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SLSF Delayed Neutron Detection With the On-Line Sodium Sampling System

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An on-line sodium sampling system (OLSS) is being installed in the Sodium Loop Safety Facility (SLSF) at INEL. The OLSS will provide real time detection of failed fuel pins via fission products deposited in the sodium. The SLSF, now in its fourth test in the Engineering Test Reactor (ETR), permits failed fuel testing under simulated LMFBR transient conditions[1]. The OLSS loop will withdraw a sample stream from the SLSF test loop, and transport it through a delayed neutron monitor (DNM). The oxide control and indication system is provided as a subloop of OLSS to purify the OLSS/SLSF sodium.

A diagram showing the OLSS and its connection with the SLSF loop is shown in Figure 1; this is normal sampling mode. An electromagnetic (EM) pump provides a nominal OLSS sodium flowrate of .05 kg/s (1 gpm) with delayed neutron precursors in solution and transports them to the DNM in ∿ 12 seconds. The DNM consists of the sodium chamber, lead shielding, a moderator and an array of BF_3 detector tubes; moderator and detector are provided by ANL-East.

On startup, OLSS sodium is loaded from a hold tank. During the pre-test phase, the OLSS/SLSF sodium inventory is purified with a conventional cold trap and the purity verified with a plugging indicator. After the experiment the contaminated sodium is drained to the SLSF loop and flushed with fresh sodium from the hold tank. As a safety feature, a shielded drain tank provides alternate disposal for OLSS contaminated sodium.

Following the SLSF test and draining of OLSS, the SLSF loop containing the test train is removed vertically into a shielded transport cask. This requires remote removal of the "pinch-off section" of the OLSS suction and discharge lines as shown in Figure 1. Disconnect is accomplished by a remotely operated severing tool. The reactor biological shielding is then removed allowing routine maintenance on the OLSS and the reactor.

Space constraints dictated a compact design featuring 13 mm diameter 316 S.S. tubing. The EM pump is capable of delivering the design sodium flow rate, .05 kg/s, against a 250 kPa head. The calculated design OLSS loop resistance is ∿ 100 kPa in the expected sodium temperature range of 700 - 920 K. The requirement to operate the SLSF loop cover gas at 70 kPa to simulate current LMFBR design, imposes a constraint on pressure drop to the pump inlet to prevent cavitation. At .05 kg/s this pressure drop, including vapor pressure loss allows ∿ 15% margin for design conservatism below the cover gas pressure.

The OLSS loop transit time for sodium and fission product transport from the SLSF sodium plenum to the DNM inlet is a further requirement on the system. The total transit time, t, will include a constant 1.8 s from the test fuel to the SLSF plenum, a function of the SLSF sodium loop flowrate. The sample stream will then spend a residence time, Δt, in the 70 cm long DNM. The fraction of delayed neutrons released in the DNM is given by:

