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INTEGRAL FAST REACTOR FUEL PIN PROCESSOR

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ABSTRACT The pin processor receives metal alloy pins cast from recycled Integral Fast Reactor (IFR) fuel and prepares them for assembly into new IFR fuel elements. Either full length as-cast or pre-cut pins are fed to the machine from a magazine, cut if necessary, and measured for length, weight, diameter and deviation from straightness. Accepted pins are loaded into cladding jackets located in a magazine, while rejects and cutting scraps are separated into trays. The magazines, trays, and the individual modules that perform the different machine functions are assembled and removed using remote manipulators and master-slaves.

INTRODUCTION

The Integral Fast Reactor Fuel Cycle Facility, located at Argonne National Laboratory-West on the Idaho National Engineering Laboratory, will demonstrate the commercial-scale remote pyrometalurgical recycling of metallic fuels from liquid metal cooled reactors. Process operations will be carried out in the facility inert gas hot cell. Anticipated average radiation exposure rates to the equipment are on the order of 100 Gy/hr. Operations involving subassemblies and intact fuel elements are performed in the adjacent air atmosphere hot cell.

Experimental Breeder Reactor II (EBR-II) sub assemblies are dismantled and the fuel elements are chopped into small pieces. Uranium, plutonium, and other actinides are electro-chemically extracted, purified, and then injection cast into new ternary alloy fuel pins. The pins are used to fabricate fuel elements and produce new subassemblies for EBR-II. The pin processor resides in the fuel cycle between the casting furnace and the element welder. After casting and mold removal, the pins are placed into a magazine and loaded onto the processor.

The pin processor is a modular assembly; the delivery module, the pin pusher, the shears, the gauging module, the inspection module, and the processed pin carrier. The modules all mount to a support table located in the argon cell. Control signals, monitoring, and data acquisition are handled through a programmable logic controller and various signal conditioners arranged in a single cabinet located outside the cell. A personal computer based operator control station allows personnel to issue commands, change control variables, and perform material accountability functions. The pin processor is currently being qualified prior to transfer into the hot cell.

OPERATION

Using the electro-mechanical manipulator (EM) and the master/slaves, personel will install an empty element fabrication magazine (EFM), pin scrap tray, reject pin tray, and a full pin magazine. Operation begins with a diagnostic program that exercises all of the modules, places moving parts in their starting positions, loads initial parameters, and then runs a standard to confirm proper operation. One at a time pins are fed from the pin magazine and, if not pre-cut during the mold removal operation, each end is sheared off to produce a pin of the desired length. When pre-cut pins are used the control software skips the cutting steps. Diameter, length, and weight are measured and the pin is checked for deviation from straightness. The result of each measurement is compared to a range of acceptable values. A result outside of the acceptable range causes the pin to be rejected without further processing.

A pin within specification allows continued processing until it is inserted into a cladding jacket. The jackets, assembled with lower end fittings and already containing bond sodium, are delivered to the pin processor in the EFM. The EFM is placed in a collar prior to operation and rotates to move new jackets into position as pins are accepted. When all the jackets have been filled the magazine is transferred to the welder, where the top fittings

are attached. Pins that do not meet specifications are collected in the reject pin tray. Cut off ends are collected in the pin scrap tray.

Three operating modes are provided. In "automatic", the machine processes one pin at a time and continues until either the pin magazine is empty or the element fabrication magazine is full. If no pins are rejected, filling the 36 position EFM takes about 2 hours. The "semi-automatic" mode allows portions of the operating sequence to be performed using single commands. A "manual" mode permits an operator to exercise individual parts or instruments for troubleshooting and maintenance.

Interlocks are imposed through the control software and prevent operations that would damage the machine, such as firing a shear with the pin pusher extended. Proximity switches provide signals indicating the status of trays and magazines, and help to ensure that material control and criticality safety requirements are met. Errors, generated by timers, a motor/resolver mismatch, improper magazine status, or challenges to interlocks immediately terminate operation and produce an alarm.

MODULES

The delivery module, shown in Figure 1 below, consists of the pin magazine, the linear actuator which feeds pins from the magazine, and the shuttle arms and drive that deliver the pin to the shear module. Two flat plates held apart by spacers form the main part of the pin magazine, which contains up to 36 pins. A grooved drun in the magazine base is rotated back and forth by the strok of a linear actuator. A pin rolls on to the shuttle arm when the groove is uncovered and a new pin drops into th groove as the drum rotates back into the magazine. A standard stepper motor/resolver drives a ball screw linea positioning table to move the shuttle arms between the pi magazine and the shear. The table and magazine bot mount to a plate which bolts to a bearing supported shaft The entire module pivots around the shaft axis to expos the shear module for maintenance.

