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Test Results for the FAST Facility Delayed Neutron Interrogator Source Transfer System

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TEST RESULTS FOR THE FAST FACILITY DELAYED NEUTRON INTERROGATOR SOURCE TRANSFER SYSTEM

by

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ABSTRACT

A long-term test of the source transfer mechanism for the FAST Facility Delayed Neutron Interrogator has been completed. Test results and analysis are presented. The observed performance is well within that required for successful assays over a long-term period.

I. INTRODUCTION

Results from a long-term test of the source transfer mechanism for the FAST Facility Delayed Neutron Interrogator are presented. This system consists of an improved and upgraded version of early transfer system designs that were used on the initial shufflers.[1,2] Hardware electronics have been reduced to a minimum and control of the transfer system is now accomplished using computer software. The testing procedure was designed to evaluate the overall performance of the transfer system and to measure wear of components resulting from long-term cycling. The long-term test entailed running 1 700 000 cycles on the source transfer system. Transfer times and displacement were consistent throughout the test to better than 1%. No mechanical failures of the transfer mechanism were encountered. Wear on components was negligible, and the system appeared capable of running many more cycles at the time the test was ended.

II. SYSTEM DESCRIPTION

The system used to test the ^{252}Cf source transfer mechanism was constructed to be identical to the transfer mechanism designed for the Fluorinel and Storage (FAST) Facility Delayed Neutron Interrogator.[3] The transfer system moves a ^{252}Cf source, in two modes, between a sample interrogation position and a source storage position. The first mode, to be used to assay waste material, is a fast transfer of the source to the waste interrogation position and then a fast transfer back to storage. The second mode, to be used to assay spent fuel elements, will transfer the source around the element to ensure a more uniform interrogation since the element itself cannot be rotated. This is accomplished by a fast transfer out, change to a slow speed, interrogation of the fuel element by traversing a circle, retracing the circle again at the slower speed, and then a rapid return to the storage position.

The geometry of the source transfer system is shown in Fig. 1. The fast transfer time between the source storage and waste irradiate position (~150 cm) is completed in 0.5 s. The slower transfer time around the fuel tube (~300 cm) is accomplished in about 3 s. The transfers are achieved by driving the source inside a stainless steel tube, using a Teleflex helix-wound cable driven by a stepping motor with an optical encoder. The sigma stepping motor, model 21-3500-2382, with 200 steps/rev, has a solid coupling to a gear box, which drives the Teleflex cable.

The solid coupling and stainless steel gear box represent an evolution from initially a hard rubber star-gear coupling, to a brass star-gear coupling,

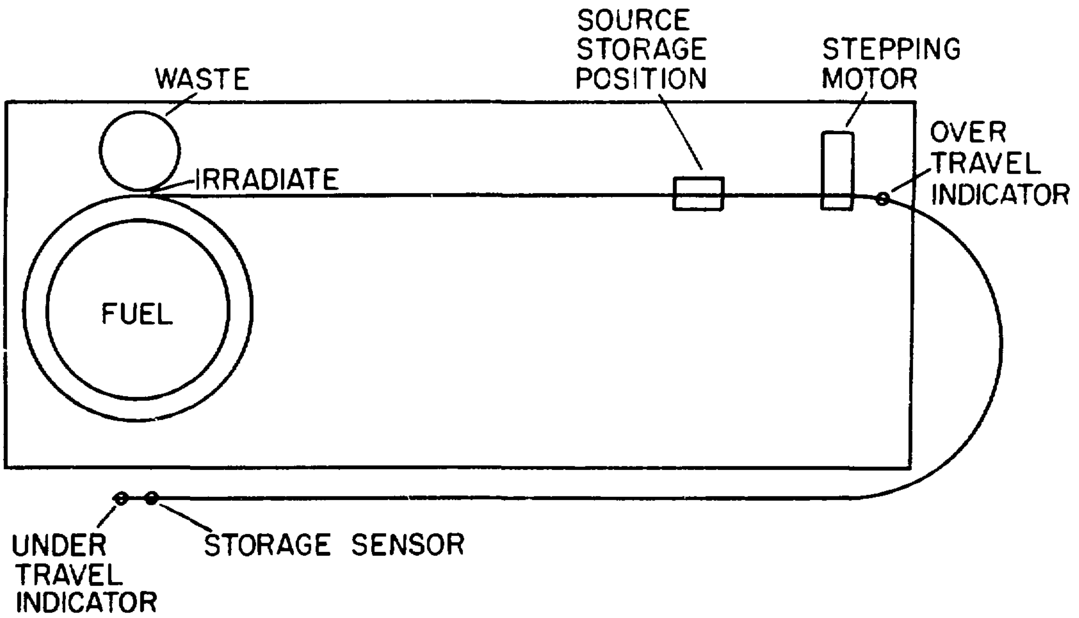

Fig. 1. Transport system geometry.

