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A Pneumatic System for
Transferring Samples Automatically
Between Irradiation and Detection Positions

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A PNEUMATIC SYSTEM FOR TRANSFERRING SAMPLES AUTOMATICALLY
BETWEEN IRRADIATION AND DETECTION POSITIONS

by

B. M. Moore, H. M. Ruess, and J. E. Swansen

ABSTRACT

A pneumatic system for transferring samples from a storage chamber to irradiation and detection stations and back to the storage chamber has been constructed. This report describes the mechanical, pneumatic, and electronic systems used. With this device, many samples can be irradiated and counted with little work on the part of the experimenter.

INTRODUCTION

An automatic sample transfer machine was designed for an experiment in which small plutonium samples will be irradiated by an unshielded critical assembly and delayed gamma rays from the fission products will be counted. Since many of the fission products of interest have half-lives of a few seconds to a few minutes, counting intervals must be short. These short counting intervals and the small sample size give rise to low counting rates. Rapid automatic transfer of the samples will make it possible to analyze the gamma rays from the short-lived fission products and to analyze enough samples to obtain good statistics for the gamma-ray spectra. Remote operation is necessary because personnel will be located about one-quarter mile away from the critical assembly.

In automatic operation, the system pneumatically transfers a sample from the shielded storage chamber to the irradiation station, where the sample is irradiated for a predetermined period. When the irradiation is completed, the electronic logics cause the sample to be transferred to the detection station, and a signal is sent to the detection system logics to start counting. At the end of the counting period, a signal is sent to the automatic transfer logics to return the sample to the storage chamber, and a new cycle is started with a new sample.

The system logics are also designed for one-cycle and manual operation. In the one-cycle mode, the system stops at the end of a cycle and waits for a signal to start again. In the manual mode, the operator must perform all operations by pushing the appropriate buttons on the control panel.

MECHANICAL SYSTEM

The mechanical system consists mainly of the irradiation station, the detection station, the storage chamber, and the transfer line (Fig. 1).

The irradiation and detection stations are constructed identically. Each has an air pressure inlet-outlet port and a microswitch which indicates

Fig. 1. Automatic transfer system.

whether a sample holder (rabbit) is in position. The transfer tube (1-in.-o.d., 3/4-in.-i.d. Tygon tubing) is attached to each station with eight set-screws modified at the end to needles 3/32-in. long. These needle points penetrate into the Tygon tubing to provide a good connection between the station and the transfer line.

The storage chamber holds up to 20 irradiation samples mounted in rabbits, positions the appropriate rabbit in line with the transfer tube, opens the line to the irradiation and detection stations at the appropriate times, and closes the line so that the sample will return to the storage chamber. The storage chamber is composed of the housing, the storage cylinder, the control disk, the control disk switch, two Slo-Syn motors (SS 250-1058), the transfer-tube attachment sleeves, and two encoders (Fig. 2). The housing provides a loading port and aligns the other components.

The storage cylinder has individual chambers for 20 rabbits. A Slo-Syn motor with 200 steps/revolution, connected to the cylinder shaft, positions the cylinder according to a preset indexer so that any of the 20 rabbits can be chosen to be irradiated. O-rings are provided to prevent the high-pressure air (up to 40 psi) from blowing through the ball bearings, blowing the bearing grease out, and contaminating the bearings with dust.

The control disk has a large and a small hole to open or close the transfer line. A second Slo-Syn motor, connected to the control disk shaft,

positions the holes so that, when the small hole is aligned with the transfer tube, the large hole is not aligned with a stored rabbit. When a rabbit is to be transferred to the irradiation station, the large hole (whose diameter is the same as the transfer line inside diameter) is aligned with the transfer line, providing free passage for the rabbit to the irradiation station and back through the storage chamber to the detection station. When the rabbit is in the detection chamber, the small hole is aligned with the transfer line to stop the rabbit when it returns to the storage cylinder. The hole allows the air being displaced by the returning rabbit to escape, and the pressure differential prevents the rabbit from bouncing back out of the storage chamber.

The control disk switch (Fig. 2) attached to the double-ended Slo-Syn motor contains two micro-switches which indicate whether the large or small hole is in position. The switch is also designed to prevent the holes from going past their limit position.

The transfer line extends 40 ft from the storage chamber to the irradiation station and 10 ft from the storage chamber to the detection station. Its transparency aids in locating a stuck rabbit or foreign particles within it. Its flexibility simplifies installation and operation. The tube expands so that the rabbit can move freely with a minimum of air bypassing it.

PNEUMATIC SYSTEM

The rabbit is blown from station to station by air or nitrogen at an average speed of more than 50 ft/sec from start to stop. Nitrogen from eight bottles is collected at 80 psi in a 2-in.-o.d., 4-ft-long, 1/8-in.-wall manifold. A reduction valve at the outlet of the manifold reduces the pressure to 30 psi (system pressure). Figures 3 and 4 show the manifold and solenoid valve assembly.

Four 1/2-in. solenoid valves (two normally closed and two normally open) provide the proper sequence of pressure and bleed control. When the rabbit is stationary, the closed valves prevent gas from entering the system and the open valves maintain atmospheric pressure in the system. When the

Fig. 2. Main assembly.

