USAEC - AECL COOPERATIVE PROGRAM

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E. I. du Pont de Nemours and Co.
Savannah River Laboratory
Aiken, South Carolina

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CONTENTS

SECTION I

PHYSICS EXPERIMENTS WITH FUEL ASSEMBLIES SIMULATING BURNED-UP FUEL

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INTRODUCTION

Experiments are being performed in the Process Development Pile (PDP) and the Subcritical Experiment (SE) at the Savannah River Laboratory (SRL) to investigate the physics behavior of burned-up fuel in the CANDU and similar heavy-water power reactors. These experiments use specially fabricated fuel assemblies containing plutonium and uranium in approximately the isotopic compositions expected for fuel irradiated to 5000 MWD/ton. Separate sets of fuel assemblies also vary the total plutonium content and the isotopic fraction of ^{240}Pu.

SUMMARY

Analysis of the PDP substitution buckling measurements by the HERESY code has been completed as has the analysis of the SE temperature coefficient measurements. Analysis is still progressing in the activation measurements. Arrangements are being made to ship the SRL fuel to AECL for further lattice studies at Chalk River from September 1966 through March 1967.

DISCUSSION

The analysis of the substitution buckling measurements in the PDP is continuing. Buckling numbers have been obtained by the source-sink method using the SRL HERESY code for all test-fuel, coolant combinations having an infinite multiplication factor greater than one. The remaining combinations are being analyzed by means of the Persson perturbation method. The AECL code MICRETE is being investigated for use as a comparison method of analysis. The results of the analysis with HERESY method are very consistent and compare favorably with the available Persson method results. Preliminary buckling results are shown in Table I-I.

Analysis has also been completed of the lattice temperature coefficient measurements in the SE. Sample results are given in Figure I-1.

Foil weight calibration for the SE irradiation experiments has been completed for the nonfissionable foils (Cu, W, In, and Lu-Mn). The data for these foils have been reduced but no comparison of the neutron temperature indices or flux shape has been made with calculations, pending completion of running those problems on the HAMMER code.

Calibration of the Pu and ^{235}U bearing foils should be completed next month.

Arrangements are being made to loan the experimental UO_2 and PuO_2 fuel elements to AECL from September 1966 through March 1967. The fissionable material listing is given in Table I-II. The SRL housing tubes and support pieces will also be loaned at the same time.

Nuclear Fuel Service (NFS) has requested that the shipping-receiving discrepancies in the PuO_2-UO_2 fabricated by them be resolved by submitting samples to a referee.

TABLE I-I

MATERIAL BUCKLINGS FROM HERESY ANALYSIS

	Buckling, m^{-2}, for Fuel Type*				
	A	B	C	D	E
Lattice 1, 19 rods/cluster, 9.33-inch pitch					
Coolant					
D_2O	4.48	5.29	7.22	-	5.35
HB-40**	1.60	2.35	-	-	-
Void	4.65	5.45	7.40	-	5.52
Lattice 2, 31 rods/cluster, 12.12-inch pitch					
Coolant					
D_2O	3.58	4.30	5.98	-	4.41
HB-40**	0.66	1.30	3.00	-	1.35
Void	3.96	4.65	6.40	-	4.75
Lattice 3, 31 rods/cluster, 9.33-inch pitch					
Coolant					
D_2O	3.73	5.01	7.23	-	4.99
HB-40**	0.84	2.14	4.62	-	1.90
Void	3.77	5.03	7.32	-	5.05

*See Table I-II.

**Monsanto Company, St. Louis, Missouri.

TABLE I-II

FUEL TO BE LOANED TO AECL

1) Fuel Compositions

Fuel Type	Isotopic Composition - weight % of total U + Pu				
	^{235}U	^{239}Pu	^{240}Pu	^{241}Pu	^{242}Pu
A	0.30	0.24	0.062	0.009	0.001
B	0.30	0.25	0.016	0.002	<0.001
C	0.30	0.35	0.023	0.002	<0.001
D	0.50	0.00	0.00	0.00	0.00
E (Nat.)	0.712	0.00	0.00	0.00	0.00