to the present configuration. The rubber coupling caused numerous over- and undershoots, which the brass coupling corrected. However, after about 100 000 cycles, the brass absorber started to wear allowing play in the system and errors to occur. The long-term test reported here used the solid coupling with no sign of wear during or at the end of the test.

Complete system control for source transfer is achieved with software executed by a LSI-11 microcomputer. The software ensures the correct positioning of the source at the start of a cycle, ramps the source up or down to a specified speed, and then maintains the desired speed over a given distance. Position feedback is provided from an optical encoder to ensure that a step is completed before the next one is initiated. Interrupts are generated by fault indicators for over or under travel of the Teleflex cable. The interrupts are then serviced by the software. Table I lists details of the source transfer mechanism.

TABLE I

SOURCE TRANSFER MECHANISM

Stepping Motor	Sigma, Model 21-3500-2382 200 steps/revolution
Power Supply	Sigma, Model 29B-16-105
Gear Box	Stainless Steel, LASL designed Drawing Number 68Y-155585 D-54
Gear	Teleflex C 6805-6 (Stainless Steel Wheel)
Cable	Teleflex 187 Regular

The stepping motor completes one revolution in 200 steps. The gear wheel provides a position resolution of 0.10 cm (0.04 in.) per step. Distance of source travel from the storage location to the waste irradiation position is 152 cm (60 in.) requiring 1500 motor steps (7.5 revolutions). To cycle the source around the spent fuel region requires an additional 213 cm (84 in.) of travel. Table II lists details of the source transfer parameters for the waste and fuel assay modes of operation.

TABLE II

SOURCE TRANSFER PARAMETERS

Assay Region	Transfer Distance cm	in.	Motor Revolutions	Position Resolution cm	in.
Waste	152	84	7.5	0.10	0.04
Fuel	213	144	18	0.10	0.04

Three position sensors, shown in Fig. 1, are mounted on the stainless steel tube that guides the Teleflex cable. The sensors detect the Teleflex cable position and provide both fault and reset information to the software. The storage sensor resets the motor encoder position counter to zero and indicates when the source is positioned in the storage block. The other two sensors provide fault information and ensure fail-safe operation of the transfer mechanism. If the Teleflex cable blocks the under-travel sensor or unblocks the over-travel sensor by moving too far in either direction, a fault condition occurs. When these sensors are triggered, they prevent any additional steps from being taken in the fault direction. The software is able to move the cable in the opposite direction to clear the fault. A special software routine has been written to process overshoot conditions and is given control by an interrupt when a fault sensor is triggered. No fault conditions occurred during the 1 700 000 cycles completed during the continuous testing of the transfer system.

III. TEST RESULTS

Continuous operation of the source transfer mechanism was performed for a total of 1 700 000 cycles. Transfers were run by alternat[illegible] [illegible] the waste and fuel-transfer modes. A sequence of 10 cycles was completed before switching transfer modes. Transfers were run in batches of 100 000, providing 50 000 transfers in each mode. The data were grouped in sets of [illegible] transfers for statistical analysis.

Collected data consisted of transfer times and positions for each cycle. Times were recorded in milliseconds, which was the reference time unit for the system. Position deviations were collected in [illegible] cm increments, which was the position resolution of the stepping motor. A sample of the collected data is listed and described in Appendix A. Average values for the transfer mechanism are listed in Table III. Observation of the data in batches was completed to determine if the positioning and time became worse as the system completed more cycles. The system continued to operate consistently and showed no significant change in operating parameters.

TABLE III

AVERAGE TRANSFER AND POSITIONING VALUES

Mode	Position (cm)	Transfer Time Fast (s)	Transfer Time Slow (s)
Waste Assay	152.4	0.502	None
Fuel Assay	152.4 213.3	0.502	3.00

The trend analysis consisted of computing averages on the first 1000 cycles of a batch of data according to

$$\bar{X} = \frac{1}{N} \sum_{i=1}^{N} X_i \quad , \qquad (1)$$

and comparing the averages between batches. The averages (Fig. 2) were consistent to 2 ms (±0.4%) in time for the fast transfer, ±6 ms (±0.2%) in time for the slow transfer, and ±0.04 cm (±0.04%) in position.