The pin pusher moves the fuel pins through the shear the gauging module, the inspection module, and on to th processed pin carrier. A support rail mounts to the tabl and the shear module. In turn, a ball screw and its steppe motor/resolver drive mount to the support rail. A 4.7 mm diameter rod, connected to the ball housing at one end through a linear potentiometer and supported at the other by a guide near the shear, pushes each pin along the pin path described above. Position is referenced to a hard stop (zero). Along the direction of pin travel distance between points is determined using the difference in resolver output at identical potentiometer readings. Positions are achieved by simply running the push rod (or the fuel pin) into a hard stop until a certain potentiometer output is sensed. Motor slip is detected by a mismatch between motor "position", measured by the number of steps ordered, and the change in resolver output. A typical operating speed for the pin pusher is about 2.5 cm./sec.

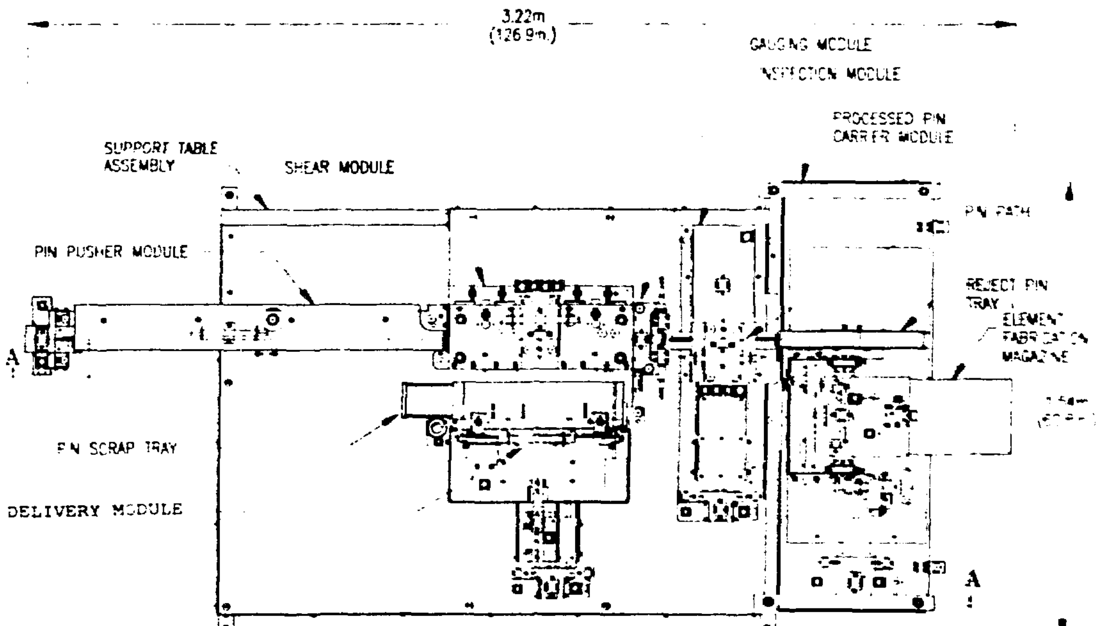

Figure 1 Pin Processor - Plan View

A pair of solenoid driven die sets is the main assembly of the shear module. A load sensitive gag mounts above and between the die sets, and a hinged plate, referred to as the number one stop, mounts near the right hand die. Pins are received from the delivery module and rest in a grooved support. The pin pusher forces each pin against the number one stop, the gag holds the pin in the groove, and the right shear cuts about 2.5 cm. from what will become the bottom of the fuel pin. The sequence is repeated for the left hand shear which cuts about 10 cm. from the top of the pin. The cut ends fall down ramps and collect in the pin scrap tray. The cut pin is again forced into the number one stop to obtain the first position for the length measurement. Finally, the gag and number one stop are raised to allow the pin to be pushed through the diameter gauging module and up against the number two stop. The pin length is then calculated as the distance traveled between the two stops.

Diameter measurements are made using a pair of contacting gauge probes located on the pin path immediately after the number one stop. As it moves along the pin path each pin is guided by rollers attached to the ends of the probes. Deflection of the probes by the pin generates the signals used to produce the diameter measurement. At a pin speed of about 2.5 centimeters per second the system is able to deliver about four readings each centimeter.

The inspection module contains a digital balance, a straightness gauge, and the shuttle necessary to move pins between the two. The shuttle consists of a pair of arms attached to a ball screw with a standard stepper motor/resolver drive assembly. As pins leave the diameter gauge they approach the number two stop through two grooved blocks, which can be seen in Figure 2 below. The blocks are arranged such that bent pins will hang up in the groove. The pin pusher stops when a pre-set force is achieved and the length is computed. Bent pins will give a long result for this first test. The upper block is raised, the pin pusher runs until the force is again reached, and a second length is calculated. A straight pin of the correct length should produce two "good" length measurements. Straight but short or long pins will fail the second test. If both lengths are acceptable the scale shuttle arms move the pin out of the pin path, deposit it on the balance, and return it to the pin path.

