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EBR-II FUEL-UNLOADING MACHINE:

Design and Performance Characteristics

by

E. Hutter, P. Elias,

D. J. Veith, and W. R. Ware

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Reactor Engineering Division

June 1966

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*Plant Engineering Division

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EBR-II FUEL-UNLOADING MACHINE: Design and Performance Characteristics

by

E. Hutter, P. Elias,
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ABSTRACT

The fuel-unloading machine forms the link between the fuel-handling mechanisms inside the sodium-filled primary tank and the interbuilding coffin. The machine consists of a self-propelled shielding cask, which moves between the primary-tank transfer port and the interbuilding-coffin pit. A gripper mechanism can be extended through the cask shielding valve to grip the fuel subassembly and pull it into, or lower it out of, the shielding cask. An automatic argon-circulating system provides cooling, heating, and sodium blow-off capabilities. The electrical control is interlocked with the fuel-handling control systems.

This report describes the fuel-handling system, in general, the design features of the fuel-unloading machine, and the operation of the system.

I. INTRODUCTION

The Experimental Breeder Reactor II (EBR-II) is an unmoderated, heterogeneous, sodium-cooled reactor, designed to produce 62.5 MW of reactor heat. The associated power plant converts this heat into 20 MW of electricity. The spent reactor fuel is channeled through the Fuel Cycle Facility, where it is melted, re-enriched, and refabricated for return into the reactor.^{1,2} The fuel, in the form of fuel subassemblies, remains fully submerged in sodium during its transfer between the reactor and the close-by storage rack. This transfer is made in groups of up to 17 subassemblies. After a cooling period in sodium, each fuel subassembly is moved (unaffected by reactor operation) by the fuel-handling system, the fuel-unloading machine, and the interbuilding coffin³ into the Fuel Cycle Facility. Such a transfer is performed in both directions every second day.

A. Plant Description

EBR-II is an integrated nuclear power plant,^{1,2} located at the National Reactor Testing Station in Idaho. Its main facilities are the reactor plant, the Fuel Cycle Facility, the sodium-boiler plant, the power plant, and the laboratory and service building. The reactor, the primary sodium-coolant system, and several ancillary systems are housed in the reactor plant (Fig. 1), which is a steel containment vessel, 80 ft in diameter, 140 ft high. The fuel reprocessing is done in the Fuel Cycle Facility, which contains a circular shielded cell. The major part of the secondary sodium system, including the ac electromagnetic pump and the sodium-to-water steam-generating equipment, is located in the sodium-boiler plant. The power plant houses the steam turbine and generator and the associated electrical system, as well as the control room for the reactor.

B. Reactor Description

The reactor and the entire primary system (including the heat exchanger) are contained in a large vessel (primary tank) and operate completely submerged in the bulk-sodium coolant. The primary-sodium coolant is pumped directly from the bulk sodium into the reactor vessel and up through the core. The effluent coolant flows from the vessel, through the shell side of the heat exchanger, and back to the bulk sodium. The secondary-sodium system transfers the heat to a steam generator, which supplies the steam for a turbine-generator.

The reactor assembly (Fig. 2) consists of the reactor vessel, the grid-plenum assembly, and the vessel cover. The assembly is surrounded by the neutron shield and is submerged beneath approximately 10 ft of sodium.

The grid-plenum assembly is a core grid structure, which supports and locates the subassemblies and incorporates the coolant inlet plena. The grid structure accommodates 637 hexagonal subassemblies spaced on a triangular pitch of 2.320 in. The nominal core loading consists of 47 enriched-uranium core subassemblies, six enriched-uranium inner-blanket-type subassemblies, two safety subassemblies, 12 control subassemblies, 60 natural-uranium inner-blanket subassemblies, and 510 natural-uranium outer-blanket subassemblies. Each subassembly contains a number of fuel elements and blanket elements of size and shape appropriate to its particular type (Figs. 3 and 4).

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Fig. 1. EBR-II Reactor Plant

112-496 Rev. 1

Fig. 2. Reactor Assembly

111-5157

Fig. 3. Core Subassembly

112-4458

Fig. 4. Control Subassembly

A single fuel-subassembly size is employed, resulting in a closely-packed reactor geometry (Fig. 5). Each hexagonal fuel-subassembly tube is 2.290 in. across external flats, with a 0.040-in. wall thickness. A nominal clearance of 0.030 in. between fuel subassemblies facilitates their removal from the reactor. The upper adapter on each type of fuel subassembly is identical, so that all fuel subassemblies are accommodated by the same handling and transfer mechanisms. The lower adapters are of different sizes to distinguish between the three basic types of fuel subassemblies, and are of different configurations to accommodate the two coolant systems.

The reactor-vessel cover, serving as a neutron shield as well as a closure, is clamped to the vessel flange by three holddown clamps. When the cover is lowered, it forms the reactor upper plenum from which the coolant flows to the heat exchanger.

The control-rod drive shafts operate through seals and guide bearings in the vessel cover. Each control rod is operated independently by an electromechanical drive mounted on top of the rotating-shield plug (Fig. 6). In the event of a reactor scram, the 12 control rods operate simultaneously.

Normal operational control is not effected by the two safety rods, which are a separate part of the system. The main purpose of these rods is to provide available negative reactivity during reactor shutdown.

The primary tank contains the reactor vessel, the two primary sodium pumps, the heat exchanger, the storage rack, various instruments, mechanisms, and ancillary systems, as well as 80,000 gal of sodium. The primary tank is of double-wall construction to provide maximum reliability of sodium containment. The inner tank is 26 ft in diameter; the side walls are constructed of 0.5-in.-thick plates, and 1-in.-thick plates are used for the tank bottoms. The bottom-plate structure of the inner tank is designed to support the reactor-vessel assembly, the neutron shield, some of the primary-sodium piping, and the entire sodium load. This load is transferred by the tank wall to the top cover, which supports the tank. The structure of the outer tank is designed to carry only the sodium load, in the event of a leak developing in the inner tank. The cover of the primary tank is 39 in. deep and contains shielding material and thermal insulation. The region above the bulk sodium is filled with inert argon gas.

The primary tank has no side or bottom openings but allows access to its interior through 67 nozzles in the cover and one large circular opening in the center of the cover. Each nozzle accommodates one, in most cases removable, primary-system component, and the central opening accommodates the rotating shield plugs.

112-4467 Rev. 1

Fig. 5. Reactor Arrangement

112-4396

Fig. 6. Control-rod Drive

The primary tank and its contents and the components that are connected to the primary-tank cover are supported by six hangers, which in turn transfer these loads to the top structure beams. Each hanger is supported by a roller so that differential radial expansion between the top structure and the primary-tank cover will not produce additional stresses in the system. The primary-tank design and the method of support are arranged to provide radial expansion about the vertical centerline of the system. The most critical units, the reactor, the rotating plugs, which index the control-rod drives, and part of the fuel-unloading mechanisms, are centered on the physical centerline of the system. Differential vertical expansion is reduced by using identical material for all equipment in the system, and maintaining isothermal conditions wherever possible.

C. Fuel-handling Description

The fuel-handling system (Fig. 7) is designed to perform fuel-subassembly transfers in two phases: The first phase begins immediately after reactor shutdown and includes all transfer steps between the reactor and the storage rack, both of which are submerged in the sodium-filled primary tank. The fuel subassemblies remain below the bulk sodium surface at all times, making the transfers relatively simple since no special cooling requirements are needed. Neither are complex logistics involved that might depend on the work load in the Fuel Cycle Facility. Thus, the first phase of fuel handling is fast and interrupts reactor operation for a short time only. The subsequent steps in fuel handling can be performed during reactor operation, including a 15-day cooling-off period for spent-fuel subassemblies in the storage rack. This permits the decay of fission-heat generation to a level at which a fuel subassembly can be conveniently gas-cooled. The second phase of fuel handling includes the transfers between the storage rack, the fuel-unloading machine, the interbuilding coffin, and the Fuel Cycle Facility. The timing of these transfers is affected by the cooling-off period in the storage rack and the refabrication schedule in the Fuel Cycle Facility.

The individual steps of the fuel-handling operations (described in the paragraphs below) are as follows:

- (1) Preparation for fuel handling.
- (2) Transfer of a fuel subassembly from the reactor to the storage rack.
- (3) Transfer of a fuel subassembly from the storage rack into the Fuel Cycle Facility.
- (4) Loading sequences.

112-4625 Rev. 1

Fig. 7. Fuel-handling System

1. Preparation for Fuel Handling

This step includes the administrative and technical transfer from the operating mode to the fuel-handling mode. It also consists of such steps as melting the dip-ring seals of the rotating shield plugs, releasing the control rods from the control drives and raising the control-drive cluster to increase the separation, unlocking the cover from the reactor vessel, raising the reactor vessel cover, and preparing various fuel-handling mechanisms for operation.

2. Transfer of a Fuel Subassembly from the Reactor to the Storage Rack

The core-gripper mechanism is an electromechanical device which grips a fuel subassembly by its upper adapter and raises it vertically to an elevation that places its lower end above the flange of the reactor vessel (see Fig. 8). The gripper mechanism employs a force-limiting device and a sensor and is assisted by the holddown mechanism, whose principal function is to hold the six adjacent subassemblies in the reactor while the central one is being removed. In addition, the holddown mechanism spreads the six fuel subassemblies slightly, thus providing more clearance for the fuel subassembly being removed. The holddown also acts as a guide for the gripper and prevents the fuel subassembly from swinging during plug rotation. The gripper and the holddown mechanisms are mounted on the small rotating shield plug, which is eccentrically located in the larger rotating shield plug. Proper rotation of the two plugs positions the gripper and hold-down mechanisms not only over any selected reactor grid location, but also over the "transfer point" where the fuel subassembly is transferred from the core gripper to the transfer arm (see Fig. 9). During this step, the fuel subassembly is held simultaneously by the core gripper and the transfer arm, and special sensing tests are performed before and during the transfer from one mechanism to the other. The transfer arm is rotated, carrying the fuel subassembly in a horizontal arc over the storage rack or below the transfer port. A funnel-shaped, fuel-subassembly basin (Fig. 10) is located directly below this path. In the remote possibility that a fuel subassembly would be dropped from the transfer arm, it will fall into the basin and then slide into a removable container.

The storage rack is a cylindrical container with a storage capacity for 75 fuel subassemblies, which are held in the upright position in a distinct spacing pattern consisting of three concentric circles. The storage rack can be rotated and moved vertically about 9 ft, yet it always remains submerged in the primary-tank bulk sodium, exposing the fuel subassemblies to the sodium coolant. With the fuel subassembly hanging from the transfer arm, the storage rack is raised and the fuel subassembly is thus inserted into the available storage location, where it remains until its heat generation has decreased to a level that will permit gas cooling.

3. Transfer of a Fuel Subassembly from the Storage Rack into the Fuel Cycle Facility

After approximately 15 days of cooling in the primary-tank bulk sodium, the fuel subassembly is removed from the storage rack by the transfer arm, which moves it under the transfer port. The fuel-unloading-machine gripper passes through the transfer port and lifts the fuel subassembly out of the sodium into the shielding cask. An argon gas system

provides the necessary cooling. By operations described in later chapters, the fuel subassembly is transferred into an "interbuilding coffin," where forced argon-gas cooling continues. The interbuilding coffin is passed through an air lock out of the reactor plant into a cleaning area, where the sodium clinging to the fuel subassembly is removed by circulating steam and water through the interbuilding coffin. The cooling medium is changed from argon to air, and the fuel subassembly is moved into the air cell of the Fuel Cycle Facility for disassembly and subsequent refabrication.

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Fig. 8. Core Gripper

the core-gripper mechanism, the two rotating shield plugs, and the storage rack is controlled by a punched-card system. The "address" for each fuel subassembly to be transferred is preprogrammed and compared with a record card, punched out automatically after arrival at its destination. In general, the EBR-II fuel-handling philosophy is based on a permissive system, requiring each step to be initiated by the operator, but providing an electrical control which permits its performance only if all the preceding steps have been properly executed.

4. Loading Sequences

The loading sequence of a new or refabricated fuel subassembly involves steps similar to steps 2 and 3 above but in reversed order. The fuel-handling operations concerning transfers between the reactor and the interbuilding coffin are divided into electrically sequenced steps performed mainly by electrically or pneumatically actuated mechanisms. The major exception is the transfer-arm mechanism, which is also electrically sequenced but which is manually operated to provide special sensing between the transfer steps. Rotation of

112-1998 Rev. 1

Fig. 9. Fuel-handling Mechanisms in Primary Tank

Fig. 10. Fuel-subassembly Basin

II. FUEL-UNLOADING MACHINE

A. General

EBR-II fuel-handling operations encompass the transport of fuel subassemblies between the reactor (inside the primary tank in the reactor plant) and the shielded cave in the Fuel Cycle Facility. The fuel-unloading machine (Fig. 11) acts as a link between the transfer-arm mechanism, which is operating submerged in sodium inside the primary tank, and the interbuilding coffin, which is used for fuel-subassembly movement into or out of the reactor plant.

The basic types of fuel subassemblies that have to be handled are the a) core subassemblies; b) inner-blanket subassemblies; c) outer-blanket subassemblies; d) control rods and thimbles; and e) safety rods and thimbles.

Various special fuel subassemblies and tools that have to be accommodated also include the oscillator rod, irradiation subassemblies, experimental subassemblies, dummy subassemblies, tools for the control- and safety-rod thimbles, etc.

Calculations show that a 13.5-in.-thick lead shield is required to reduce the radiation from the most radioactive fuel subassembly to a permissible level, even after a 15-day storing period.⁴ Such a fuel subassembly, after 2 a/o maximum burnup, generates approximately 2.3 kW of heat. An argon-gas system, which is also compatible with the primary-tank blanket gas, prevents a meltdown while the fuel subassembly is in the fuel-unloading machine.⁵ Similarly, the argon system heats new fuel subassemblies to a temperature that allows the sodium bond to melt, and that reduces the thermal shock sustained by a cold fuel subassembly when it is submerged into the 700°F primary-tank bulk sodium. The argon-gas system is also used to "blow off" sodium that continues to cling to the fuel-subassembly surfaces after it has been pulled out of the primary-tank sodium.

The shielding cask and the gripper assembly are mounted on a carriage which moves on two 24.5-ft-long rails to its points of destination (see Fig. 12). One stop is located above the primary tank directly in line with a sealable and shielded access nozzle, called the "transfer port." The bottom of the shielding cask can be sealed against the top of the transfer port, and the remaining air inside the closure can be replaced with argon. Subsequently the shielding valves of the cask and transfer port are opened, allowing the gripper of the fuel-unloading machine to descend 27 ft, to the level of the transfer arm. Depending upon the fuel-handling sequence, the gripper either delivers a refabricated-fuel subassembly to the transfer arm or removes a spent-fuel subassembly from the primary tank and lifts it up into the shielding cask. During these operations, as applicable, fuel-subassembly preheating or sodium blow-off and argon cooling are performed

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Fig. 11. Photograph of Fuel-unloading Machine

Fig 12. Cutaway View of Fuel-unloading Machine

also. The other end of the carriage rails straddles the pit of the interbuilding coffin. By moving the carriage over this location and performing fuel-handling operations similar to those described above, one can move fuel subassemblies in or out of the interbuilding coffin.