Deviations within a batch were calculated about the average as

$$\text{DEVIATIONS}_i = \bar{X} - X_i \quad . \qquad (2)$$

The data have been analyzed by histogramming the position and time deviations about the averages for each set of 1000 cycles. Figure 3 shows a typical set of the four time distributions in the fuel-transfer mode, which represents the average time in transferring from storage to irradiate, around the fuel element and back, and return to storage. All deviations lie within a 7-ms window representing an uncertainty in the transfer time of less than 1.5%. Figure 4 shows the corresponding set of position distributions. Positions are measured relative to the storage position. All the deviations lie within 1 cm (0.4 in.) representing a position uncertainty of less than 0.7%. Identical performance was observed in the waste mode.

IV. CONCLUSIONS

An average of 30 cycles will be required for an assay. The 1 700 000 cycles completed represents approximately 57 000 assays corresponding to roughly 10 years of operation in which 15 samples per day are measured, 7 days a week. No mechanical malfunction or excessive wear in the source transfer system (using the solid stainless steel coupling gear) was observed during this simulated 10-year test. The system was shut-down with all components still operational; no indication of any trend towards a system failure was evident. The observed performance is within that required for successful assays over a long continuous operational period.

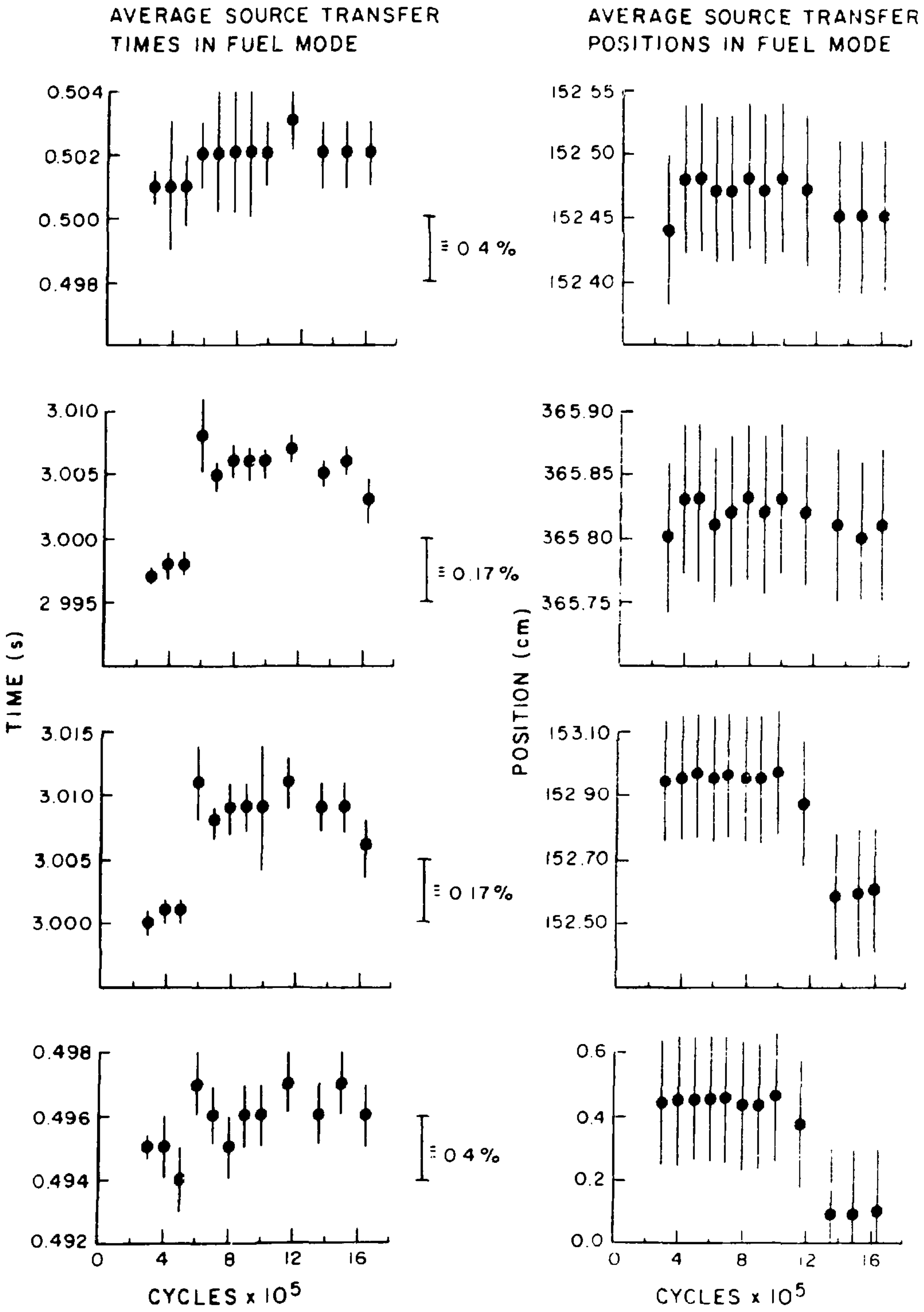

Fig. 2. Average source transfer times and positions per batch.

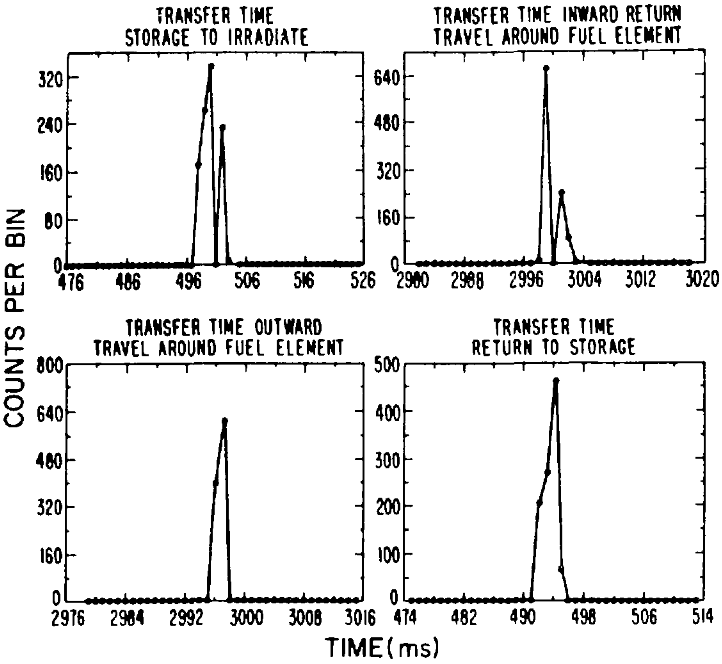

Fig. 3. Source transfer time deviations in fuel mode.

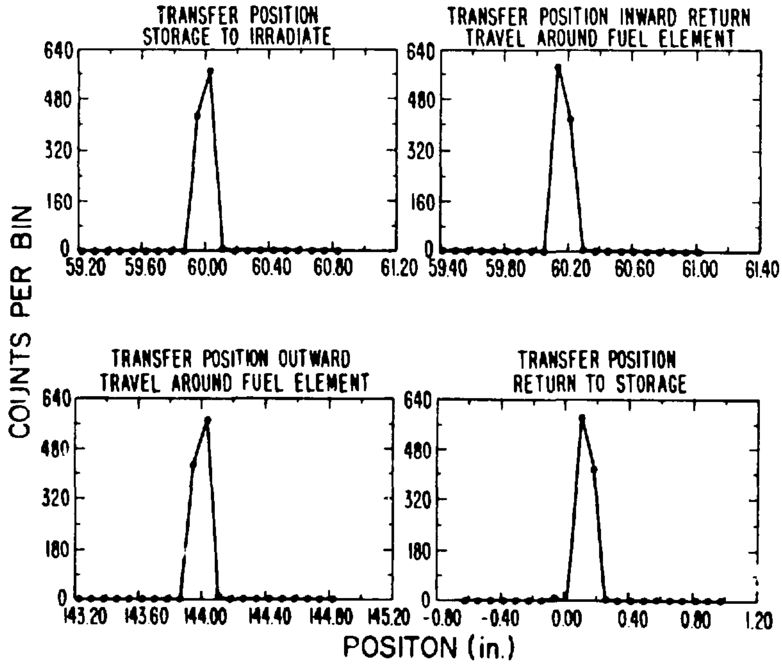

Fig. 4. Source transfer position deviation in fuel mode.