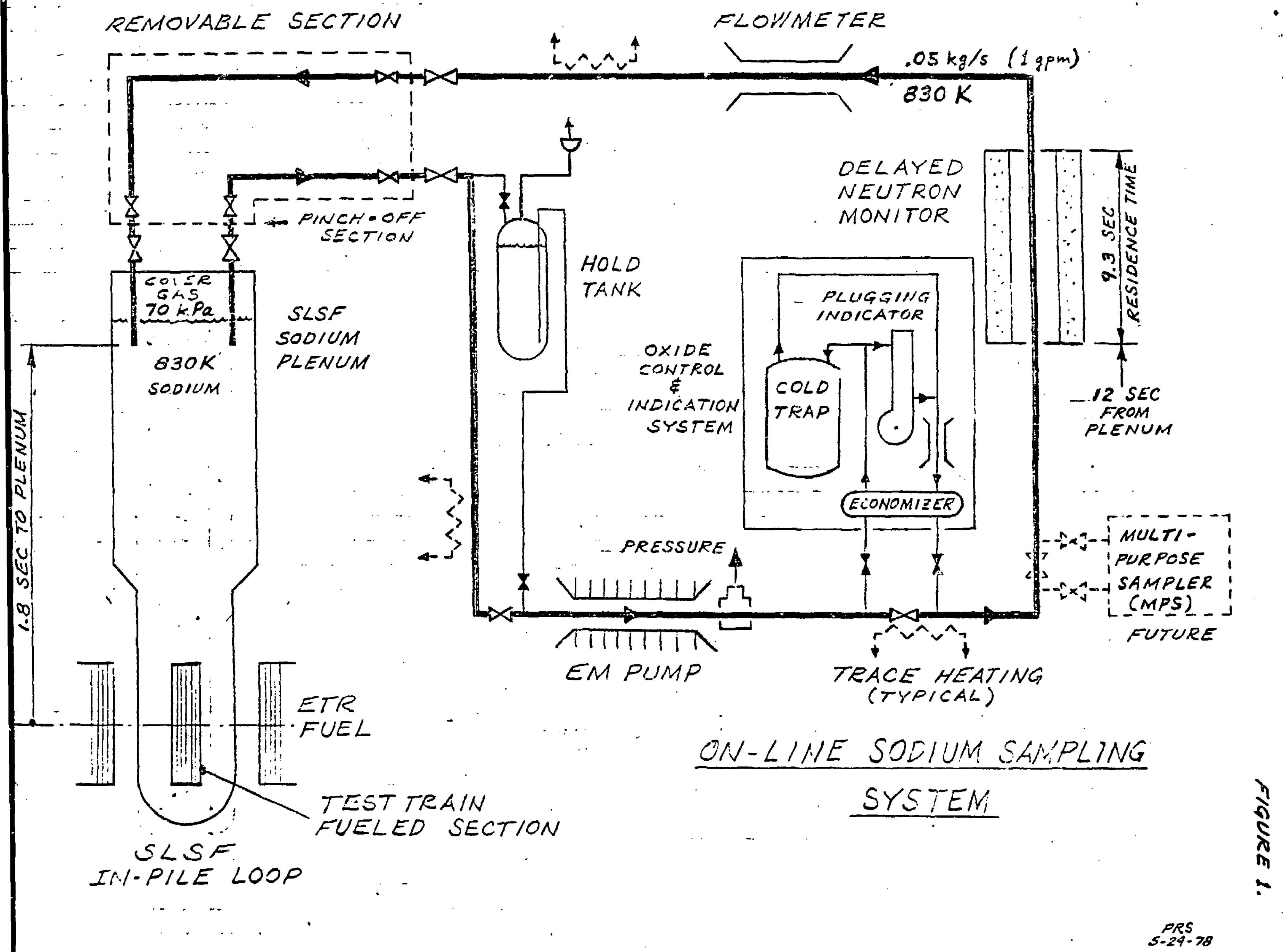
$$\frac{1}{\beta}\sum_i \lambda_i \beta_i \int_t^{t+\Delta t} e^{-\lambda_i t}\,dt \qquad \left(\beta = \sum \beta_i\right)$$

λ_i and β_i are the decay constant and delayed neutron fraction for the i th group of precursors for mixed-oxide fuel[2]. When the above expression is plotted versus OLSS transit time (t - 1.8 s) a maximum at $\sim$ 4 s is indicated in Figure 2. The .05 kg/s design flowrate will provide 13.8 s total transit time from the fuel bundle to the DNM inlet or 12 s transit time in the OLSS.

Predicted performance of OLSS for fuels safety tests in SLSF assures adequate margin for constraints such as plenum pressure, pump cavitation, loop pressure drop and optimum transit time to the delayed neutron monitor.

