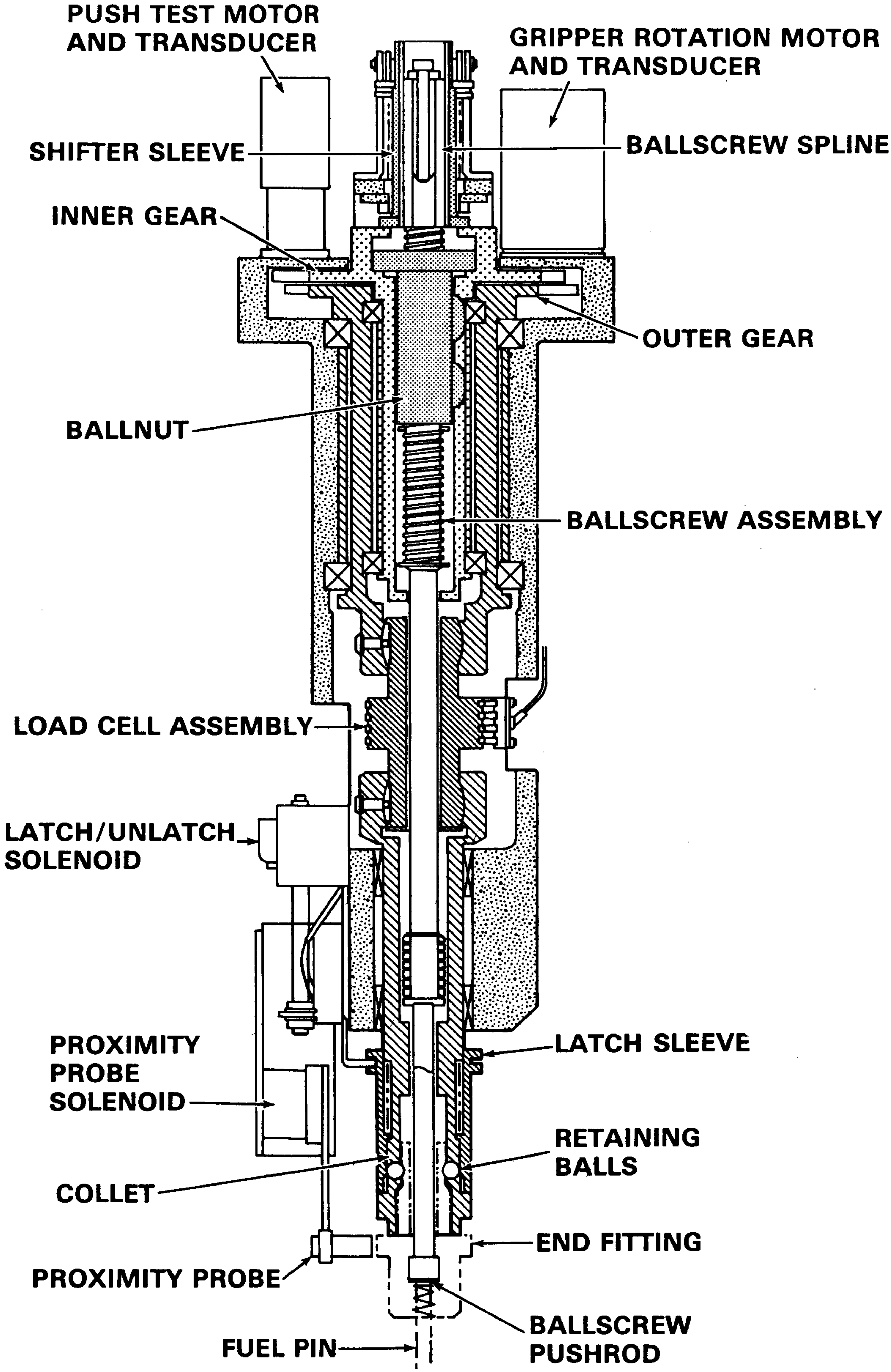

Figure 6. SES Gripper Assembly - Schematic Representation

- Install a Pin in the End Fitting - The ballscrew and nut assembly internal to the gripper are used to actuate a torsion spring in the end fitting. This spring grips the upper end cap of the pin and secures it in the end fitting.