Although most of the operations are performed electrically, manual actuation is possible as part of the emergency procedures described in Section II-C-6 on "Emergency Features."

B. Design Criteria

The following criteria were established for the design of the fuel-unloading machine:

1. The fuel-unloading machine shall incorporate a device, called a gripper, to grasp or to release one fuel subassembly at a time.
2. The gripper shall move vertically over a distance of 27 ft and shall operate in molten sodium at up to 700°F or in dry argon gas at 210 to 700°F.
3. The gripper shall incorporate a sensing device, which will positively indicate the presence or absence of a fuel-subassembly upper-adapter head between the gripper jaws.
4. The gripper shall incorporate a feature enabling argon gas to be blown through the fuel subassembly.
5. The gripper shall be remotely controlled, and prevented from releasing a fuel subassembly accidentally at the wrong elevation or in the wrong sequence.
6. The gripper-jaw drive and vertical drive shall incorporate power-limiting devices.
7. Automatic controls shall stop the gripper at predetermined elevations.
8. Lead shielding shall be provided around the fuel-subassembly location inside the shielding cask and around piping containing radioactive gas and particles.
9. The argon-gas system of the fuel-unloading machine shall be practically leakproof to allow circulation of argon with less than 40 ppm of oxygen through the fuel subassembly.

10. The bottom of the shielding cask shall incorporate a gastight shielding valve.

11. A "fail-safe" gas seal shall be established between the shielding-cask bottom and the top of the transfer port or the top of the interbuilding coffin.

12. An argon purge shall be provided for the space created by the seal in Item 11.

13. A movable lead shield shall surround the seal in Item 11.

14. Gastight seals shall be provided for the shafts of the gripper drive on top of the shielding cask where they penetrate the walls.

15. All components of the fuel-unloading machine within the circulating argon flow shall be able to operate in temperatures up to 450°F.

16. The argon system shall incorporate sodium-vapor traps, and fission-product filters.

17. The carriage for the shielding cask shall be self-propelled.

18. The shielding cask shall incorporate self-aligning features with the transfer port and with the interbuilding coffin.

19. In case of a power failure, the fuel-unloading machine shall be operated by the stand-by diesel power supply.

20. An emergency power supply shall be available to operate the cooling section of the argon system.

21. In case of a stand-by power failure, the fuel-unloading machine shall be operated manually.

C. Design of the Fuel-unloading Machine

The fuel-unloading machine consists of a 14-ft-high shielding cask, which rests on a self-propelled carriage. The carriage moves on rails between two locations, which are about 16 ft apart (see Fig. 12). One location is directly above the primary-tank transfer port, the other is above the pit of the interbuilding coffin. The shielding cask supports a fuel-subassembly gripper and its drive assembly. The gripper can be lowered through the vertical storage tube of the shielding cask and past a rotary shielding valve. An argon system connects to the shielding cask on the carriage by two flexible stainless-steel hoses. Thus the fuel-unloading machine can be divided into major components, which are the mobile shielding, the gripper and its drive mechanism, the argon system, the electrical system, and, as an associated part, the transfer port.

1. Mobile Shielding

a. General. Handling of a highly radioactive fuel subassembly requires containment of radioactivity, cooling of the fuel subassembly to keep it from melting, and containment of the cooling medium.

Calculations show that a subassembly that has received 2 a/o maximum burnup has a 1.03×10^{16} -MeV/sec energy release after a 15-day storage period. Radioactivity varies along the axis of the fuel subassembly, being heaviest near the core section. Thirteen inches of lead reduces the maximum possible dose to 7 mR/hr at a distance of 36 in. from the center of the fuel subassembly. Fourteen inches of lead reduces the dose to 2 mR/hr.⁶

The lead-filled shielding cask is mounted on a self-propelled carriage that moves on rails between the transfer port and the interbuilding-coffin location. It is connected to the argon system by flexible hoses.

b. Shielding Cask. The shielding cask (Fig. 13) consists of a hexagonal tube, 140 in. long, surrounded by lead which is contained in an 32-in.-OD outer shell. The hexagonal tube, 2.962 in. between inside flats, acts as a guide for the gripper mechanism and as a storage tube for the fuel subassembly. The outer shell is a structural member and allows a unique suspension from the carriage (discussed in par. f below). To reduce weight, the lead shielding in the shielding cask is tapered off near the upper end. The most radioactive section of a fuel subassembly is surrounded by 13.5 in. of lead in the radial direction. In the upward direction, the gripper mechanism components provide adequate shielding; in the downward direction, the shielding valve provides a minimum of 7 in. of lead shielding.

A horizontal gap ($1/8$ in. high) exists between the bottom of the shielding cask and the top of the transfer port or the top of the interbuilding coffin. During fuel-subassembly transfer between these units, this gap is sealed off by the bottom-ring seal and shielded by a doughnut-shaped shield ring that is lowered into this position from the shielding cask and thus also provides 13 in. of lead shielding.

The argon exhaust tubing is shielded with a 4-in.-thick layer of lead between the shielding cask and the lead shielding for the molecular sieve and vapor trap, which are also mounted on the carriage (see Fig. 14). The argon flow leaving the shielding cask is radioactive, because in certain sequences it mixes with the primary-tank argon blanket gas and also because it suspends activated sodium vapors. The filter and the molecular sieve scrub the particulate matter from the argon, so that the remaining tubing on the carriage and the flexible connection hoses can be left unshielded.

Fig. 13. Shielding Cask

Fig. 14. Sodium-vapor Filter and Molecular Sieve

c. Shielding Valve. The shielding valve seals off the lower end of the hexagonal storage tube inside the shielding cask. The shielding valve consists of a 13.5-in.-diam, Type 304 stainless-steel, cylindrical plug, 7 in. wide, which is filled with lead. Perpendicular to the cylindrical axis, a 3.5-in.-diam hole, lined with a hexagonal tube, provides access into the shielding cask if the hole is turned to its vertical position. A 90° rotation of the cylindrical plug closes the valve. The plug is rotated by a manually actuated (by a sprocket, chain, and crank), electrically interlocked shaft, which also carries the cylinder weight of approximately 325 lb. A gap of 0.010 in. between the valve cylinder and the housing is sealed by special 1/4-in.-diam O rings. Each O ring is fabricated with a 1/16-in. wire ring in the center, which keeps the O rings in the saddle-shaped circular grooves cut into the cylindrical periphery of the shielding cylinder.

When the shielding valve is in the closed position, a removable "drip cup" faces with its open end upward into the hexagonal storage tube. Sodium droplets from spend-fuel subassemblies collect in the drip cup rather than clogging the 0.010-in. gap between the valve cylinder and its housing. An inwardly tilted lip prevents sodium spilling due to valve rotation. The drip cup is removed and cleaned at regular intervals.

The shielding valve is surrounded by the lead of the shielding cask. Removal of a shield gate provides access to the shielding-valve cylinder and its housing.

d. Bottom Ring Seal and Purge System. The horizontal gap between the bottom of the shielding cask and the top of the transfer port or the top of the interbuilding coffin is sealed, during vertical gripper motion, by the bottom ring seal (see Fig. 15). The sealed-off space thus created is purged of air or of radioactive argon by the associated, electrically interlocked, purge system.

The bottom ring seal is contained in a housing, which is fastened and sealed to the underside of the shielding-valve housing. The ring-seal piston is 5 in. in diam, has a T-shaped cross section, and fits into the closed-off groove of its housing. Thirty-three small coil springs push against the top of the T of the ring-seal piston, forcing its lower end, equipped with an imbedded O ring, against the mating sealing surface. Compressed gas, acting under the top of the T-like cross section, moves the ring-seal piston up, breaking the seal and creating the necessary clearance for horizontal movement of the fuel-unloading machine.

Seating of the bottom ring seal creates a closed-off air space of about 0.5 ft³ between the shielding cask and the transfer port or interbuilding coffin. This space is purged with approximately 5 ft³ of argon, which replaces the air and is discharged into a gas-exhaust line. A similar purge is performed after a fuel subassembly has been transferred from the

primary tank into the shielding cask and just before the seal is released. This removes radioactive argon and prevents it from contaminating the reactor plant. The argon flow is controlled by a solenoid purge valve and an adjustable time-delay switch.

Fig. 15. Bottom Ring Seal and Shielding Valve

Leaktightness of the bottom ring seal is tested every time the seal is put to use. Internal argon pressure of 5 psig is established. In case of improper seating of the bottom ring seal, or because of other leaks, the otherwise constant pressure decreases and alerts the operator. Proper operation of the exhaust valve is tested also. The operator opens the exhaust valve electrically. The resulting drop in pressure then automatically energizes the argon-inlet solenoid valve and thus raises the purge pressure back to 5 psig.

e. Shield Ring. The gap sealed by the bottom ring seal leaves a radiation leakage path during transfer of a fuel subassembly between the fuel-unloading machine and the transfer port. The retractable shield ring (Fig. 16) blocks this radiation. It fits around the lower end of the shielding cask and has an outside diameter of 54 in. The shield ring is supported by three synchronized lead screws, which raise or lower the shield ring 2 in. The lead screws are operated by one roller chain that is driven by an electric motor, which is interlocked to prevent out-of-sequence operation. In its raised position, the shield ring clears the reactor-plant operating floor by 2 in. A bumper switch is mounted around its periphery. Should an obstacle be encountered during horizontal travel of the fuel-unloading machine, the bumper switch will be actuated and stop the carriage drive.

f. Carriage. The mobile part of the fuel-unloading machine weighs approximately 32 tons. It is mounted on a four-wheel carriage (Fig. 17) running on metal rails. The carriage frame is welded together from 10-in. channels and I beams, topped by a 1/4-in.-thick steel plate. The 14-in.-diam wheels are 58 in. apart and are mounted on roller bearings. Sideways motion of the carriage is restricted by four adjustable rollers, bearing against the outside of the rails. Two rollers on one side of the carriage are mounted in a fixed bearing; the two opposing rollers on the other side of the carriage are mounted in a spring-loaded fixture. Under the load, the carriage structure deflects 1/32 in.

The self-propelled carriage is driven by a 1.5-hp, electro-hydraulic, power unit that has a variable-output speed of 0 to 350 rpm. The output shaft is coupled to the shaft of one pair of carriage wheels through a 1:50 speed reducer, an adjustable slip clutch, an electric clutch-brake unit, and a 3/4-in.-pitch roller chain and sprocket. The carriage speed can be varied from 0 to 6 ft/min in either direction.

The electric motor of the power unit is actuated from the control panel and is interlocked to prevent its operation out of sequence. The hydraulic motor, which is coupled to the electric motor, is also controlled from the control panel. A rotating control knob is kept in the neutral position by spring action. Turning the knob manually through an increasing angle, either clockwise or counterclockwise, controls the speed and direction of the hydraulic motor and of the carriage. As the carriage approaches

either point of destination, a speed-reducing mechanism, mounted near the rails, overrides the operator action and slows down the carriage until it comes to a complete stop approximately 0.5 in. from its destination. The rest of the travel is accomplished by manual rotation of a handwheel. A signal light indicates the completion of this operation. In the case of loss of the normal and the standby electrical power, the handwheel can be used to propel the carriage over a larger distance.

Fig. 16. Shield Ring

Fig. 17. Carriage

A friction-shoe-type handbrake, applied on one carriage wheel, is used to secure the position of the carriage when it is parked between its two destination points during a period of idleness. The mechanical design of this handbrake makes it independent of the electrical power supply, which may be shut off for maintenance or other purposes.

g. Shielding-cask Alignment. For proper operation, the shielding cask should align with the transfer port or with the interbuilding coffin within 0.010 in. However, the transfer port, mounted on the transfer-arm nozzle of the primary-tank cover, moves far more than this distance depending on the primary-tank-cover temperature level and distribution, which in turn, are dependent on the bulk-sodium temperature. Also, several interbuilding coffins will be used, which cannot resemble each other within such small dimensions, nor could they be positioned repeatedly in the coffin pit with such accuracy. Thus, very careful and repeatable location of the fuel-unloading machine carriage alone does not provide the desired alignment. Therefore an automatic alignment feature is being used.

The shielding cask (see Fig. 18) is supported by the carriage on 16 1-in.-diam hardened steel balls, rolling between two sets of parallel steel plates, also hardened to RC-65. The lower set of steel plates is fastened to the carriage; the upper set of plates, imbedded in the ends of 1-3/8-in.-diam bolts, is supported from four shielding-cask brackets. Turning the bolts enables the upper-plate elevation to be adjusted and the heavy shielding load properly distributed between all balls. This arrangement allows the shielding cask to move 1/8 in. in any horizontal direction, on top of the carriage, with the application of only 150-200 lb side thrust. Because of this support feature, the very close self-alignment is achieved by the use of four locator pins.

Two sets of 1-1/2-in.-diam locator pins are guided in the vertical direction by bearings attached to the shielding cask. One pair of locator pins is aligned with sockets attached to the transfer port. The other pair is aligned with sockets attached to the interbuilding coffin. The locator pins are actuated by pneumatic cylinders and pistons, which are operated from the control panel and interlocked for the correct sequence. When the locator pins are in their "up" position, they engage a special set of bushings fastened to the carriage. This prevents motion between the shielding cask and the carriage during horizontal travel.

h. Rails. The carriage moves on horizontal rails (see Fig. 19), which are mounted 34 in. above floor level, on two support beams. One end of the rails and support beams straddles the interbuilding coffin pit. The other end of the support beams is cantilevered 97 in. and straddles the transfer port. The cantilever construction makes it possible to position the fuel-unloading machine over the transfer port, without putting any load on the primary tank. The cantilevered portion of the rails and support beams is removable to give access to several primary tank plugs and nozzles in this area. This disassembly, however, is needed only on rare occasions.