References

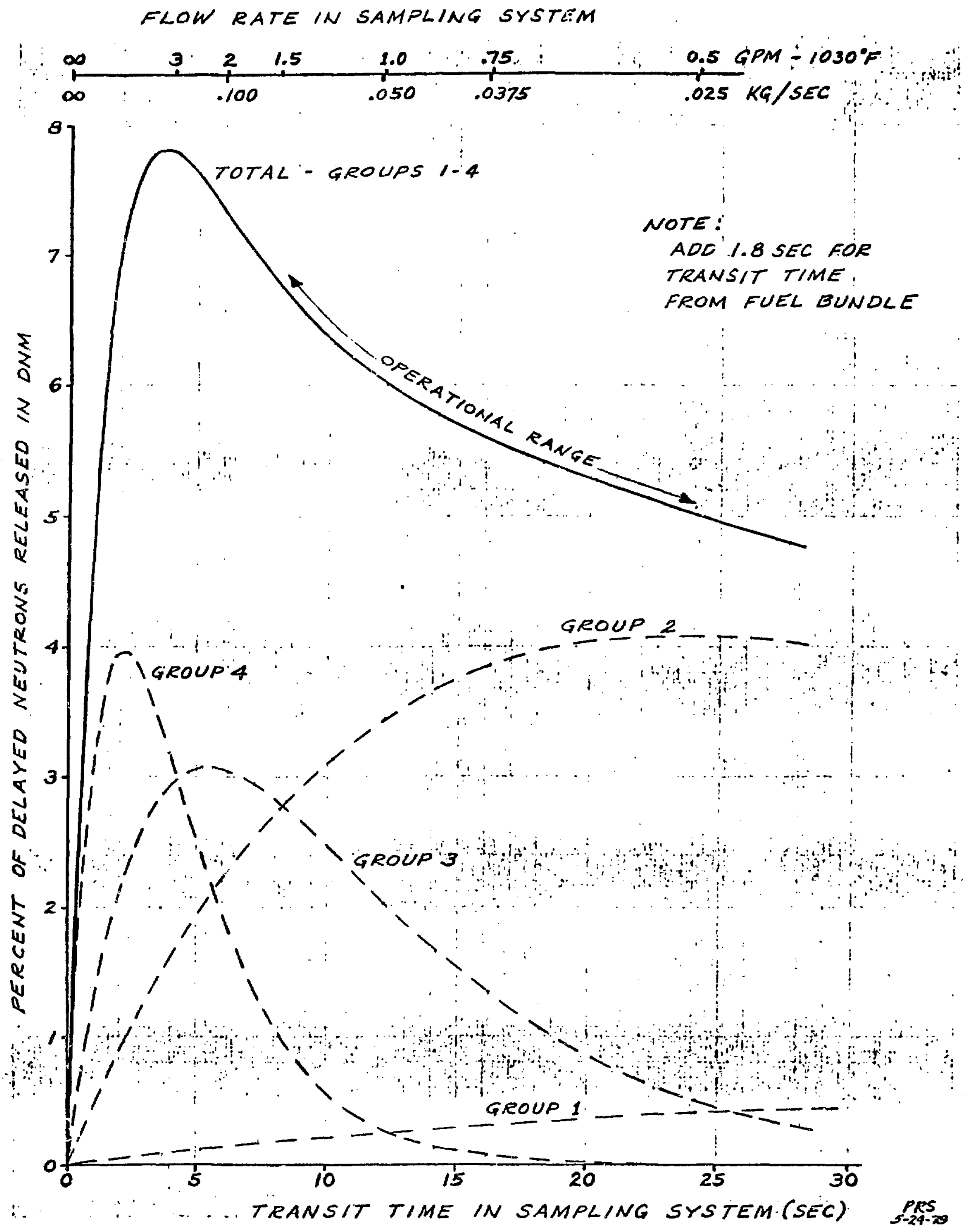
1. G. L. Bordner, et.al., "Post Test Evaluation of the SLSF Loss-of-Flow Safety Experiment P2", Trans. Am. Nucl. Soc., 27,506 (1977).
2. W. T. Sha and A. E. Waltar, "An Integrated Model for Analyzing Disruptive Accidents in Fast Reactors", Nucl. Sci, Engg., 44,135 (1971).



ON-LINE SODIUM SAMPLING SYSTEM

FIGURE 1.

FIGURE 2.


FLOW RATE IN SAMPLING SYSTEM
∞ 3 2 1.5 1.0 .75 0.5 GPM - 1030°F
∞ .100 .050 .0375 .025 KG/SEC
TOTAL - GROUPS 1-4
NOTE:
ADD 1.8 SEC FOR
TRANSIT TIME
FROM FUEL BUNDLE
OPERATIONAL RANGE
GROUP 2
GROUP 4
GROUP 3
GROUP 1
PERCENT OF DELAYED NEUTRONS RELEASED IN DNM
0 1 2 3 4 5 6 7 8
0 5 10 15 20 25 30
TRANSIT TIME IN SAMPLING SYSTEM (SEC)
PRS
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