The processed pin carrier supports the reject pin tray, the collar and drives for the EFM, and the number two stop. A linear positioning table is used to move either the EFM, the reject pin tray, or the number two stop into line with the end of the pin path. The EFM is installed in and removed from its collar while oriented vertically and is fixed into position on locating pins. A linear actuator tilts the collar to the horizontal operating position. The EFM

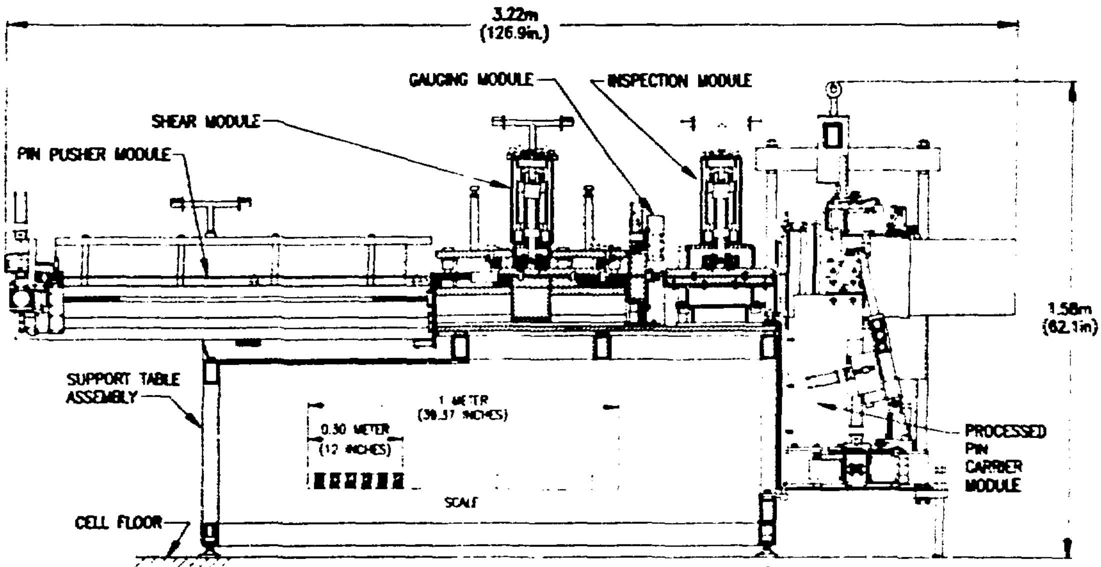

Figure 2 Pin Processor - Section Through Pin Path

is rotated by a motor/resolver driven gear that is supported in the outer sleeve of the collar by a bearing. The reject pin tray is used to collect pins that fail the inspection criteria. The number two stop is used as the second reference point for the pin length measurement.

REMOTE HANDLING FEATURES

Each module is remotely removable. An electro-mechanical manipulator (EM) handle is built in or can be attached to each module with a few simple operations. All modules (except the support table) weigh less than the 340 Kg. limit of the EM. Smaller parts have handles designed to be gripped using the Master Slaves. Guide pins position the modules to insure their correct location at assembly. Captive bolts secure the modules to the table and are used to simplify installation. Electrical connections are made using standard keyed amphenol connectors with their locking rings removed.

High maintenance items have additional features to facilitate remote operation. All motors and actuators can be accessed using the master-slaves. Three of the four ball screw drives use motors and resolvers standardized for all cell process equipment and the drive mounts for these three are interchangeable. The delivery module mounts to a bearing supported shaft, allowing the entire part to pivot and provide access to the shears for replacement of the cutting blades. The gage for both the shear and the straightness gauge use identical mounting towers and stepper motor driven linear actuators. The mounting towers can be removed without disturbing the rest of the module. Similarly, the scale can be removed from the machine without disturbing the rest of the inspection module.

OPERATOR CONTROL

An Operator Control Station (OCS) allows personnel in the facility operating corridor to monitor the machines' status, issue commands, change parameters, and perform material accountablility tasks. The OCS is a networked PC with touchscreen control. Resident I/O drivers communicate with an Allen-Bradley Programmable Logic Controller (PLC). In turn the PLC sends and receives signals to and from the various stepper motor translators, R-D converters, and instrument electronics. The PLC and the other control electrical and electronic devices all mount in a single cabinet which is located in the facility basement. Cable bundles lead from the cabinet and plug in to connectors on the outside of the cell. Similar wire bundles run from the machine to the connectors inside the cell.