The rails are made of 2 x 2-in. AISI 4140 H. T. CR steel bars, bolted to 3/4 x 8-in. H. R. steel slabs. The steel slabs sit on jackscrews, which bear against the upper flange of the support beams. In this position, the rail-carrying steel slabs are bolted to the support beams, and the gap created by the jackscrews is filled with ceramic grout (Sauereisen cured at 150°F). This arrangement makes it possible to mount the rails level and parallel to each other within ± 0.005 in.

i. Carrier Drum for Flexible Hoses. Two, 2.5-in.-diam, bellows-type, stainless-steel, flexible hoses connect the shielding-cask and argon-system ducts. Irrespective of the carriage movement or its location, the carrier drum (Fig. 20) keeps the flexible hoses under slight but constant tension by sliding parallel to the carriage rails on two guide rods and ball bushings. The drum contains two constant-torque spring motors comprising two, 2.5-in.-wide and 0.025-in.-thick, torque springs, wound in parallel

Fig. 18. Shielding Cask Alignment

Fig. 19. Rail Assembly

Fig. 20. Carrier Drum for Flexible Hoses

opposite their curvature around a 7-3/4-in.-diam output reel, keyed to the nonrotating shaft. Two 3-3/4-in.-diam take-up reels rotate freely in the interior of the drum. The constant-torque springs tend to assume their normal curvature and wrap around the take-up reels, but due to the arrangement of the drum and the reel shafts the force is enslaved to rotate the drum around the output reel. One end of the steel cable is fastened near the ends of the guide rods; the other is fastened to the periphery of the drum. Spring-forced rotation of the drum winds the cable around the periphery, shortening the free length of the cable and moving the drum towards the fixed end of the cable. The spring-induced movement keeps the flexible hoses under tension since they are looped around the drum. Carriage movement in the opposite direction pulls the hoses and thus rotates the drum, winding up the torque springs.

2. Gripper and Gripper-drive Mechanism

a. General. The gripper is a mechanism that moves a fuel subassembly into or out of the shielding cask. It is remotely controlled to sense, grasp, or release a fuel subassembly by its upper adapter. The gripper is attached to a push-pull chain by which it can be lowered or elevated more than 27 ft to various levels during its operational cycle. The internal guide tube of the shielding cask, the gripper-drive enclosure, and the shielding valve on the bottom ring seal form a gastight chamber. This chamber is connected to the argon system that heats or cools the fuel subassembly, depending upon which fuel-handling activity is being performed. An electro-hydraulic drive supplies power to the gripper mechanism, whose actions are monitored on the gripper motion indicator.

b. Gripper Mechanism. The gripper mechanism (Figs. 21 and 22) consists of the following major components: the outer shell, the core, and the sensing device.

The outer shell, as the name implies, is a 5-ft-long tubular member of the gripper, surrounding the other components. Its main purpose is to act as the gripper-jaw actuating device. Spacers and guides maintain a concentric annulus between the outer shell and the next internal component, the core, keeping the orientation of both components fixed. Axial streaming of radioactivity through annuli is impeded by stainless-steel blocks. The lower end of the outer shell surrounds the gripper jaws closely as it pivots them on 3/8-in.-diam Stellite balls. Movement of the outer shell with respect to the core pivots the jaws about 5°. The total outer-shell movement of 1-1/2 in. is divided into three equal-travel zones: approach, action, and departure. Movement through the action zone applies cam pressure on the upper or lower ends of the jaws, depending upon the direction of movement, thus causing them to close or open. The outer-shell movements through the approach and departure zones are actually pre- and overtravels of the action zone to secure the open or closed position of the jaws, even if a slight shift occurs between the zones.

Fig. 21. Cutaway View of Gripper Mechanism, Mark-I

Fig. 22. Photograph of Gripper Mechanism, Mark-I

The gripper core, enveloped by the outer shell, has the function to support the jaws that carry the weight of a fuel subassembly. The lower end is funnel-shaped, forming a 1-in.-diam cavity. At 1-1/2-in. depth, inside the cylindrical cavity, are mounted the fuel-subassembly stop and the sensing-device orientation guide. Into the outer surface are machined 3/16-in.-deep spherical seats for the pivot balls of the jaws. The tooth ends of the three jaws, when operated by the outer shell, reach through slots in the core wall into the center to grasp the upper adapter of a fuel subassembly. The jaws can be closed or opened only if the ball-lock mechanism, located in the upper end of the core, is released by the sensing-device movement.

The sensing device, about 5 ft long and 5/8 in. in diameter, with longitudinal grooves for sodium and argon flow, is housed in the center of the core. The lower end of the sensing device is shaped like a screw-driver blade to match the slot in the head of the fuel-subassembly upper adapter.

Before a transfer operation, a fuel subassembly is held stationary, either by the transfer arm in the primary tank or by the bottom support in the interbuilding coffin. As the gripper approaches the latch elevation, physical contact is made first between the sensing device and the fuel-subassembly upper adapter. This contact stops the movement of the sensing device, but since the core continues its movement downward, the previous relative position between these two components is changed. The information about the movements of the gripper component is relayed to the gripper-motion indicator by a chain-pulley arrangement, mounted into the upper end of the gripper core. This arrangement includes a roller chain, attached to the upper end of sensing device, and a pulley, mounted on the shaft attached to the gripper core below the sensing-device and roller-chain connection. The roller chain is looped around the pulley and then kept under tension by the torque spring, attached to the chain-collector drum. The loop changes upward pull of the chain into downward push of the rigid sensing device and tends to keep it at its lowest possible position. When the sensing device contacts a fuel-subassembly upper adapter, the downward-moving core and pulley increase the chain loop, causing the sensing chain and gripper chain to travel unequal distances. The gripper-motion indicator measures the difference in chain movement by the separation of the gripper-elevation and sensing pointers. Actually, this separation measures the distance the fuel subassembly has moved into the gripper core. The maximum distance the fuel subassembly can move into the core is controlled by a rigid stop. However, the pointer separation may vary depending upon the mode of contact between the sensing device and the fuel-subassembly upper adapter. For normal loading, the contact is made at the bottom of the fuel-subassembly adapter slot and produces maximum 1-in. separation of the pointers. Misalignment of the sensing-device blade and the slot causes an earlier contact and increases the maximum separation of the pointer up to 1-3/8 in. Thus the sensing-pointer movement indicates the presence of the fuel subassembly in the gripper and specifically, by the indicated maximum separation, whether the loading is normal or misaligned.

Fig. 23. Gripper Ball-lock Mechanism

The gripper jaws are operable when the sensing device has been moved up into the gripper core a minimum of 1 in. or, for jaws-testing purposes, when the sensing device is at its lowest position. Between these sensing-device positions, the gripper outer shell is locked to the core by the ball-lock mechanism, and the jaws cannot be opened.

The gripper ball-lock mechanism (Fig. 23) is comprised of a $3/8$ -in.-diam Stellite ball, housing, and ball seats.

The ball housing is formed by the $3/8$ -in.-diam hole through the $1/4$ -in.-thick wall of the core upper end, which leaves $1/8$ in. of the ball diameter uncovered. A steel block with two $1/8$ -in.-deep spherical ball seats is attached to the outer shell, opposite the ball-housing seats. The upper seat is aligned with the ball housing when the gripper is closed, the lower seat is aligned when the gripper is open. Two ball seats are also machined into the upper end of the sensing device, opposite the ball housing. The upper seat is aligned with the ball housing when the sensing device is in its lowest position. The lower, elongated, seat is aligned when the sensing device is pushed up 1 to $1-3/8$ in. from its lowest position in reference to the core (by movement of the fuel subassembly into the core). The alignment of the ball housing and the sensing-device ball seat releases the ball from the outer shell, which can then be moved up or down to close or open the jaws.

The gripper-jaw tooth ends are closed around the

fuel-subassembly upper-adapter stem 0.5 in. below the adapter's head. When the gripper moves upward, the fuel subassembly remains stationary during the first 0.5 in. of gripper travel until the head of the fuel-subassembly adapter is seated on the tooth ends of the jaws. Tension in the sensing chain forces the sensing device to follow the fuel subassembly and change its position with respect to the gripper core. This sensing-device intermediate position keeps the locking ball between the core housing and outer shell seat, locking these components together. This locked condition remains as long as the fuel subassembly is supported by the jaws. The ball lock is released automatically when the alignment between the ball housing and the sensing-device ball seat is restored. In the primary tank, this occurs as soon as the transfer-arm carrier block supports the fuel subassembly at the predetermined elevation. An additional 0.5-in. downward movement of the gripper from this elevation pushes the fuel subassembly against the stop and restores the sensing-device ball-seat alignment with respect to the ball housing (in case of microswitch maladjustment, the transfer arm can be manually lifted until the gripper-motion indicator shows the correct movement of the sensing device). At the interbuilding coffin, the fuel subassembly is lowered to the bottom and the gripper is moved an additional 0.5 in. downward. Normally the limit switch stops the gripper at the correct elevation (the microswitch bypass can be used when the movement is too short).

The lower end of the gripper outer shell is enveloped by the 1.5-ft-long, hexagonal floating guide. The guide has dual functions: (1) to keep the gripper in predetermined orientation with respect to the hexagonal guide tube, and (2) to guide argon flow through the fuel subassembly.

The floating guide fits closely into the hexagonal guide tubes of the shielding cask and of the transfer port. The argon flow is forced into the gripper assembly through a number of access holes. Since the bottom ring of the floating guide covers the rim of the fuel-subassembly top, the argon must then blow through the inside of the fuel subassembly. A coil spring applies pressure on the guide and keeps the connection between the guide ring and the fuel subassembly self-adjusting.

Two grippers, models called Mark-I and Mark-II (Figs. 21, 22, and 24), have been designed and fabricated and can be interchanged for use in the fuel-unloading machine. Basically the components of both designs are similar. As a result of operating experience, the gripper Mark-II is built 4 in. longer to more effectively keep sodium and sodium vapor away from the sensitive upper mechanisms. Sodium drip-off and argon flow area between the outer shell, the core, and the sensing device are increased by reduced sizes of guides and stops. Elimination of insignificant adjustments has simplified assembly and disassembly procedures for cleaning and checking purposes. Figures 21 and 24 show the floating guide and the lower section of the core of the Mark-I and Mark-II grippers, respectively. The Stellite inserts at the floating-guide corners of the Mark-I gripper are

Fig. 24. Gripper Mechanism, Mark-II

replaced by balls on the Mark-II gripper. The sensing-device sleeve-type orientation guide and fuel-subassembly stop are replaced by nonadjustable pin-type guide and stop (inside the core; not shown in Fig. 22), creating more space for sodium drip-off and argon flow.

Interchange of the Mark-I and Mark-II grippers only requires a change of the length of the limit-switch actuator chain. A Lucite glovebox, attached to the lower end of the shielding cask, allows the grippers to be removed and installed or cleaned without loss of argon-system purity.

c. Gripper Drive. The gripper drive (Fig. 25) moves the gripper mechanism over a 27-ft vertical distance and provides the means of remote sensing and remote opening and closing of the jaws. The gripper mechanism is actuated by a push-pull chain arrangement. The chain (Fig. 26) is of a special design. The links, stamped out of 1/8-in.-thick SST-304 sheet and machined exactly for 2.500-in. pitch, are connected by 5/16-in.-diam pins, bearing 0.437-in.-OD rollers. The capacity of each chain in tension, as tested, is 5500-lb yield strength and 9300-lb rupture load. The chain links are nested into each other so that they can be wrapped around a drum in one direction only. A 27-ft piece of such chain wraps around a 4-1/2-in.-diam drum into a 23-in.-diam coil. Two chains, installed closely in back-to-back positions, form a rigid, bar-like, structure capable of exerting push and pull forces together or separately. Irrespective of the length of the chain assembly, only one guide on each end is necessary to assure orientation and rigidity. One guide is provided by connecting the chains to the gripper; the other guide is formed by drive sprockets closely mounted together and by a set of rollers (see Fig. 27) that prevent the chains from rolling off the sprocket teeth.

The chains drive sprockets, eight teeth at 6-in.-diam, are keyed to their shafts and rotate in opposite directions. The teeth match the pitch of the chain within 0.001 in. The portions of the chains that have passed the drive sprockets are wrapped around drums by constant-torque spring motors (see Fig. 28). The output reel of the spring motor is keyed to the drum's shaft, and the take-up reel shaft is attached to the housing. A 2.5-in.-wide, 0.032-in.-thick, spring leaf is wound around the output reel, opposite to its curvature. The spring tends to restore its normal curvature around the take-up reel and thus rotates the drum that reels in the excess length of the chain during upward movement of the gripper. Downward movement of the gripper pulls the chain from the drum and by this action rotates the output reel that rewinds the spring. The spring-actuated drums keep the chains under tension and respond automatically to the demands of the changing elevations of the gripper.

Fig. 25. Cutaway View of Gripper Drive

Fig. 26. Push-Pull Chain

Fig. 27. Push-Pull Chain Guide

Fig. 28. Chain Take-up System

The drive sprockets are operated by an electrohydraulic power unit (see Fig. 29). The gripper-core drive shaft is coupled directly to the main-power transmission shaft. The outer shell drive is connected to the main transmission shaft through a differential gear system. This system is comprised of spur gears, two bevel gears, and a pinion. The spur gears transmit the torque from the main transmission shaft to the differential shaft in a 1:1 ratio. One bevel gear is rigidly attached to the end of the differential shaft. The other bevel gear is keyed to the gripper outer-shell-drive sprocket shaft, mounted in line with the differential shaft. The pinion is mounted on an arm, which can rotate about the differential shaft, and transmits torque between the level gears in a 1:1 ratio when the arm is stationary. When the main transmission shaft is stationary and the pinion arm is rotated, the planetary movement of the pinion produces

Fig. 29. Plain View of Gripper Drive

rotation of the gripper outer-shell bevel gear. A 13.5° rotation of the pinion arm rotates the bevel gear 27° and causes 1.5-in. vertical movement of the outer shell to operate the gripper jaws. The rotating arm is connected to a lead-screw nut and is driven by an electric motor. A slip-clutch and limit switches protect the mechanisms from overtravel and overloads.

The third controlling component of the gripper, the sensing device, is connected to a standard No. 48 roller chain. The upper end of the chain is guided over an idler sprocket and then attached to the collector drum. The sprocket meters the vertical movements of the chain and relays the information to the gripper motion indicator.

The sensing-device movement with respect to the gripper core is caused by the fuel-subassembly upper adapter only, whenever a fuel subassembly is gripped or released. During the change of vertical elevation of the gripper, whether loaded with a fuel subassembly or empty, the gripper components travel in unison and the sensing chain is pulled from or wound around the collector drum, depending upon the vertical direction of gripper movement.

The electric motor of the main drive is energized by a push-button on the control panel. A hand knob controls a cam-operated electrical system, which energizes the electric clutch-brake and starts the movement of the gripper up or down, depending on the direction in which the knob is turned. The speed of the gripper travel is regulated by how far the knob is turned from its neutral position. When the knob is released it returns automatically to the neutral position to stop the movement. Electrical interlocks permit movement only in the proper sequence and direction.

The gripper drive can be made manually operable by making minor adjustments. The electrohydraulic power unit is disengaged from the main transmission shaft by a mechanical slip-clutch. A drive-pin arrangement is used to engage the field and armature of the electric clutch when it is inoperable due to loss of electric power. Then a handwheel, attached to the end of the main transmission shaft, can be used to actuate the gripper-drive system manually. A 100-150-in.-lb torque is required to drive the gripper up or down, under normal conditions.

d. Gripper Motion Indicator. The principal objective of the gripper motion indicator is to meter continuously the elevations of the gripper components and to indicate the various elevations and positions on a dial.