ACKNOWLEDGMENTS

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2. T. Crane, S. Bourret, G. Eccleston, H. Menlove, L. Speir, and R. Studley, "Design of a ^{252}Cf Neutron Assay System for Evaluation at the Savannah River Plant Fuel Fabrication Facility," Proceedings, American Nuclear Society Topical Meeting held in Williamsburg, Virginia, May 15, 1978.

3. G. Eccleston, "FAST Facility Source Transfer System Manual," (to be published).

APPENDIX

SAMPLE TEST DATA

The software to control the long-term source transfer mechanism test was run on a DEC LSI-11 using the RT-11 operating system. Two special software handlers were written for the system, both of which were loaded at startup time. The first handler serviced interrupts generated by the transfer system. The other handler permitted directing input/output to a second terminal (RT-11 normally supports only a single terminal environment). At the start of the test program the user could modify transfer times and positions and specify the number of cycles to run.

The console terminal gave a cycle-by-cycle description during the test showing the current cycle and approximately 25 previous cycles (Fig. A-1). The displayed information included the transfer times in seconds (columns 1 through 4), the cycle number (column 5), and the transfer position in inches (columns 6 through 9). All positions recorded were relative to the storage location defined by the zero position sensor. The notation T0-T1 (P0-P1) refers to the transfer time (distance) from storage to the waste irradiate location, T1-T2 (P1-P2), the transfer time (distance) around the fuel element, T2-T1 (P2-P1), the transfer time back around the fuel element, and T1-T0 (P1-P0) is the return time (distance) to the storage location. For example, cycle 29814 shown in Fig. A-1, took 0.503 s (T0-T1) to move the source 60.04 inches from storage to the waste irradiate position. Note that the times (T1-T2, T2-T1) and positions (P1-P2, P2-P1) recorded for movement of the source around the fuel tube are zero during waste cycles 29801 through 29810 in Fig. A-1. This occurs because the waste assay mode only requires the source to be moved to position P1 and held there during sample irradiation. All distances were measured relative to zero at the storage position. Ten cycles were run in the fuel mode, then 10 cycles were run in the waste mode throughout the test. The second terminal was used to give an overall picture of the test.

After the first 1000 cycles of a test were run, an average value of each transfer time and position was calculated along with its standard deviation. All further cycles were compared to these averages. The second terminal at refresh intervals of 20 cycles listed the averages and the running sum of deviations. This permitted the operator to immediately compare current cycle information on the console terminal with the averages on the second terminal, and by observing the deviation, observe if any long-term drifts had occurred.

T0-T1	T1-T2	T2-T1	T1-T0	CYCLE	P0-P1	P1-P2	P2-P1	P1-P0
0.501	0.000	0.000	0.499	29801	60.04	0.00	0.00	0.64
0.501	0.000	0.000	0.498	29802	60.04	0.00	0.00	0.40
0.501	0.000	0.000	0.500	29803	60.00	0.00	0.00	0.60
0.502	0.000	0.000	0.500	29804	60.00	0.00	0.00	0.72
0.502	0.000	0.000	0.500	29805	60.08	0.00	0.00	0.64
0.503	0.000	0.000	0.499	29806	60.04	0.00	0.00	0.68
0.501	0.000	0.000	0.500	29807	60.00	0.00	0.00	0.52
0.501	0.000	0.000	0.504	29808	60.00	0.00	0.00	0.84
0.502	0.000	0.000	0.500	29809	60.04	0.00	0.00	0.64
0.501	0.000	0.000	0.499	29810	60.00	0.00	0.00	0.60

T0-T1	T1-T2	T2-T1	T1-T0	CYCLE	P0-P1	P1-P2	P2-P1	P1-P0
0.502	3.004	3.008	0.496	29811	60.04	144.04	60.20	0.16
0.502	3.004	3.008	0.496	29812	60.00	144.04	60.24	0.32
0.501	3.005	3.007	0.497	29813	60.08	144.08	60.24	0.20
0.503	3.005	3.007	0.497	29814	60.00	144.04	60.20	0.04
0.502	3.004	3.008	0.496	29815	60.04	144.00	60.16	0.16
0.501	3.004	3.008	0.496	29816	60.04	144.00	60.16	0.36
0.501	3.003	3.409	4.495	29817	60.00	144.04	60.20	0.12
0.501	3.003	3.009	0.496	29818	60.04	144.08	60.24	0.08
0.502	3.004	3.008	0.496	29819	60.00	144.04	60.20	0.24
0.502	3.004	3.008	0.497	29820	60.00	144.04	60.20	0.16

Fig. A-1. Sample cycle-by-cycle data output.