  The ballscrew is placed in either a translation or rotation mode (not simultaneously) by a solenoid actuated shifter mechanism at the top of the gripper assembly. Rotation is used to actuate the end fitting springs; translation forces the ballscrew push rod against the top of the pin with an axial force up to 34 kg (75 lb) to verify that the pin is securely held by the end fitting. The push force is determined by controlled compression of a calibrated, high rate spring as the ballscrew is lowered against the pin.

- Identify an End Fitting - Each end fitting is assigned a unique identifier number which is encoded in the identification flange by a group of notches machined into the flange (Plan View, Figure 5). An electromagnetic proximity probe on the gripper senses these notches as binary coded numbers when the end fitting is rotated past the probe by the GR-motor.

- Sense, Measure, and Limit Vertical Loads - An accurate and sensitive strain gage load cell is incorporated in the gripper to perform these functions. It protects the pin from excessive buckling or tensile loads, detects when the gripper is properly engaged with an end fitting before latching, and senses when the end fitting is properly supported before delatching. The load cell rotates with the gripper, so its output signal is transmitted to the control system by a slipring assembly mounted on the fixed gripper housing.

The load cell is designed to measure loads over a range of ± 2500 grams (± 5.5 lb) relative to the empty gripper. The weight of a pin and end fitting is ∿ 1000 grams. In this range, load cell accuracy is ± 25 grams; sensitivity is ± 10 grams. Operating load limits will normally be set to within ± 250 grams (0.5 lb) of the nominal pin/end fitting weight.

MAINTENANCE AND MAINTAINABILITY

Because the FMEF is a high throughput facility, the SES is designed for maximum practicable operating availability. This is achieved by selecting components with appropriate derating factors to maximize operating life and minimize down time.

The four major modules of the SES are replaceable using the in-cell overhead crane, EMM's or MSM's. Most malfunctions will be repaired by remote removal and replacement of modules containing the defective components. Exceptions to this approach are the drive motors, encoders, and electrical cables which are designed to be replaceable in-cell, since they are the components considered most likely to fail. For installation, modules are guided and located by tapered pins or keys. Fasteners are captive on the module and are designed with appropriate leads to aid engagement of remotely positioned and actuated tools or fixtures.

Each remotely removable module or component is provided with appropriately designed lifting bails or lugs, or is otherwise capable of having necessary lifting fixtures attached remotely. These lifting devices are located so that lifting equipment can be attached at or near the center of gravity to stabilize the module during handling.

Individually removable modules or components are permanently marked with a unique identifier number or symbol that will permit reading and interpreting the identifier by direct visual observation.

The SES is designed and constructed to simplify decontamination to the maximum extent practicable. Crevices, cracks, and blind holes are avoided. Unpainted, machined surfaces are finished to 125 rms. maximum. Fabrication techniques, such as casting, that result in surface porosity are avoided or surfaces are sealed with non-porous protective coatings. Welds have an as-welded surface roughness of 125 rms or better and are free of surface porosity, or are ground smooth.

CONCLUSIONS

The Standard Examination Stage is a precision machine that is designed to function either in a fully automated, preprogrammed, closed loop computer-controlled mode, or as a manually-operated device that can be used for a variety of pin handling, positioning, and examination functions in the FMEF NDE cell. The SES design reflects extensive application of state-of-the-art technology from the fields of automated machine tool practice, industrial robotics, and sophisticated computer control. All the required functional capabilities discussed in this paper have been satisfied. Modular construction has been used on both the machine and its control system to facilitate in-cell maintenance. Acceptance testing thus far indicates the machine will be capable of satisfactorily meeting all key performance requirements listed in Table I. Final acceptance testing of the SES will be completed and the SES will be used in prototype examination station testing starting in late 1980.

ACKNOWLEDGEMENT

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LIST OF FIGURES