Figure 30 illustrates the major components of the gripper motion indicator: four telescoped shafts with pointers, a two-scale dial, and a drive system.

- 1 - ROLLER CHAIN (JAWS)
- 2 - ROLLER CHAIN (GRIPPER)
- 3 - ROLLER CHAIN (SENSING)
- 4 - GRIPPER ELEVATION POINTER ($360^\circ = 12''$)
- 5 - GRIPPER ELEVATION POINTER ($360'' = 30'$)
- 6 - SENSING POINTER
- 7 - JAW POSITION POINTER

- 8 - DRIVE PINS
- 9 - SENSING DEVICE TRAVEL INDICATOR SWITCH
- 10 - JAWS SHAFT
- 11 - GRIPPER SHAFT
- 12 - SENSING SHAFT
- 13 - GEAR TRAIN

Fig. 30. Gripper Motion Indicator

The gripper core is used as the reference component, and its drive-shaft movements are geared to the outer shaft of the telescoping assembly in a 3:5 ratio, that equates one revolution of the shaft to 12-in. vertical movement of the gripper core. The center shaft of the telescoping assembly is connected to the outer shaft through a gear train, which reduces the center-shaft angular speed by a 30:1 ratio and thus measures the total vertical movement in less than one revolution.

The second telescoping shaft, next to the outer shaft, is geared to the gripper outer-shell drive shaft with the same ratio as the core drive shaft and indicates the jaw position.

The third telescoping shaft is geared to the sensing-device idler-sprocket shaft to indicate 12 in. of vertical movement by one revolution.

Colored pointers are attached to the front ends of the telescoping shafts. All pointers are set to zero when the gripper is in its top elevation in the shielding cask and the gripper jaws are open.

The drive system between the gripper motion indicator and the gripper core, outer shell, and sensing-device drive shafts in the upper plenum, composed of roller chains and sprockets, transmits the motions of any of these components separately. In the upper plenum, the core and sensing-device shafts rotate counterclockwise when the gripper moves downward. At the gripper motion indicator, all telescoping shafts move clockwise when the gripper moves downward, and vice versa. Thus any relative change of the elevations between the gripper components is observable and metered by the separation of the inner-scale pointers of the gripper motion indicator.

The sensing-device pointer movements in reference to the core pointer on the gripper motion indicator are caused by the presence of a fuel-subassembly upper adapter in the gripper. Three essential sensing-device movements have to be noted: (1) minimum 1-in. clockwise movement to release the ball lock for operation of the jaws (the fuel subassembly is against the stop in the gripper core), (2) 0.5-in. counterclockwise movement to seat the fuel subassembly on the jaw teeth and to close the ball lock (the subassembly is ready for upward movement), and (3) 0.5-in. clockwise movement to release the ball lock of a loaded gripper (the fuel-subassembly upper adapter butts against the stop in the core). When the gripper with open jaws moves away from the transferred-fuel subassembly, the core, the outer shell, and the sensing-device pointers assume in-line position and read the same elevation.

A cam is mounted between the core and sensing-device sprockets inside the gripper motion indicator. When the sensing-device sprocket rotates faster than the core sprocket, the cam causes the sensing-device sprocket to move axially toward the rear. A 0.1-in. axial movement

(corresponding to 5/8-in. vertical movement of the fuel subassembly into the gripper core) energizes the normal load switch, and 11/64-in. movement (corresponding to 1-in. vertical insertion of the fuel subassembly into the core) energizes the overload switch. These switches turn on the respective signal lights and actuate the electrical interlocks for the next power operation.

The gripper outer-shell movements close and open the gripper jaws. When the jaws are open, the jaws pointer is in line with the core pointer. A 1.5-in. downward movement of the gripper outer shell closes the jaws, and this movement is indicated by the jaws pointer movement 1.5-in. clockwise in reference to the core pointer.

e. Shaft Seals. The upper plenum of the shielding cask houses the gripper-drive sprockets and the collector drums for push-pull and roller chains and is part of the closed system containing radioactive argon and possibly some sodium vapors. Eight rotating shafts penetrate the plenum wall and must be sealed. Two types of shaft seals are used: (1) pressure seals and (2) crankplate seals.

The pressure shaft seal (Fig. 31) employs a pressurized oil well to stop gas leakage past the rotating-shaft penetration. The seal is comprised of a floating housing, penetrated by the shaft, two dynamic O rings, imbedded at the entrance and exit of the housing, and a cavity between the O rings, filled with heavy oil. The floating housing is sealed to the plenum wall by a flexible Viton rubber diaphragm. A metal frame prevents the housing from rotating with the shaft. The O rings prevent oil from leaking out at any significant rate. The oil in the cavity is maintained under argon pressure higher than the argon pressure in the plenum to avoid gas leakage from the plenum.

Since the maximum pressure inside the upper plenum does not exceed 3 psig, the argon pressure in the oil cavity is kept at 5 psig. The argon pressure and the oil level in the seal are monitored by readily observable gages and indicators at the control panel. The floating seal housing keeps the O-ring pressure around the shaft uniform and thus eliminates the effects of shaft dynamics and eccentricity.

The crankplate shaft seal (Fig. 32) stops the leakage past the shaft penetration through the upper plenum wall by intersecting the rotating shaft and forming a statically sealed enclosure with a flexible diaphragm. Both shaft ends at the intersection are machined eccentric and mounted into the blind-bearing housings, attached to both sides of the crankplate. The crankplate is guided between two parallel plates, attached rigidly to the plenum wall. The guides keep the movement of the crankplate at right angle to the shafts. Two crankplate guide rollers are confined in such a way as to prevent crankplate rotation, thus forcing the plate into circular

Fig. 31. Pressure Shaft Seal

Fig. 32. Crankplate Shaft Seal

oscillations that transmit the cranking motion from one shaft end to the other. The blind-bearing housing is sealed to the plenum wall by a cup-like diaphragm, which follows the crankplate circular oscillations due to the natural flexibility of the diaphragm. Symmetric mounting of the eccentric shaft ends in reference to the crankplate permits either shaft to act as the driver.

f. Gripper-drive-chain Failure-detection System. The purpose of the gripper-drive-chain failure-detection system is to stop operation if one of the drive chains should break.

The detection system is comprised of three potentiometers, geared to the collector drum shafts and wired together to form an electric bridge circuit. Normally all collector drums are synchronized and the current in the electric bridge circuit is kept balanced. If the speed of one of the collector drums changes due to malfunction, the imbalance of the bridge current triggers a relay that stops the gripper drive. The allowable margin of the imbalance is set so that normal movement of the outer shell to close or open the jaws falls within the allowed tolerance.

3. Transfer Port

a. General. The purpose of the transfer port is to provide shielded and sealed access into the primary tank. The transfer port

(Fig. 33) consists of a nozzle (through the primary-tank cover) that is lined with hexagonal tubing and topped by a shielding valve. The port is opened and closed by a 90° rotation of the shielding-valve cylinder.

Fig. 33. Transfer Port

b. Shielding Valve and Guide Tube. The shielding valve consists of a sealed housing and a rotary cylinder, which are connected by a bolted flange to the fuel-transfer nozzle on the top of the transfer-arm plug. The interior surface of the housing is precision-machined to accept the 13.5-in.-diam, lead-filled, shielding cylinder. The cylinder shaft ends are fitted with ball bearings and O-ring seals, and the cylinder is centered in the housing with a radial clearance of 0.005 in. The 3.5-in.-diam hole passes radially through the cylinder to allow passage of the gripper and of

a fuel subassembly. Four O rings are restrained by grooves in the wall of the cylinder, two are concentric with the ends of the radial hole, and the other two are located at 90° to them. The O rings are made of silicone rubber with a wire core. When the port is closed, the O rings at 90° from the radial hole seal the port. To open the port, the shielding cylinder is rotated 90° to line up the radial hole with the hexagonal guide tube, and the O rings seal the space between the cylinder and the housing. The top of the housing is equipped with mechanical stops, which travel in grooves cut into the surface of the rotary cylinder. Thus, the rotation is limited to 90° and assures exact alignment of the passage through the port.

The O rings are replaceable by removing the top seat plug and rotating the cylinder 360° to expose each of the four O rings. To prevent either contamination of the primary-tank blanket gas with air, or the release of activated argon into the reactor building during replacement of the O rings, a Lucite glovebox is sealed to the top of the housing and filled with argon gas.

The rotary cylinder is manually operated through a chain drive by a crank located on the operating floor (see Fig. 33). The opening and closing of the port is controlled by a pin-type locking mechanism that is solenoid-operated and electrically interlocked with other fuel-handling equipment. The position of the shielding valve is indicated by pilot lights. During emergency procedures, the shielding valve is opened, without electrical power to the interlocks, by manual engagement of the push-pull control that disengages the locking pin.

The lower end of the sealed housing, which is bolted to the transfer-arm plug, contains the removable O-ring seat. Below this seat is the bolting flange for the hexagonal-gripper guide tube. The guide tube extends downward through the primary-tank cover, through the blanket gas, and 50 in. into the sodium. A mechanical stop is attached to the bottom end of the guide tube, by which the floating sleeve of the gripper is restrained and held as the gripper jaws latch onto the upper adapter of the fuel subassembly. The hexagonal guide tube is removable after the rotary cylinder and the upper and lower O-ring seal seats are removed.

c. Argon Circulating System. When the valves G and W are open and the valves H, I, F, and J are closed, argon flow is directed through the fuel-transfer port, down into the primary-tank blanket gas (see Fig. 34). Argon is drawn back into the system from the primary tank through the A-3 nozzle. This flow path is required for the "blowing" cycle, when a fuel subassembly is removed from the primary tank, and for the "heating" cycle, when a fuel subassembly is heated before the insertion into the primary tank.

The argon flow is passed through a heating section (see Fig. 35) similar to the gas heater, mentioned in Section 4b below, consisting of a 10-kW electrical immersion heater, mounted axially in a 4-in.-diam

Fig. 34. Argon Circulating System Schematic Diagram

Fig. 35. Argon Circulating System Pictorial Drawing

pipe section. The gas is then blown into the transfer port at a point just below the rotary cylinder. There it enters the fuel-unloading machine gripper and the fuel subassembly in the hexagonal guide tube. The argon flow then leaves the hexagonal guide tube and the outer support tube through a series of 1-in.-diam holes, located above the sodium level in the primary-tank gas-blanket zone. Two cylindrical baffles around the support tube provide a mixing action of the incoming gas with that of the gas blanket.

d. Shielding. Due to high gamma radiation of an irradiated-fuel subassembly, the transfer port must be completely surrounded by a lead-filled shield assembly at least 13 in. thick. The shielding (Fig. 36) is constructed in three principal sections, which are doweled and bolted together. The sections are stepped to prevent radiation streaming through the joints. For the same reason, the argon inlet-pipe penetration to the housing is bent into a Z form.

4. Argon System

a. General. The gas system of the fuel-unloading machine is designed to furnish flow of argon through the fuel subassemblies during transfer operations between the primary tank and the interbuilding coffin. The main functions of the argon system are as follows:

(1) To remove decay heat from spent and reprocessed fuel subassemblies during the transfer operation to keep the temperatures between 400 and 700°F.

(2) To preheat the fuel subassemblies to 450°F before their insertion into the 700°F primary tank sodium to assure a molten sodium bond in the fuel pins and to reduce thermal shock to the fuel-subassembly structure.

(3) To blow off excess liquid sodium from the inner and outer surfaces of a fuel subassembly and from the fuel-unloading machine gripper, after they emerge from the primary-tank sodium.

(4) To preheat the fuel-unloading machine gripper and the circulating system to operating temperature before fuel-handling operations.

(5) To preheat the transfer port to operating temperature to reduce heat loss into this relatively large heat sink.

The argon system is mainly automatic in its operation, but some manual control is required. The argon-system control console is provided with visual display showing the flow route of the gas during all modes of fuel transfer by means of individually lighted plastic sections

Fig. 36. Transfer-port Shielding

laid out as a schematic representation of the entire system. The console operator primarily makes adjustments in flow control while checking the visual display and instrumentation. The instruments are provided with annunciator and visual alarms to call attention to abnormal conditions (see Section C-5-c below). At any time during the fuel-handling sequence, the operator may switch from automatic to manual control if the conditions require or if the normal sequence needs to be changed.

The argon-system console is electrically interlocked with the fuel-handling console to prevent accidental or improper sequence of operations. Procedures are followed that are necessary for testing of the argon system before fuel-handling operations are started. These checks assure that the essential components of the system are in working order and functioning properly.

The argon system includes the following parts, which are described in the paragraphs below:

- (1) Argon flow in shielding cask.
- (2) Argon loop.
- (3) Argon filters.
- (4) Heat exchanger.
- (5) Argon turbine blowers.
- (6) Gas purifier.
- (7) Argon heaters.

b. Argon Flow in the Shielding Cask. The shielding cask is connected to the argon system by two 2.5-in., stainless-steel, flexible-bellows-type hoses. These hoses are protected by a covering of braided stainless-steel wire. The inlet hose is insulated by thin layers of asbestos cloth and silicone rubber. The flexible hoses are connected to the carriage system by union-type couplings. A slack take-up mechanism maintains a constant tension while the carriage is moving (Fig. 20).

The argon enters the shielding cask through 2-in.-diam tubing at the top of the hexagonal guide tube, and flows downward to an outlet tubing just above the shielding valve. At 60-70-cpm flow, the pressure drop between the inlet and outlet of the hexagonal guide tube with a fuel subassembly in the gripper is approximately 1 psi. The gas leaving the hexagonal guide tube passes upward through a 1-1/4-in. Schedule 40 SST pipe, inside the lead shielding, and near the top of the shield passes into the lead-shielded vapor trap and molecular sieve. A manually operated 2-in. ball

valve (Fig. 34, valve III), in conjunction with valve II, provides isolation of the above-mentioned filters for their removal and replacement. Closing of valves I and II isolates the shielding-cask section from the rest of the system.

The argon temperatures and flow rates are monitored at the inlet of the hexagonal guide tube; the outlet is provided with temperature monitoring only. The filters are monitored for differential pressure between the inlet and outlet, indicating the degree of plugging.

The sodium-vapor trap consists of a 10.5-in.-diam cylinder. Except for a plenum at the bottom end, it is filled with stainless-steel mesh of 0.004-0.005-in. round wire, compacted to 20 lb/cu ft density. The mesh removes sodium vapor and droplets by cold-trapping and impingement. The molecular sieve removes sodium and fission-product gases entrained in the argon. The molecular sieve consists of a cylinder 8.5 in. in diameter, 24 in. high, with stainless-steel pads at each end. Between the two pads is a bed of crystalline sodium aluminosilicate pellets (Linde No. 4A), 1/8 in. in diameter. The clean gas flows from the shielded container through a 2-in. pipe and through the flexible hose into the argon loop located below the operating-floor level.