Operators log on to the machine and proceed through multi-level menus to the screens needed to perform a desired task. Overview screens, like the one for the automatic mode shown in Figure 3, indicate the status of the main modules. From this screen an operator can initiate the automatic sequence and obtain additional information by touching the outline of a module. Figure 4 shows some of the detailed information and control functions available on the manual control screens. Commands are issued in a two step process that requires the operator to first select an action and then initiate it by using a GO button.

CONCLUSION

The remote operating features and modular approach used in the design and construction of the pin processor will enhance its ability to perform in the IFR fuel cycle hot cell environment. The machine is currently being qualified, which will demonstrate assembly, operation, disassembly, and corrective and preventive maintenance by remote means. Additional qualification will include demonstrations of the ability to correctly measure and accept or reject precise standards. After qualification the pin processor will be transferred into the hot cell and operated for the entire IFR fuel cycle demonstration.

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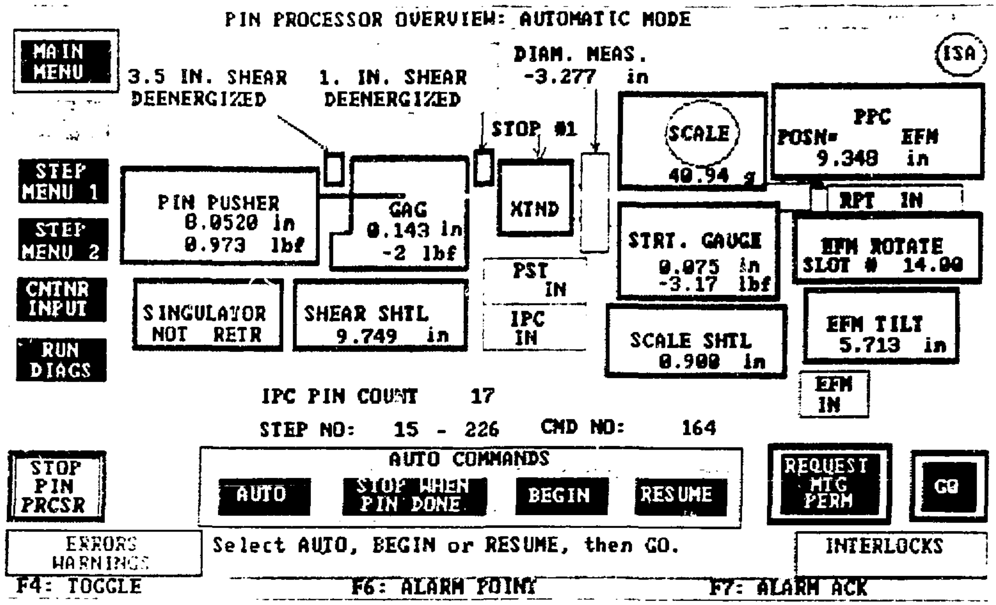

Figure 3 Pin Processor Operator Control Automatic Overview Screen

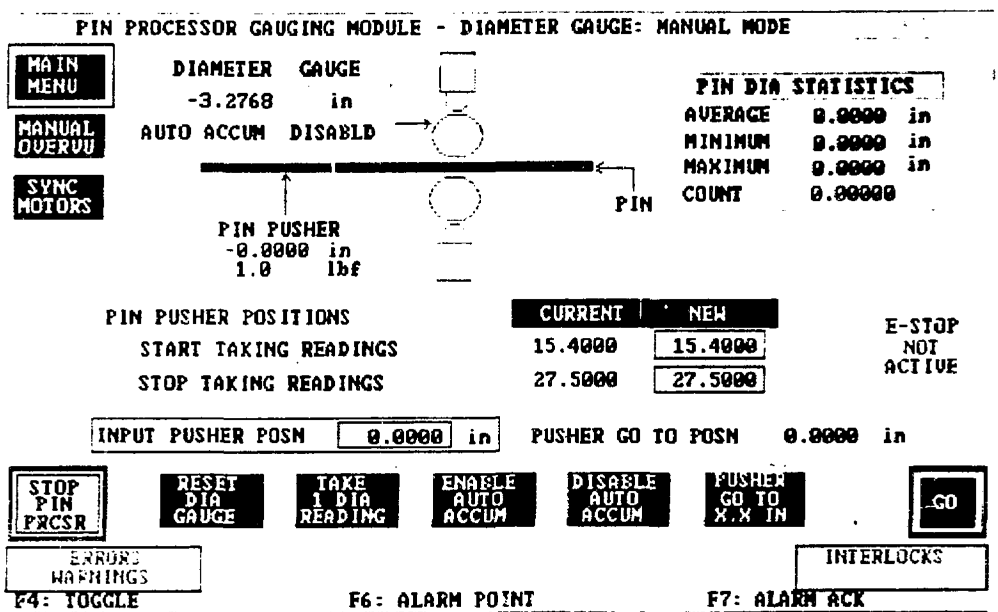

Figure 4 Pin Processor Operator Control Manual Control Screen