Fig. 3. Manifold and solenoid valve assembly.

rabbit is to be moved from one station to another, the normally open and normally closed valves on the pressure side of the rabbit are energized to allow the pressure to build up on that side of the rabbit. On the low-pressure side of the rabbit, the normally open valve remains de-energized to allow the gas to bleed to atmospheric pressure.

RABBITS

The rabbit is designed to accept a few-mil-thick nickel-coated plutonium sample sandwiched between a plastic washer and a membrane in the center of the rabbit (Fig. 5). The rabbit is bored on both sides, leaving a 0.100-in. membrane at the center. The irradiation sample is held in place by a washer pressed into a groove 0.025-in. deep and 0.040 in. from the membrane.

A 0.030-in.-deep recess was machined around the outside of the rabbit, leaving a ring on each end. Rabbits without this recess had a tendency to stick on turns until sufficient air pressure had built up to bulge the tube.

The material for the rabbit had to have a low neutron activation cross section, low shielding for gamma rays, and high impact strength. Teflon, polyethylene, Kel-F, extruded nylon, monocast nylon, and Lexan were tested. Lexan was found to be the best material for this application. Lexan rabbits showed only slight wear after 700 cycles, with fatigue marks evident near the washer groove.

Fig. 4. Schematic of manifold and solenoid valve assembly.

ELECTRONIC CIRCUITRY

Figure 6 is a diagram of the electronic circuitry for the automatic transfer system. The diagram is best explained by describing its operation for one automatic cycle.

For automatic operation, the three-way switch shown at the top of the diagram is set to AUTO. Then the start button is depressed, energizing relay coil K1. This, in turn, opens normally closed solenoid valve V1 and closes normally open valve V3, and the rabbit is blown toward the irradiation station. In the irradiation station, the rabbit closes the limit switch, which energizes the coil of relay K3. The contacts of this relay then start the timer and energize the coils to relays K8 and K6, which activate the irradiation time recorder and de-energize the solenoids of valves V1 and V3.

Fig. 5. Rabbit and sample.

Fig. 6. Electronic circuitry for automatic transfer system.

Latching relay K5 is also energized. At the end of the desired irradiation time, relays K8 and K6 drop out, opening normally closed solenoid valve V2 and closing normally open solenoid valve V4, and the rabbit is blown toward the detection station. When the rabbit leaves the irradiation station, the limit switch opens and de-energizes relay K3. In the detection station, the rabbit closes the limit switch, which energizes the coil of relay K4. This reverses indexer 1 and energizes delay relay K6, which de-energizes latching relay K5 and solenoid valves V2 and V4, signals the analyzer logics to start counting, and starts indexer 1. Indexer 1 drives the Slo-Syn motor to put the small hole in the control disk in position to stop the rabbit upon its return to the storage chamber. After the analyzer has finished counting the sample, it energizes an end-of-analyze relay (EOA), whose contacts are in the automatic transfer logics. Solenoid valves V1 and

V3 are thereby energized, and the rabbit is blown toward the storage chamber. The EOA also energizes latching relay K9, which energizes delay relay K10. The delay on K10 shuts off the gas after the rabbit is in the storage chamber. K10 energizes delay relay K6 ($<1/4$ sec) and enables indexer 2 to index the next rabbit into position. K6 now starts indexers 1 and 2. After the EOA signal is over (about 1.5 sec) and indexers 1 and 2 have stopped indexing, relays K9, K10, and K6 are de-energized. The next rabbit is then blown toward the irradiation chamber, starting the next cycle.

The three-way switch also allows one-cycle and manual operation. In the one-cycle mode, all operations are performed as in the automatic mode, but, at the end of the cycle, after the next rabbit is positioned, the system stops until the operator gives the signal to proceed. In manual operation, the operator must perform all operations with push buttons on the control panel.

Figure 7 shows the control chassis. The top and bottom panels contain readouts from the shaft encoders. The top panel indicates which of the 20 rabbits is in the cycle, and the bottom panel indicates how many cycles have been run. The output signals can also be read out on magnetic tape. The panel next to the bottom contains the preset indexers which control the Slo-Syn motors. The master control panel containing the automatic transfer logics is the panel next to the top of the chassis.

CONCLUSIONS AND RECOMMENDATIONS

The automatic transfer system has functioned very reliably, but some modifications would improve its performance. Oiled felt washers substituted for O-rings in the storage chamber would better protect the bearings from plastic fragments. A photo-cell switching system might prove more reliable than the mechanical microswitches now in use. In the storage chamber very close tolerances are needed on all moving parts. Because of the high operating temperature of the Slo-Syn motors, 75°C above ambient, either the tolerances have to allow for thermal expansion or a heat shield must be interposed between the motors and the chamber. Hole spacing on the control disk should differ from the hole spacing

Fig. 7. Control chassis.

in the storage cylinder to prevent the rabbits from being half in the control disk and half in the storage chamber, interfering with the normal movement of the disk and cylinder. The minimum operating pressures on the solenoid valves must not interfere with normal operation but must still be reliable. We found that solenoid valves with a minimum operating pressure of 5 psi performed adequately. Also, depending on the length of tubing the rabbit is pushed through, a delay may be necessary for de-energizing the solenoid valves.

Until the Tygon tubing has had enough use that the rabbits require the same length of time to move through the tube on each cycle, a lubricating rabbit should be cycled through periodically to remove plastic dust and lubricate the tubing.

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