The mobile shielding is preheated to the operating temperature of 250°F, by an argon stream that emerges from the inlet-gas heater (Fig. 34). The heater is located at the inlet to the shielding cask and heats the gas to 450°F. The inlet gas heater also provides extra capacity for preheating fuel subassemblies to melt the sodium bond in the fuel pins. The temperature of the heater is controlled and regulated automatically by a controller on the gripper and mobile shielding control panel. The controlling information is supplied by a thermocouple in the outlet of the heater pipe section. The heater consists of replaceable elements, 440 V, ac, immersion type, rated at 10 kW, enclosed in a 4-in.-diam section of the pipe.

c. Argon Loop. The argon loop consists of the integrated transfer-port, shielding-cask, and interbuilding-coffin loops, connected together in such a manner that by opening or closing combinations of various pneumatically operated, solenoid-controlled, 4-in. ball valves in the piping, the flow may be diverted as necessary to maintain a constant flow of argon gas through the fuel subassembly during the transfer operations. The flow paths are illustrated in Fig. 37.

The system is primarily 4-in. Schedule 10 piping with butt-welded fittings. Because of structural necessity, a short section of 2-in. Schedule 10 pipe is used in the supply line to the transfer port. Replaceable and repairable items of the equipment are provided with temperature-compensating couplings or bolted flanges with gaskets.

(A)
FLOW THROUGH
INTERBUILDING COFFIN ONLY

(B)
FLOW THROUGH
INTERBUILDING COFFIN AND
MOBILE SHIELDING

(C)
FLOW THROUGH
MOBILE SHIELDING ONLY

(D)
FLOW THROUGH
MOBILE SHIELDING AND
TRANSFER PORT

(E)
FLOW THROUGH
TRANSFER PORT ONLY

Fig. 37. Argon Flow Paths

The main portion of the loop, except the shielding cask section, is located below the operating-floor level in the depressed areas (see Fig. 35). The loop is composed of the following major parts:

(1) One 10-hp, 440-V ac, motor-driven turbine blower, rated 150 cfm at 5-psi differential pressure across the inlet and outlet.

(2) One 5-hp, 125-V dc, motor-driven turbine blower, rated 150 cfm at 3-psi differential pressure across the inlet and outlet.

(3) A flow-regulating, 4-in. ball valve (valve C), provided with a remote-position indicator, remotely controlled from the argon-system console by a pilot valve and a pressure regulator.

(4) An electrically heated, gas-purifier (oxygen-removal), bed, consisting of an 8-in. pipe section filled with copper wire and stainless-steel-mesh retaining pads.

(5) A natural-convection-type heat exchanger, located at the inlet to the turbine blowers.

(6) Two molecular sieves manifolded in parallel and located in the return line from the A-3 nozzle of the primary tank.

(7) A stainless-steel-mesh, sodium-vapor trap, located between the A-3 nozzle and the molecular sieves.

(8) A fuel-subassembly electric heater, immersion type, 10-kW capacity, 440-V ac, three-phase supply. This heater is located in the section of pipe that supplies gas to the transfer port for heating and blowing-off operations.

(9) Nine 4-in. ball valves (valves A, B, D, F, G, H, I, J, and W), with remotely controlled pneumatic operators, primarily used to divert argon flow to the appropriate circuit during fuel handling (see Fig. 35).

(10) Six manually operated 4-in. ball valves (valves R, S, T, U, V, and Z), normally open during the operations. These valves are used to isolate various items of equipment for repairs or replacement.

(11) A 2-in. gate valve (valve O), manually operated, to close the line to the fuel-transfer port.

(12) Two flexible steel hoses (bellows type) for argon supply and return to the interbuilding coffin. The ends of the hoses are equipped with color-coded, quick-disconnect couplings for attachment to mating fittings on the argon-circulating system of the interbuilding coffin.

(13) The control console for the argon loop with features for schematic visual display of the various argon flow paths and valve positions, temperature controls and indicators, pressure gages, flow control and indication, and turbine blower control. This console is electrically interlocked by relays to the fuel-handling console, fuel-unloading machine, and interbuilding coffin for automatic control of the fuel-handling sequences.

The associated items that supplement the above-mentioned equipment consist of thermocouples, located at points throughout the loop for instrumentation and control of equipment and gas temperature; differential pressure switches, for annunciator warnings of excessive pressure drops due to plugging; and pressure transmitters, located at various points to furnish the operator with information of pressure drops or abnormal conditions in the loop.

A system-pressure averaging arrangement is provided with pressure-limit switches adjusting automatically for abnormal increase or decrease of the average system pressure due to leaks or temperature changes. The required pressure is set for 2 in. minimum and 6 in. maximum of water pressure above the ambient air pressure. Electrical interlocks prevent the opening of valves G and W (to the primary tank) if the average system pressure exceeds 10 in. of water pressure above the ambient air.

The plant argon is available for the purging system to obtain low oxygen content in the interbuilding coffin and the spaces between the fuel-unloading-machine shielding valve and the transfer-port shielding valve or the interbuilding-coffin valve. The purge gas is dumped into the primary-tank shield-cooling gas exhaust.

A sensitive (0-1000-ppm range) oxygen analyzer is used for checking the argon at various points in the loop and in the interbuilding coffin during the purging operation to determine the existence of required minimum purity of 40 ppm of oxygen.

d. Argon Filters. Filters are used in the argon system to remove radioactive sodium vapor and mist from the gas stream to prevent accumulations of sodium or its oxide. The filters are placed close to the source of entrainment of these materials.

The principal source of sodium vapor and aerosol is the primary tank. The argon emerging from the A-3 nozzle is at approximately 500°F, saturated with sodium vapor equivalent to approximately 0.003 g of metallic sodium per cubic ft. It also carries many times more sodium suspension as aerosol. This mixture enters the inlet plenum of the sodium-vapor trap and passes through the closely packed stainless-steel mesh. The relatively cold mesh provides a large surface area over which the sodium must pass and condense. The remaining sodium in argon is then

filtered out by passing through the molecular sieves. Two molecular sieves are connected in parallel. This arrangement provides for reduction of pressure drop in the gas by lowering the flow velocity through the bed of pellets, and gives more versatility in operating the system by providing the capability of isolating and replacing one molecular sieve while the other is in use.

The molecular-sieve bed is made of 1/8-in. pellets of Linde No. 4A crystalline sodium aluminosilicate material, which is highly porous. The pores, being of molecular dimensions 6-8 billionths of a centimeter in diameter and of uniform size, will admit molecules smaller than 4 Å to enter the cellular structure. The internal surface area is 650 to 800 sq m/g, and the external area is 1 to 3 sq m/g. The molecular-sieve bed is prevented from being blown out of the containers by pads of stainless-steel mesh, 2 in. thick, located at both ends of each container. These pads also provide additional filtering of larger particles entrained in the gas stream.

The molecular-sieve containers are housed in an insulated and electrically heated oven with a thermostatically controlled temperature of 350°F that prevents solidification of sodium on the surface of the bed material. For heating, 12-kW electric strip heaters, bolted to the inside wall of the oven, are used.

The argon, having passed over the sodium wetted gripper and fuel subassembly, is filtered by the vapor trap and the molecular sieve mounted on the carriage.

e. Heat Exchanger. The heat exchanger reduces the argon-gas temperature below 100°F. The gas entering the turbine blowers keeps the temperature of the motors and blowers below the tolerated maximum of 250°F for continuous service.

The three argon loops (fuel-unloading machine, transfer port, and interbuilding coffin) are connected together at a point near the inlet to the heat exchanger. The heat exchanger is of a natural-convection, air-cooled, horizontal multiple-tube type with design capacity of cooling 70 cfm argon from 700 to 100°F. In actual operation, the outlet-gas temperature is reduced to nearly ambient room temperature.

f. Argon Turbine Blowers. The argon blowers are of the "canned-motor" type to eliminate possible shaft-seal leakage. The motors are cooled by the cool argon flow through the motor enclosure. The inlet piping to the two blowers is manifolded in parallel to the outlet header of the heat exchanger so that either blower may be operated independently of the other.

The 10-hp, 440-V ac, three-phase, centrifugal-type blower, with two-stage compressor for 150-cfm capacity at 5-psi pressure differential across the inlet and outlet, is used for normal operation. The emergency turbine, 5 hp, 125 V dc, is started automatically if normal ac power is interrupted or if the argon flow drops below the required minimum. The power is supplied by a bank of nickel-cadmium batteries kept on floating charge. The batteries will run the blower for more than 60 min.

The gas flow from the 10-hp ac blower is regulated by remote adjustment of the outlet ball valve C. The position of the valve and the flow rate are indicated on the console. The emergency blower operates at its maximum capacity, and has no flow control.

g. Gas Purifier. The purpose of the gas purifier is to maintain the oxygen content of the argon gas at less than 40 ppm. It consists of a cylindrical container, 8 in. in diameter, packed with curled and flattened copper wire. Stainless-steel pads at each end of the copper bed restrain and act as filters for small copper particles, which might be dislodged and carried along in the gas flow. The entire container is heated and maintained electrically by clam-shell-type heaters at 650°F. At this temperature the copper oxidizes readily, and any oxygen in the argon flowing over the hot copper surfaces is removed by the oxidation reaction.

h. Argon Heaters. The argon system must furnish hot argon at the controlled temperature as required for the various modes of operation. The following heaters are provided: (1) the fuel-unloading-machine inlet-gas heater and (2) the fuel-subassembly heater.

The shielding cask, gripper, and associated piping must be warmed to 250°F to free any moving parts of solid sodium. For this purpose the inlet-gas heater, of 10 kW, 440-V ac, three-phase, immersion-rod type is used. It is located in the inlet pipe of the fuel-unloading machine. The control thermocouple is located near the heater outlet connection and provides information for the controller on the control panel, so that proper gas temperature is maintained and the heater is protected against burn-out.

Before entering the heater, argon is heated to approximately 200°F by the gas purifier. The inlet-gas heater raises the argon temperature to 450°F.

The fuel-subassembly heater raises the temperature of a reprocessed-fuel subassembly to a minimum of 450°F. This heating is necessary to reduce thermal shock before the assembly is immersed into the primary sodium at approximately 700°F. Also, when a spent-fuel subassembly or any subassembly is removed from the primary tank it has to be cleaned of excess sodium, clinging to or dripping from the surfaces.

Each of these operations is accomplished by blowing hot (600-650°F) argon over and through the fuel subassembly while it is located in the hexagonal guide tube below the transfer port at the "blowing-off" or "heating" elevation (13 ft below the top elevation of the fuel-unloading machine).

The fuel-subassembly heater is located in the section of 4-in. piping, connected to the transfer port. In addition to this immersion heater, this section of pipe is wrapped with 300 ft of heater wire. Proper temperature is maintained by the automatic controller, located on the argon system console.

5. Electrical System

a. General. The fuel-unloading machine is controlled and supervised from two control centers: one, the gripper and mobile shielding control panel, is located on the mobile shielding; the other, the argon system control console is located near the tracks. These control centers are described in detail in Sections b and c below. With the exception of the relay cabinet located on the mobile shielding, all other major pieces of electrical equipment are located in the depressed area below the operating floor. This includes the 125-V battery, battery charger, the ac starter rack, the dc starter rack, and the argon-system relay cabinet.

Normal operation of the fuel-unloading machine requires 440-V, three-phase power for the ac motor-driven turbine blower and heaters, 220-V, single-phase power for battery charging, and 120-V, single-phase power for control. The ac motor-driven turbine blower and ac control power are supplied from emergency-power panels that are automatically transferred to the standby diesel generating unit in the event of a normal power failure. The heaters are connected to the normal building supply since loss of heat cannot damage the fuel subassembly.

The dc motor-driven turbine blower, which is a standby unit for the ac motor-driven turbine blower, is powered by a battery. This, 92-cell, nickel-cadmium-type battery, rated 125 V and 62 Amp-hr at the 8-hr rate, is capable of driving the blower at rated speed for 1 hr. All control functions that are essential to maintain the system in operation, when the dc blower is in use, are direct-current circuits and are also supplied by the battery.

Instrumentation and indication require 42 and 28-V dc, respectively. These voltages are normally supplied from the ac control-power circuit by transformation and rectification. In the event of an ac power failure, these voltages are supplied by taps on the 125-V battery by the operation of an automatic transfer switch.

Power and control connections with the mobile shielding are made by coiled cords. One four-conductor power cord and two 19-conductor control cords are used. One end of each cord is clamped to an arm, which projects down from the mobile shielding; the other end is clamped near the end of the rails. Each cord is supported and held in the horizontal position by a Teflon tube, which is passed through each convolution of the cord. The Teflon tube is supported by a 1/4-in. steel cable, which is passed through its center and then anchored at each end of the rails (see Fig. 11).

The relay cabinet, located on the mobile shielding, contains the motor starters, heater contactor, and control relays required for operation of the equipment on the mobile shielding (see Fig. 11). On the ac starter rack, in the depressed area, are mounted the disconnect switches for the battery and battery charger and the switch and two starters for the dc motor-driven turbine. The argon-system relay cabinet contains more than 90 relays. The cabinet has ac relays on one side and dc relays on the other; these are 300-V class relays, and there are standard, latching, and timing types.

The operation of the fuel-unloading machine is interlocked with, and monitored by, an operator at the fuel-handling console, which is the main control center for the fuel-handling system. The control and interlock system for the fuel-unloading machine and the fuel-handling system is a permissive system in that the operator initiates an action, and it is permitted by the interlocks only if it is the correct and proper action of the sequence and conditions are satisfactory for it to proceed.

b. Gripper and Mobile Shielding Control Panel. This control panel, located on top of the shielding cask, is surrounded by an elevated platform to provide easy access to all controls. The gripper, its drive, the carriage motion, the seal, and the ring shield are controlled from this panel. The branch of the argon system that includes the mobile shielding is also supervised from this panel (Fig. 11). The functions of the meters and controls are described below; their location on the panel is designated by numbers as shown on Fig. 38.

The PURGE CHAMBER PRESSURE meter (1) and pilot light at top left of the panel and the group (11) of two pushbuttons and two pilot lights at the lower left are used in the testing and purging operations, for the space sealed between the fuel-unloading-machine cask-shielding valve and the fuel-transfer port shielding valve or the interbuilding-coffin port. The AIR PURGE light, group (11), indicates that the argon supply hose for these operations has been connected. The SEAL TEST pushbutton energizes a solenoid valve, which admits argon to the sealed space. The pressure meter indicates the pressure in the sealed space; the light above the meter indicates that the pressure is proper for the test. The light remains on after the SEAL TEST pushbutton is released to indicate a good seal. The

1 - PURGE CHAMBER PRESSURE INDICATOR & INDICATING LIGHT	16 - CARRIAGE SPEED CONTROL KNOB & DIRECTION INDICATOR: (A) TO REACTOR (B) NEUTRAL (C) TO COFFIN
2 - SHAFT SEAL PRESSURE INDICATOR	17 - GRIPPER MOTION INDICATOR
3 - ARGON TO FUEL TEMPERATURE INDICATOR OR HEX TUBE TEMPERATURE	18 - GRIPPER JAW PUSHBUTTONS & INDICATING LIGHTS
4 - ARGON FROM FUEL TEMPERATURE INDICATOR RESET PUSHBUTTON & ALARM LIGHT	19 - EMERGENCY STOP PUSHBUTTON
5 - ARGON FLOW INDICATOR & ALARM LIGHT	20 - SENSING CHAIN ADJUSTMENT
6 - DEMISTER DIFFERENTIAL PRESSURE INDICATOR	21 - SPRING MOTOR FAILURE ALARM LIGHT
7 - ARGON TO FUEL PRESSURE INDICATOR & ALARM LIGHT.	22 - BUZZER SILENCER PUSHBUTTON
8 - LOCATOR PINS POSITION INDICATING LIGHTS	23 - BUZZER TEST PUSHBUTTON
9 - BOTTOM SHIELD UP & DOWN PUSHBUTTONS & INDICATING LIGHTS	24 - KEY SWITCH, KS-R1
10 - BOTTOM SEAL RAISE & LOWER PUSHBUTTONS & INDICATING LIGHTS	25 - GRIPPER DRIVE MOTOR OFF & ON, CLUTCH & BRAKE PUSHBUTTONS & INDICATING LIGHTS
11 - AIR PURGE & TEST PUSHBUTTONS & INDICATING LIGHTS	26 - GRIPPER DRIVE SPEED CONTROL KNOB & DIRECTION INDICATOR (A) UP (B) NEUTRAL (C) DOWN
12 - PORT PLUG POSITION INDICATING LIGHTS	27 - FUEL TRANSFER ARM POSITION INDICATING LIGHTS
13 - COOLING SYSTEM CONTROLS & INDICATING LIGHTS	28 - COFFIN POSITION INDICATING LIGHT
14 - INSTRUCTIONS	29 - UNASSIGNED
15 - CARRIAGE MOTOR OFF & ON, CLUTCH & BRAKE PUSHBUTTONS & INDICATING LIGHTS	30 - INLET LINE HEATER CONTROLLER
	31 - SHAFT SEAL FILLER VALVE

Fig. 38. Gripper and Mobile Shielding Control Panel

PURGE pushbutton energizes a solenoid in the exhaust line from the sealed space. Switch contacts on the pressure meter sense the drop in pressure and open the valve in the argon inlet to start the purge. The PURGING pilot light indicates that the purge is in progress; after a timed interval, the valves in both inlet and outlet lines are closed by relays and the purge is completed.

The LOCATOR PINS group (8) of two pushbuttons and two pilot lights at the upper left pertains to the locator pins. The INSERT and EXTRACT pushbuttons energize solenoid valves that put air pressure on the locator pins to insert or extract them. The pilot lights indicate that the pins are in or out.

The COOLING SYSTEMS group (13) of lights and switch at upper left pertain to the argon system. The ON-OFF selector switch energizes the "inlet line heater." This heater is controlled by the proportional-type, indicating temperature controller (30) at the lower left. The red pilot light above the switch in group (13) indicates when the switch is in the ON position. The three green pilot lights indicate through which one of the three argon-system branches, which include the mobile shielding, the argon is circulating. The red pilot light indicates that the argon system is in the blowing or heating period. This light informs the operator that he can continue the upward or downward movement of the gripper.

The SHAFT SEAL PRESSURE meter (2) at the top left indicates the pressure of the argon gas in the space above the oil, in seals for the two gripper-drive sprocket shafts. The SHAFT SEAL FILLER VALVE knob (31) at the right of the meter operates a valve that bleeds additional argon into this space above the oil.

The BOTTOM SHIELD group (9) of three pushbuttons and four pilot lights at left pertains to the ring shield. The UP pushbutton energizes the motor drive to raise the ring shield; the DOWN pushbutton causes the ring shield to be lowered; the third pushbutton is the STOP button. The UP and DOWN pilot lights indicate the direction of the movement. The TOP and BOTTOM pilot lights indicate the position of the ring shield after the completed up or down movement.

The GRIPPER JAWS group (18) at the left consists of two pushbuttons and two pilot lights. The OPEN and CLOSE pushbuttons energize the jaw-drive motor to drive the jaws to the open or closed position, as indicated by the OPEN or CLOSED pilot light.

The BOTTOM SEAL group (10) of two pushbuttons and two pilot lights at the left pertain to the bottom ring seal. The RAISE SEAL pushbutton energizes a coil in a three-way solenoid valve to admit pressurized air to raise the seal; the LOWER SEAL pushbutton energizes the other coil in the valve to exhaust the air and lower the seal. The pilot lights indicate SEAL UP and SEAL DOWN.

The CARRIAGE group (15) of three pushbuttons, four pilot lights, a selector switch, and the knob and pointer (16) at the lower left are the carriage-drive controls. The START and STOP pushbuttons control the carriage drive motor; one pilot light indicates that the drive motor is on. The "emergency power" selector switch permits switching the clutch from the normal power supply to the battery supply. The ENGAGE BRAKE pushbutton energizes the brake and disengages the clutch. The three remaining pilot lights indicate MANUAL BRAKE ON, CLUTCH ENGAGED, and BRAKE ENGAGED. The CARRIAGE SPEED CONTROL knob (16) is connected by a flexible shaft to the hydraulic speed control unit. When the knob is turned, limit switches are actuated to energize the clutch. The pointer indicates in what direction the carriage is traveling. The farther the knob is turned, the higher the speed.

The PORT PLUGS group (12) of six pilot lights at the lower left indicates the position of the transfer port-shielding valve, the cask-shielding valve, and the interbuilding-coffin port. There is an OPEN and a CLOSED light for each valve or port.

The two meters at the top center are indicating pyrometers. The AUX. TEMP. METER (3) on the left normally indicates the temperature of the circulating argon entering the top of the gripper guide tube. Using the selector switch below the meter connects the meter to a thermocouple on the guide tube 6 ft above the rotating plug. The ARGON FROM FUEL TEMP. meter (4) on the right indicates the temperature of the argon leaving the guide tube and actuates a contact when an adjustable set-point is exceeded. Operation of this contact is indicated by the pilot light above the meter. The pushbutton to the left of the light is a RESET button; the light will remain on until this button is pressed, even if the meter indication drops below the set-point.

The three meters at the upper right of the panel are pressure indicators. The ARGON FLOW meter (5) on the left indicates a differential pressure from which the flow of the circulating argon can be calculated. This differential pressure is derived from a pitot tube and a standard tap. The pilot light above the meter indicates low flow; it is controlled by relay contacts, and the relay is actuated by a differential-pressure switch that senses the same pressure as the meter. The center DEMISTER DIFF. PRESSURE meter (6) indicates the pressure drop across the molecular sieve and vapor trap, thereby indicating when these units require cleaning. When clean, the pressure drop across these units is 0.5 psi for a 70-cfm flow. The ARGON TO FUEL PRESSURE meter (7) on the right indicates the static pressure of the circulating argon at the inlet to the gripper guide tube. The pilot light above the meter indicates when the pressure is too high or too low.

The EMERGENCY STOP pushbutton (19) in the center of the panel is pressed to stop all three motor drives on the mobile shielding. The pilot light (21) at the upper right indicates that the chain take-up reels for the gripper, jaws, and sensing are out of synchronism. Another pilot light (28) at the upper right indicates that the interbuilding coffin is in place in the coffin pit. Still another pilot light (29) at the upper right is a spare at present. The two pushbuttons at the upper right are the ALARM SILENCER (22) and ALARM TEST (23) buttons for the audible alarm system that is automatically actuated in the event of "argon to subassembly, pressure abnormal," "argon from subassembly, temperature high," "argon flow low," and "chain take-up reels out of synchronism." The FHC INTERLOCK BYPASS key switch (24) at the upper right permits bypassing certain interlocks located in the fuel-handling console from which the overall fuel-handling system is normally supervised. The GRIPPER MOTION INDICATOR (17) at the lower center of the panel is described in Section C-2-d above (pp. 50-53).

The GRIPPER DRIVE group (25), at the lower right, of four pushbuttons, five pilot lights, and a selector switch which are used in conjunction with the GRIPPER DRIVE SPEED CONTROL; the knob and pointer (26). The START and STOP pushbuttons, on the left, control the gripper-drive motor; one pilot light indicates that the drive motor is on. The EMERGENCY POWER selector switch permits switching the clutch from the normal power supply to the battery supply. The third (ENGAGE BRAKE) pushbutton energizes the brake and disengages the clutch. The four remaining pilot lights indicate CLUTCH ENGAGED, BRAKE ENGAGED, JAWS LOADED, and JAWS OVERLOADED. Jaws overloaded means that the gripper sensing pin has not dropped into the slot in the head of the fuel subassembly upper adapter. This condition normally prevents operation of the gripper drive; however, under certain circumstances, it is desirable to operate the drive in this condition. The fourth (JAW OVERLOADED OVERRIDE) pushbutton is for bypassing this interlock. The pointer indicates whether the gripper is travelling UP or DOWN. The knob controls the gripper motion; the farther it is turned, the faster the gripper travels.

Of the several positions for the transfer arm, only three are relative to the operation of the fuel-unloading machine. Three pilot lights, the FUEL TRANSFER ARM group (27) at the lower right, indicate that the transfer arm is in the RAISED TO GRIPPER, PICK-UP, or PRE-TRANSFER position.

c. Argon-system Control Console. The argon system is controlled from the control console located near the tracks of the fuel-unloading machine (Fig. 11). The functions of the instruments and controls on this console are described below; the location of these instruments and controls on this console is designated by numbers that refer to Fig. 39.

LEGEND

- 1 - PURIFIER BED TEMP. CONTROLLER
- 2 - ARGON FLOW CONTROL VALVE POSITION
- 3 - ANNUNCIATOR LIGHT CABINET
- 4 - BATTERY VOLTAGE - CHARGER "ON" - GRD. TEST SW.
- 5 - MOLECULAR SIEVE OVEN - TEMP. CONTROLLER
- 6 - SUBASSEMBLY HEATER - TEMP. CONTROLLER
- 7 - PRESSURE TO F.T.P.
- 8 - ARGON COOLANT FLOW
- 9 - A - TURBINE OUTLET PRESS.
B - PRESSURE TO IBC
C - PRESSURE TO FUM
- 10 - A - TURBINE INLET PRESS.
B - PRESSURE FROM IBC

- 11 - RETURN FROM PRIMARY TANK
- 12 - BLOWING TIMER
- 13 - IBC - HOSES CONNECTED
- 14 - AC TURBINE
- 15 - DC TURBINE
- 16 - FTP - GAS CLEAN-UP
- 17 - IBC - COOLING
- 18 - ARGON FLOW CONTROL
- 19 - CONTROL POWER "ON" (AC & DC)
- 20 - OPERATION SELECTOR SWITCH
- 21 - CONTROL POWER SWITCH
- 22 - VALVE RESET
- 23 - ANNUNCIATOR - ACKNOWLEDGE
- 24 - ANNUNCIATOR - LAMP TEST

- 25 - GRAPHIC PANEL
- 26 - SPARE
- 27 - HEATER TIMER
- 28 - A - PRIMARY TANK GAS TEMP.
B - IBC GAS RETURN TEMP.
C - FUM GAS RETURN TEMP.
- 29 - A - MOLECULAR SIEVE NO. 1
B - MOLECULAR SIEVE NO. 2
- 30 - TURBINE OUTLET TEMP.
- 31 - HEAT EXCHANGER OUTLET TEMP.
- 32 - DC TURBINE - STARTER NO. 2
- 33 - POWER "ON"
- 34 - PIPE LINE HEATER - TEMP. CONTROLLER
- 35 - SUBASSEMBLY HEATER HIGH TEMP. CUTOFF
- 36 - PURIFIER BED HIGH TEMP. CUTOFF

Fig. 39. Argon System Control Console

On the upper section of the console are mounted four indicating temperature controllers (34-1-5-6), which control the pipe line, purifier bed, molecular sieve oven, and subassembly heaters. Each controller has an ON-OFF switch and a red pilot light for indicating when the switch is in the ON position. All temperature sensors in the system are Chromel-Alumel thermocouples, and they are connected with Chromel-Alumel lead wire.

In the center of the upper section is an annunciator (3) with 18 windows (15 of which are used). These are sequence "A" annunciator units; this means the window lamp and audible alarm are: 1) both off, for normal conditions; 2) on-flashing, with audible alarm for off-normal condition; and 3) on-steady, with audible alarm silenced in the acknowledged condition. System conditions that are annunciated are as follows:

OXYGEN CONTENT HIGH	TURBINE OUTLET TEMP. HIGH	HEAT EXCH. OUTLET TEMP. HIGH
VAPOR TRAP PLUGGED	MOLECULAR SIEVE NO. 1 PLUGGED	MOLECULAR SIEVE NO. 2 PLUGGED
ACCUMULATOR PRESS. LOW	PLANT AIR SYSTEM PRESS. LOW	BATTERY VOLTAGE LOW
DC TURBINE OVERLOADED	TURBINE OUTLET PRESS. LOW	VALVES IMPROPERLY POSITIONED
GAMMA INTENSITY HIGH	SYSTEM ON EMERGENCY OPERATION	VALVE ON EMERGENCY OPERATION

The ANNUNCIATOR ACKNOWLEDGE (23) and ANNUNCIATOR LAMP TEST (24) pushbuttons are located below the annunciator, and the audible alarm is mounted at the left end of the console. All remote contacts that actuate annunciator units are normally closed to provide fail-safe circuits.

The ARGON FLOW CONTROL knob (18) determines the position of the argon flow control valve; since the relation between the position of the knob and the position of the valve is not fixed or positive a valve-position indicator is provided. The ARGON FLOW CONTROL VALVE POSITION meter (2) at the left of the annunciator indicates the position of this valve. More specifically, the ARGON FLOW CONTROL knob (18) operates a pressure regulator located beneath the panel. The regulator provides

a differential air pressure to a pilot valve on the air operator for positioning the main valve. Any movement of the main-valve stem is transmitted through gears to a potentiometer. This potentiometer is connected to the ARGON FLOW CONTROL VALVE POSITION meter (2), which senses any change in position of the potentiometer. Below the meter are two potentiometers, a ZERO ADJ. control for adjusting the meter indication to closed, and an F.S. ADJ. control for adjusting the indication to full open. With these, the meter indications can be made to correspond exactly to the positions of the valve.

The meter (4) at the right of the annunciator is a dc voltmeter-relay and operates in conjunction with a load-relay unit. Utilizing fiber optics and solid-state electronics, load contacts in the relay unit are operated when an adjustable set-point on the meter is exceeded by the meter indication. With the three-position (POS.-OFF-NEG.) BATTERY VOLTAGE CHARGER "ON"-GRD. TEST SW. selector switch below the meter in the OFF position, the meter indicates the voltage of the 92-cell, 125-V, emergency battery. Should this battery voltage drop to 115 V, which is the meter set-point, the load relay unit contacts open to actuate the BATTERY VOLTAGE LOW annunciator point. With the selector switch in the POS. position, the meter is connected between the positive side of the battery and ground; likewise, with the switch in the NEG. position, the meter is connected between the negative side of the battery and ground. Should the meter indicate any voltage in either of these positions, the battery has become grounded. The battery is operated ungrounded to increase its availability for an emergency, and this test is a normal part of the system-startup procedure. The red pilot light below the meter indicates that the battery charger is on.

The two meters (30, 31) at the right of the sloping panel are controlling pyrometers. These units are the same as the meter-relay unit described above, except that the meter movement is a dc millivoltmeter; the scale is calibrated in degrees Fahrenheit, and the meters are equipped with cold-junction compensation and thermocouple-break protection. The top (TURBINE OUTLET TEMP.) meter (30) indicates the turbine-outlet temperature and should the indication rise to 250°F, the meter set-point, the load relay unit contacts open to actuate the TURBINE OUTLET TEMP. HIGH annunciator point. The lower HEAT EXCHANGER OUTLET TEMPERATURE meter (31) has a set-point of 100°F, at which the relay unit contacts open to actuate the HEAT EXCH. OUTLET TEMP. HIGH annunciator point.

The two (SUBASSEMBLY HEATER HIGH TEMP. CUTOUT and PURIFIER BED HIGH TEMP. CUTOUT) meters (35-36) at the lower right of the sloping panel are controlling pyrometers, similar to those described above. These meters, however, are used as high-limit controllers for the subassembly heater and argon-purifier-bed heater. The controllers described above for these heaters have their thermocouples located in the argon flow, downstream from the heaters, at points where it is desired to

maintain the gas at a certain temperature. The high-limit controllers have their thermocouples located to sense the temperature of the heater itself and to prevent damage to the heaters by excessively high temperatures when the gas flow through the heater is stopped.

The three meters (26, 28, 29) at the upper right of the sloping panel are indicating pyrometers. The left meter (26) is not in use at this time. The other two meters (28, 29) are equipped with selector switches to permit switching the meter to several thermocouples. The triple-throw selector switch permits the meter (28) to be switched to indicate 1) PRIMARY TANK GAS TEMP., 2) IBC (interbuilding coffin) GAS RETURN TEMP., or 3) FUM GAS RETURN TEMP. The double-throw selector switch permits the meter (29) to be switched to indicate 1) MOLECULAR SIEVE NO. 1 temperature, or 2) MOLECULAR SIEVE NO. 2 temperature. These selector switches have contacts overlaid with silver for low contact resistance.

The four meters (7, 9, 10, 11) at the upper left of the sloping panel are dc millimeters with their scales calibrated to indicate pressure in psig. These meters have a suppressed zero and operate on a 4- to 20-mA signal that is transmitted by a PP/I (process pressure-to-current) transmitter unit. These transmitters require a 42-V dc power supply. The PRESSURE TO F.T.P. meter (7) at the left indicates the pressure to the transfer port; the RETURN FROM PRIMARY TANK meter at the right (11) indicates the return-from-primary-tank pressure. The two meters (9, 10) in the center are equipped with selector switches so they can be switched to different transmitters. The selector switches are the type used with the pyrometers on the right side of the panel, except they are single-pole types. The meter (9) on the left can be switched to indicate A) TURBINE OUTLET PRESS., B) PRESSURE TO IBC, or C) PRESSURE TO FUM. The meter (10) on the right can be switched to indicate: A) TURBINE INLET PRESS., or B) PRESSURE FROM IBC.

The ARGON COOLANT FLOW meter (8) at the lower left is a dc millimeter, the same as the meters above, except that it is calibrated to indicate flow in cfm. This meter is connected to a $\Delta P/I$ (differential pressure to current) transmitter unit. This transmitter provides a proportional 4- to 20-mA dc signal, similar to the pressure transmitters above, and also requires a 42-V dc power supply.

The timers (12, 27), located one on each side of the graphic display, control the length of the blowing and heating cycles. The BLOWING TIMER (12) at the left has an adjustable timing range of zero to 15 min. The timing cycle is initiated by limit-switch actuation. At the end of the timed cycle, the timer closes a contact to energize a relay. This permits the operator to continue the upward movement of the gripper, and energizes valves that cause the argon flow to change flow paths. At the right is the HEATER TIMER (27) with an adjustable range of zero to 60 min; this timer functions in a manner similar to the BLOWING TIMER.

The lighted graphic display (25) in the center of the console shows the operator in which branch of the system the argon is flowing, which turbine blower is producing the flow, and which valves are open or closed. Figure 40 shows the appearance of this display with flow through different branches of the system, by shading the flow lines and valves that would be lighted red; (a) shows flow through the AC TURBINE and the TRANSFER PORT, (b) shows flow through the DC TURBINE and the MOBILE SHIELDING, (c) shows flow through the AC TURBINE, the MOBILE SHIELDING, and the INTERBUILDING COFFIN. Figure 41 is a cross section of this display, showing construction details; the flow lines are pieces of acrylic plastic (Lucite) lighted with edge-lighting units, and the valves are lighted push-buttons with magnetic holding coils.

(a)

Flow through AC TURBINE
and TRANSFER PORT

(b)

Flow through DC TURBINE
and MOBILE SHIELDING

(c)

Flow through AC TURBINE,
MOBILE SHIELDING, and
INTERBUILDING COFFIN

Fig. 40. Argon System Graphic Display

Fig. 41. Argon System Graphic Display Section

The key-operated CONTROL POWER SWITCH (21) is the control and instrumentation power switch. When this switch is turned to the ON position, all circuits are energized and the pilot lights indicate the existing conditions. The lights in the graphic-display pushbuttons (valves) come on red for the normally open valves and green for the normally closed

valves. A red CONTROL POWER ON (AC & DC) pilot light (19) indicates that switch (21) is in the ON position and that ac power is available. A green pilot light (19) indicates that dc power requirements for control and instrumentation are being supplied from ac power by transformation and rectification.

The three-position operation SELECTOR SWITCH (20) has the positions TEST, NORMAL and EMERGENCY. System startup procedure includes testing the flow control valves. This is accomplished by placing this switch (20) in the TEST position and pressing each pushbutton (valve) on the graphic display. When the normally open, red-lighted pushbuttons are pressed, the valves close and the lights change to green, or vice versa, for the normally closed valves, thereby, indicating that the valve has operated. After each valve is checked, the switch is returned to the NORMAL position where it remains for all normal operation. The pushbuttons on the graphic display are not used for any normal flow transfers. The lights in the pushbutton units, however, indicate, the position of the valves at all times. With this switch (20) in the EMERGENCY position, the operator can select the desired argon flow path by leaving each valve in its normal position or pressing the pushbutton (on the graphic display) to change the valve to its operated position. The flow path is changed in this operating mode by pressing the VALVE RESET pushbutton (22). This releases all valves to their normal position; a new flow path is then set up as before.

The AC TURBINE START-STOP pushbuttons (14) at the lower left control the ac turbine blower. The red pilot light above the pushbuttons indicates that the blower is on, the green pilot light that it is off. The POWER ON light (33) above these lights indicates that 440-V ac power is available to operate the blower. The DC TURBINE START-STOP pushbuttons (15), also at the lower left, control the dc turbine blower. The pilot lights above these pushbuttons indicate the on or off condition of the blower as above. The dc turbine blower is started automatically when the ac turbine blower is shut down by the overload protection, ac power failure, or low-pressure indication at the blower outlet. Should this occur, the SYSTEM ON EMERGENCY OPERATION annunciator point is actuated. If the dc turbine blower is started as a result of an ac power failure, the dc turbine blower is shut down and the ac turbine blower restarted automatically as soon as ac power is available. The dc turbine blower is not permitted to shut down automatically in the event of an overload; an overload actuates the DC TURBINE OVERLOADED annunciator point, and the operator makes the decision to shut it down or not, depending on system conditions. The DC TURBINE STARTER NO. 2 START-STOP pushbuttons (32) at the lower right control a standby or spare starter for the dc turbine blower. This starter, connected in parallel with the normal starter, is available to energize the dc turbine blower motor in the event of a coil or control-circuit failure in the normal starter.

The FTP GAS CLEAN-UP START-STOP pushbuttons (16) at the lower left permit the operator to transfer the flow of circulating argon to the transfer port. This "transfer-port cleanup" is part of the normal startup procedure. The red pilot light above the pushbuttons indicates that the flow is through the transfer port. This is also shown by the graphic display. The green light indicates that the gas is not flowing through the transfer port.

The IBC COOLING START-STOP pushbuttons (17) at the lower left permit the operator to start or stop the flow of circulating argon through the interbuilding coffin. The STOP button is used only to stop the flow through the coffin before the coffin is moved out of the reactor building with a fuel subassembly. The START button is used only to start the flow through the coffin, when the coffin with a fuel subassembly is first moved into the reactor building. The red pilot light above the pushbuttons indicates that the circulating argon is flowing through the interbuilding coffin. The green light indicates that the flow is not through the interbuilding coffin. These flow indications are also shown by the graphic display. The red IBC HOSES CONNECTED pilot light (13) above the pushbuttons indicates that the argon hoses are connected to the interbuilding coffin.

6. Emergency Features

Emergency procedures consist of immediate actions which have to be performed to protect a fuel subassembly from overheating and subsequent melting. A core-type subassembly, having achieved maximum burnup (2 a/o), still generates approximately 2.3 kW of heat after a 15-day cooling period in the storage rack inside the primary tank. Without gas cooling, such a fuel subassembly starts melting in about 5 min. Thus, it is imperative to restore gas cooling or to remove the fuel subassembly from the fuel-unloading machine in less than 5 min.

An emergency of this nature exists only when a fuel subassembly is being handled by the fuel-unloading machine and one of the following conditions develops:

- a. Loss of electrical power to the fuel-unloading machine drives and clutches.
- b. Loss of electrical power to the argon system ac turbine.
- c. Reduction of argon flow below 10 cfm.
- d. Abnormal temperature rise in the fuel subassembly.

Planning to remedy or counter such conditions has been one of the major considerations in the system's design and in the development of emergency operating procedures.

The following features are incorporated into the fuel-unloading machine or into associated components and systems:

a. In the event of normal ac power-supply failure, the power requirement is automatically transferred to the reactor-plant emergency diesel generator.

b. Should both the normal ac power supply and the emergency diesel generator power fail, the argon-system dc turbine will start automatically. This turbine and all essential instrumentation and controls have dc circuits, fed by a standby battery.

c. All power-operated drives on the fuel-unloading machine are equipped with handwheel cranks or similar devices for manual operation.

d. All electric clutches can be latched mechanically by easily actuated locking bars.

e. All solenoid locks can be operated manually.

f. The pneumatically actuated valves in the argon system are supplied through a check valve and an accumulator, which is capable of supplying air to operate the valves in the event of air-pressure failure. In addition, the valves can be operated manually by insertion of a socket and wrench assembly.

g. The interbuilding coffin has its own, battery-powered, gas-cooling system. Should the gas system fail, mercury, available from a tank near the top of the coffin, can be used to flood the fuel subassembly and prevent it from melting.

Explicit emergency operating instructions are established for the operators. The fuel subassembly can be provided with safe storage at two locations until normal operations can be resumed. One location is in the primary-tank sodium, the other is in the interbuilding coffin. The decision as to the location to which the fuel subassembly should be moved, depends on whether the transfer port is open or closed when the emergency occurs. If the transfer port is open, the fuel subassembly must be submerged into the primary-tank sodium. If the transfer port is closed, the fuel subassembly must be deposited into the interbuilding coffin. Detailed instructions direct the operators in these activities, requiring them to use manual drives whenever other power is not available due to the nature of the emergency.

D. Operation and Performance Characteristics

1. Operation

The operation of the fuel-unloading machine and its related mechanisms consist of two series of sequenced component operations. One

results in the transfer of a fuel subassembly from the transfer arm to the interbuilding coffin and the other results in the transfer of a fuel subassembly from the coffin to the transfer arm. A fuel-subassembly transfer from the transfer arm to the interbuilding coffin is described first.

a. Transfer of Fuel Subassembly from Transfer Arm to Interbuilding Coffin. Transfers start with the fuel-unloading machine at the parking position, midway between the transfer port and the interbuilding-coffin pit. For this transfer, the empty interbuilding coffin has been moved into the interbuilding-coffin pit, and the transfer arm with the fuel subassembly has been moved to the PICKUP position in the primary tank.

First, the fuel-unloading machine is heated to the operating temperature by energizing electric heaters. These heaters are the molecular-sieve heater, the purifier-bed heater, the fuel-subassembly heater, the pipe-line heater, and the inlet-line heater. The ac turbine is started and 40 to 70 cfm of argon gas at 400°F is circulated through the shielding cask (see Fig. 37c). The operating temperature of 250°F, or above, is reached in 1/2 hr. The argon-system pressure is then reduced to 1 in. of water, and the oxygen content of the argon is checked to make sure it is below 40 ppm.

When the heating requirements of the shielding cask are met, the flow path of the circulating argon is changed so that it flows through the transfer port (see Fig. 37e). The temperature of argon circulating through the transfer port is increased to 650°F by the subassembly heater, the flow rate remaining between 40 and 70 cfm. The supply and return hoses that permit the argon system to circulate argon gas through the interbuilding coffin are connected at this time, and the coffin is purged with 10 cu ft of argon from the auxiliary system.

After the argon has circulated through the transfer port for 10 min, the flow path is changed so that it circulates through the shielding cask as before. Next, the mobile-shielding bottom ring seal is raised to the "up" position, and the handbrake is released. The carriage drive is then energized, and the carriage is driven toward the transfer port. Near the port, the speed is automatically reduced and then stopped 0.5 in. before the carriage reaches the final position. (The final position is reached by manually turning a handwheel.) At the final position of the carriage, the handwheel drive is disengaged and a brake is set by the limit switch; at this final position, the carriage is in contact with the mechanical stops.

Air-operated locator pins on the shielding cask are then inserted into their sockets in the transfer port, exactly aligning the shielding cask over the transfer port. The shield ring and the bottom ring seal are then lowered to their down positions, and the sealed space between the cask-shielding valve and the transfer-port shielding valve is leak-tested and purged with 5 cu ft of argon gas. The transfer-port shielding valve and then the cask-shielding valve are manually rotated to their open positions.

The operator at the control panel on the mobile shielding checks the gripper motion indicator; if this indicator shows the gripper jaws to be open, he drives the gripper down to the LATCH-UNLATCH elevation. As the gripper approaches the LATCH-UNLATCH position, 25 ft 10 in. below its top position, the operator reduces the speed of descent. When the gripper jaws have moved down around the upper adapter head of the subassembly held by the transfer arm, the gripper is stopped by the limit switch. During the last inch of this gripper downward movement, the orange sensing pointer on the gripper motion indicator moves to a point 1 in. clockwise from the red drive pointer. This movement indicates the release of the gripper lock and indicates that the upper adapter head of the subassembly is properly inserted in the gripper jaws. (If this indication is not displayed, the subassembly upper-adapter head is not properly seated in the gripper and the transfer arm must be raised manually until the proper insertion is indicated.) The gripper-jaw drive is then energized and the jaws driven to the closed position.

The jaws having closed on the fuel-subassembly upper adapter, the gripper is driven upward 1.6 in. to the TRANSFER elevation and stopped by the limit switch. After the first 0.5 in. of this movement, the gripper jaws begin to lift the fuel subassembly and raise the support collar on the upper adapter above the transfer-arm carrier block. Next the WIGGLE TEST is performed to confirm that the fuel subassembly is held by the gripper. The transfer-arm latch is then opened, and the transfer arm is rotated away from the fuel subassembly. The sensing pointer on the gripper motion indicator now shows 0.5-in. clockwise separation from the drive pointer, indicating that the fuel subassembly is suspended from the gripper jaws.

The loaded gripper is then driven up to the DRIPPING elevation, 21 ft below its top position. At this elevation, the gripper is slightly above the surface of the sodium, and the subassembly remains submerged in the cooling sodium; the gripper remains at this elevation for 5 min while the sodium drains from its internal parts. From the DRIPPING elevation, the gripper is driven upward and is stopped automatically at the BLOWING AND HEATING elevation, 13 ft 2 in. below its top position.

At the BLOWING AND HEATING elevation, hot argon is blown through and over the fuel subassembly to remove most of the sodium adhering to it. The argon is first circulated through the shielding cask, the transfer port, and the fuel subassembly (see Fig. 37d). This path is maintained for 1 min and then changed automatically so that the flow is through the subassembly heater, the transfer port, and the fuel subassembly, bypassing the shielding cask (see Fig. 37e). The flow path is changed in this manner so that sodium near the top of the subassembly is blown down into the primary tank and not up into the shielding cask by the flow entering the transfer port from the subassembly heater. The argon flow entering the transfer port from the heater is between 50 and 70 cfm and at 650°F. The

blowing period lasts for 10 min; then the argon flow path automatically changes back through the shielding cask, the transfer port, and the fuel subassembly (see Fig. 37d).

From this point on, the temperature conditioning of the fuel subassembly with circulating argon gas is continued without interruption until it is stopped at the end of the transfer. The argon flow is switched automatically from one part of the system to the next as the subassembly is moved.

The operator then drives the gripper and the fuel subassembly to the top elevation of the shielding cask. The cask shielding valve is manually rotated to its closed position, and the argon flow path changes automatically so that it flows through the shielding cask and the fuel subassembly only (see Fig. 37c). The transfer-port shielding valve is then manually rotated to its closed position. Space between the transfer-port shielding valve and cask shielding valve is purged, and the bottom-ring seal and shield ring are raised. The locator pins are then retracted to complete the operation at the transfer port.

The carriage and the shielding cask are driven toward the interbuilding coffin and are positioned over it in the same manner as they were driven toward the transfer port and positioned over it. The bottom-ring shield and seal ring are then lowered, and the space between the cask shielding valve and the interbuilding-coffin port is tested for leaktightness and purged in the same manner as before. The interbuilding-coffin port is then opened. The cask shielding valve is opened next, and the argon flow path changes automatically so that it passes through the shielding cask, the fuel subassembly, and the interbuilding coffin (see Fig. 37b). The argon flow emerging from the coffin flows through one of the two flexible hoses connected to the coffin prior to its purge.

The fuel-unloading machine gripper, loaded with the fuel subassembly, is then driven down into the interbuilding coffin. Downward movement is stopped by the limit switch when the lower end of the fuel subassembly approaches the bottom of the coffin. The gripper is then 11 ft below the top elevation. The operator checks the gripper motion indicator; if the orange sensing pointer remains in the same relation to the red drive pointer (0.5 in. separation), the limit switch that stopped the downward movement is bypassed by a pushbutton, and the downward movement cautiously continued. During the last 0.5 in. of this downward movement, the orange sensing pointer moves from a point 0.5-in. clockwise from the red drive pointer to a point 1 in. clockwise from the red drive pointer. This movement indicates the release of the gripper lock and shows that the fuel subassembly is supported by the coffin. Next, the gripper jaws are opened.

The operator then drives the gripper to the top elevation of the shielding cask. After the first inch of gripper upward movement, the

sensing pointer on the gripper motion indicator comes into line with the drive pointer. This indicates that the fuel subassembly has been left in the interbuilding coffin. The cask shielding valve is manually rotated to its closed position, and the argon flow path changes automatically so that it flows through the interbuilding coffin and the fuel subassembly only (see Fig. 37a). The interbuilding-coffin port is then closed. The space between the coffin port and shielding-cask port is purged. The bottom ring seal and shield ring are then raised and the locator pins retracted in the same manner as at the transfer port. The shielding cask and carriage are then driven to the parking position midway between the transfer port and the coffin pit, and the handbrake is set.

The integral cooling system on the interbuilding coffin is started, and the argon flow path is changed from the interbuilding coffin to the shielding cask by operating a pushbutton on the argon control console. The flexible hoses are then disconnected from the coffin. Next, the interbuilding coffin is lifted out of the coffin pit by the building crane and placed on the equipment air-lock dolly to start its trip to the Fuel Cycle Facility.

b. Transfer of Fuel Subassembly from Interbuilding Coffin to Transfer Arm. The transfer of a fuel subassembly from the interbuilding coffin to the transfer arm is essentially the reverse of the procedure described above; however, the many differences that do exist require that the procedure be described sequentially.

First, the interbuilding coffin, loaded with a new or reprocessed fuel subassembly, is moved into the coffin pit, the flexible hoses are connected, and the coffin is purged.

If the fuel-unloading machine is at the operating temperature, due to a prior transfer, then the mobile-shielding bottom ring seal is raised to the UP position and the handbrake is released in preparation for positioning over the coffin. If the fuel-unloading machine is not at the operating temperature, the electric heaters must be energized, the ac turbine started, the pressure and oxygen content checked, and the argon flow path changed to the transfer port and back, as previously described. Then the mobile-shielding bottom-ring seal is raised to the "up" position and the handbrake is released. Next, the carriage drive is energized, and the carriage and shielding cask are driven toward the interbuilding coffin and are positioned over it in the same manner as they were driven toward the transfer port and positioned over it. The bottom shield ring and ring seal are then lowered and the space between the cask shielding valve, and the interbuilding-coffin port is tested for leaktightness and purged in the same manner as before.

The argon flow path is changed from the mobile shielding to the interbuilding coffin (see Fig. 37a) by operating a pushbutton on the argon control console, and the integral cooling system on the interbuilding

coffin is turned off. The interbuilding-coffin port is then opened. The cask shielding valve is opened next, and the argon flow path changes automatically, so that it passes through the mobile shielding, the fuel subassembly, and the interbuilding coffin (see Fig. 37b).

The operator at the gripper and mobile shielding control panel checks the gripper motion indicator; if this indicator shows the gripper jaws to be open, he proceeds to drive the gripper down. Downward movement is stopped by the limit switch when the lower end of the gripper approaches the fuel subassembly; the gripper is then 11 ft below the top elevation. The limit switch that stopped the downward movement is bypassed by a pushbutton, and the downward movement is cautiously continued. During the last inch of this downward movement, the orange sensing pointer moves from a point in line with the red drive pointer to a point 1-in. clockwise from the red drive pointer. This movement indicates the release of the gripper lock and indicates that the upper adapter head of the subassembly is properly inserted in the gripper jaws. The gripper-jaw drive is then energized and the jaws driven to the closed position.

The jaws having closed on the fuel-subassembly upper adapter, the gripper is driven upward. After the first 0.5-in. of this movement, the gripper jaws begin to lift the fuel subassembly. The sensing pointer on the gripper motion indicator shows 0.5 in. clockwise separation from the drive pointer. This separation remains as upward movement of the gripper is continued, indicating that the fuel subassembly is held in the gripper jaws. The loaded gripper is driven to the top elevation of the shielding cask.

The cask shielding valve is then manually rotated to its closed position, and the argon flow path changes automatically so that it flows through the mobile shielding and the fuel subassembly only (see Fig. 37c). The interbuilding coffin is then manually closed. Space between the interbuilding-coffin port and cask shielding valve is purged, and the bottom ring seal and shield ring are raised. The locator pins are then retracted to complete the operation at the interbuilding coffin.

The carriage drive is then energized, and the carriage is driven toward the transfer port and positioned over it as before. The shield ring and bottom ring seal are then lowered to their down positions, and the sealed space between the cask shielding valve and the transfer-port shielding valve is leak-tested and purged as before. The transfer-port shielding valve and then the cask shielding valve are manually rotated to their open positions, and the argon flow path changes automatically so that it flows through the mobile shielding, the fuel subassembly, and the transfer port (Fig. 37d).

The fuel-unloading machine gripper, loaded with the fuel subassembly, is then driven down and stopped by the limit switch at the BLOWING AND HEATING elevation, 13 ft 2 in. below its top position. At this elevation, the argon flow path changes automatically so that the flow is through the subassembly heater, the transfer port, and the fuel subassembly, bypassing the mobile shielding (see Fig. 37e). The argon flow entering the transfer port from the heater is between 50 and 70 cfm and at 650°F. The heating period lasts 15 min; at the end of the heating period, the argon flow path changes automatically back through the shielding cask. The fuel subassembly is heated at this time to prevent its being damaged when it is lowered into the primary-tank sodium, which is normally at 700°F.

The heated-fuel subassembly is driven down to the "transfer" elevation, 25 ft 8.4 in. below its top position and stopped by the limit switch. The transfer arm is rotated from the PRE-TRANSFER position to the TRANSFER position so that the transfer-arm carrier block slips around the fuel-subassembly upper adapter. The transfer-arm latch is then closed and the WIGGLE TEST is performed; this test confirms that the fuel subassembly is held by the transfer arm. The gripper and the fuel subassembly are then driven downward 1.6 in. and stopped at the LATCH-UNLATCH elevation. This downward movement against the transfer arm releases the gripper lock, and is indicated by the gripper-motion-indicator orange pointer, which moves 0.5-in. clockwise, making a 1-in. total separation from the red drive pointer. Any discrepancy in this indication can be corrected by manually raising the transfer arm. The gripper-jaw drive is then energized, and the jaws are driven to the open position.

The empty gripper is then driven upward; after the first inch of this movement, the orange pointer on the gripper motion indicator has moved into line with the red drive pointer, indicating that the fuel subassembly has been left in the transfer arm. Upward movement of the gripper is continued to the DRIPPING elevation where it remains for 5 min while sodium drains from its internal parts. At the end of the dripping period, the gripper is driven upward and stopped automatically at the BLOWING AND HEATING elevation, 13 ft 2 in. below its top position. At this elevation, hot argon is blown through and over the empty gripper; the sequence of flow-path changes is the same as for a gripper loaded with a fuel subassembly at the BLOWING AND HEATING elevation. The DRIPPING and BLOWING operations are performed on the empty gripper because it is desirable to remove all the sodium possible from the gripper. The gripper is then driven to the top elevation of the shielding cask.

The cask shielding valve is closed, and the argon flow path changes automatically from the mobile shielding and the transfer port to the mobile shielding only (see Fig. 37c). The transfer-port shielding valve is then closed. The space between the transfer port and shielding-cask port is purged. The bottom ring seal and the shield ring are raised and the

locator pins retracted in the same manner as before. The mobile shielding and the carriage are then driven to the parking position, and the handbrake is set.

If additional fuel is to be transferred, the argon system is left in operation and continues to circulate heated argon through the mobile shielding. If no further fuel is to be transferred within the next several hours, the argon system is shut down.

2. Preinstallation Tests

A temporary argon system was constructed and operated to obtain information on temperatures, flow characteristics, and pressure drops to verify the calculations and design criteria for the permanent installation. It was found that 5-psi differential pressure furnished by the blower was sufficient to establish 20 cfm or better flow, under the highest pressure-drop conditions. The vapor-trap and molecular-sieve systems were effective for removing entrained sodium from the argon. The rapid plugging of the filter suggested provisions for easy replacement of the filter material. Too rapid cooling of the argon occurred, and this indicated the need for additional heating equipment and better insulation of some pipe section.

One important phase of the testing was that of determining the best material for seats and stem packing on the ball valves. Graphitar seats were found to be the best material at 600-700°F; the reinforced Teflon demonstrated better sealing characteristics at 400-600°F. The valves, exposed to a temperature range of 200-400°F, were furnished with regular Teflon seats, satisfactory for this service.

Cycling of temperatures from high to low extremes (700-70°F) produced a gradual increase in torque necessary to operate the valves. The spring-loaded ball and tapered seat supports were modified to make the seat self-adjusting.

After the fabrication of the components of the final system, the loop was assembled and tested for 3 weeks in simulated service conditions. The results of these tests and modifications satisfied the system requirements in workability and reliability for installation.

In addition to the argon system operation, the principal concern in providing access to the primary tank for fuel-handling operations was that of sealing and shielding the opening. Extensive tests were performed especially to study the sealing capabilities of the mechanisms in various expected service conditions. Internal helium pressure up to 20 in. of water above atmospheric pressure did not produce any detectable leak. The other features of the shielding valves were tested at the reactor site, as installed. Mechanical components to open and close the shielding valves operated satisfactorily. The effectiveness of the shielding was checked, using a gamma

source lowered through the shielding cask and the transfer port. No voids or "shine" were detected.

3. Postinstallation Characteristics

Because of the previous laboratory assembly and tests, the final assembly of the argon system in the reactor building was accomplished in a short time. The operation of the system is mostly automatic after it is started and synchronized with the operations of the fuel-unloading machine (see Fig. 42). Results of the actions are indicated on the control panel. Variable factors, such as plugging of the flow passages and filters, are checked on the instruments, and the results have to be considered in adjusting the flow and temperature controls. The final checkout of the system demonstrated the capabilities and features well in range of the design requirements.

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Fig. 42. Fuel-unloading Machine and Interbuilding Coffin

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