2) Fuel Pellets

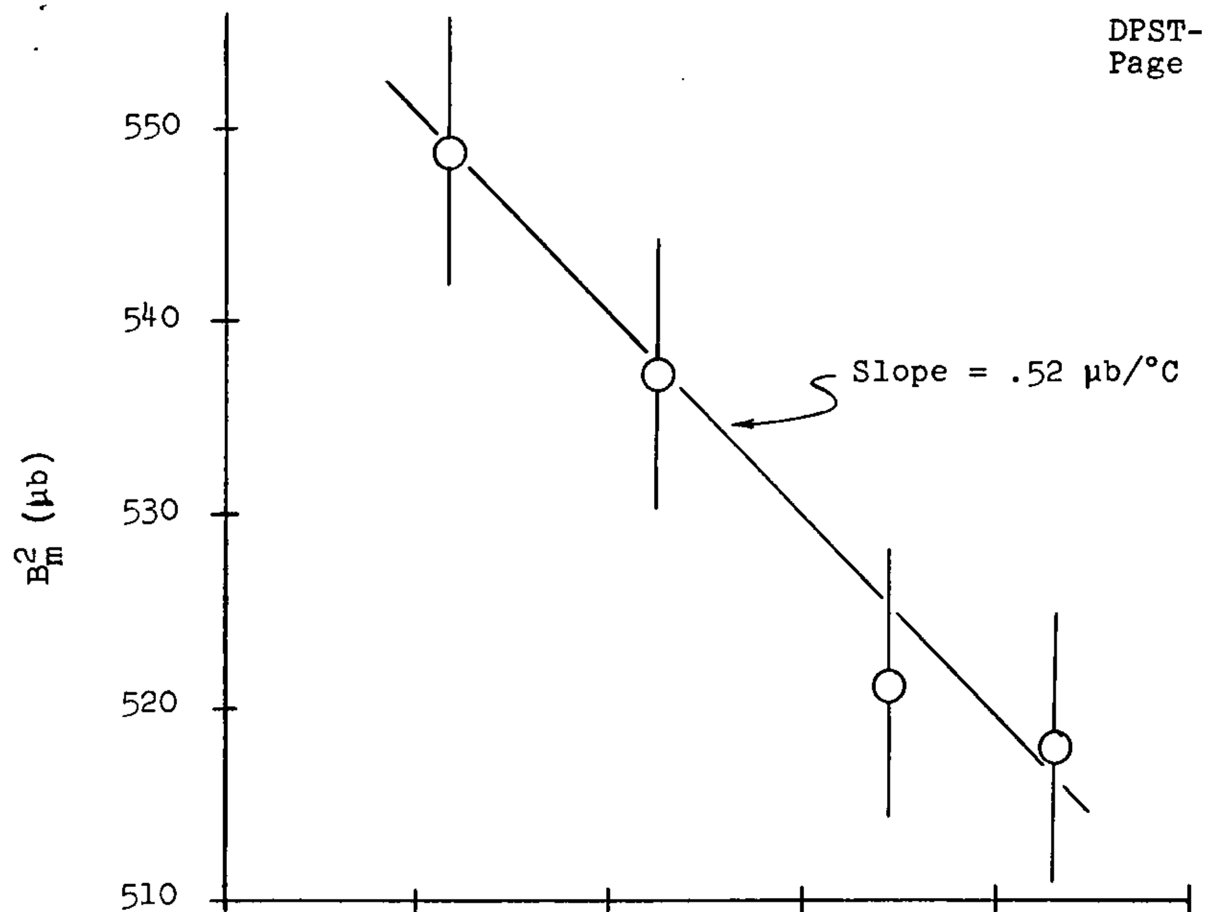
Sintered coprecipitated oxide - 95% theoretical density.

Diameter - 0.500 ±0.002 inch. Length ~0.5 inch.

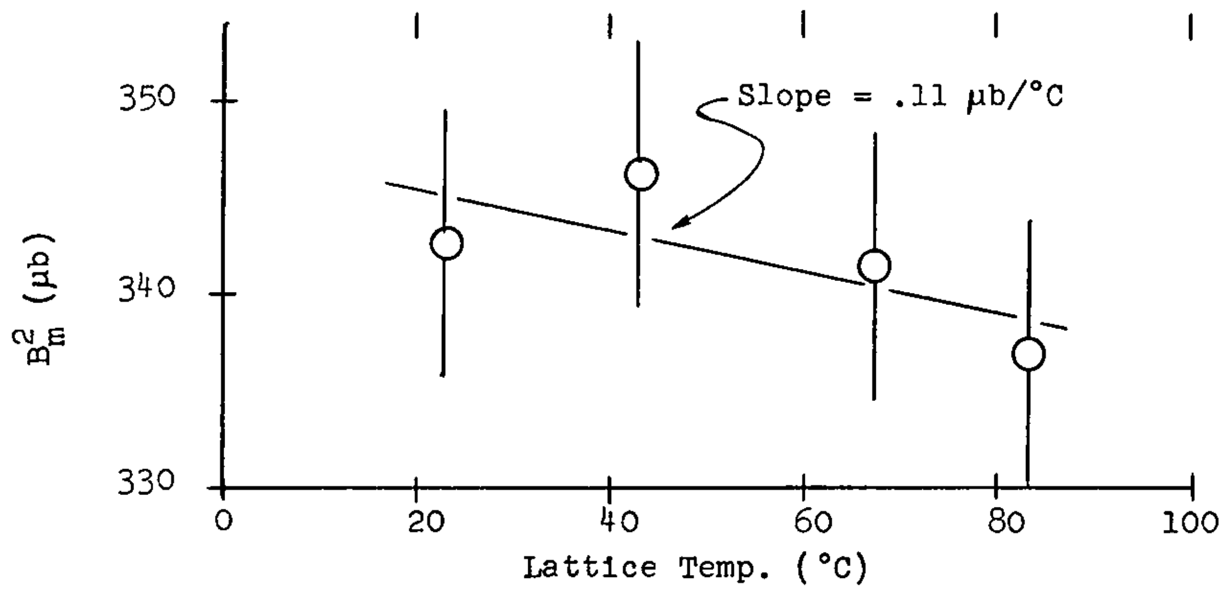
Impurities - equivalent neutron cross section <10 ppm atomic boron.

3) Fuel Rods

Fuel Type	Core Length, inches	No. Rods
A	54.00 ±0.03	138
A	15.953 ±0.02	12
A	5.000 ±0.062	24
B	54.00 ±0.03	732
B	15.953 ±0.02	12
B	5.000 ±0.062	24
C	54.00 ±0.03	271
C	15.953 ±0.02	12
C	5.000 ±0.062	24
D	54.00 ±0.03	271
D	15.953 ±0.02	12
D	5.000 ±0.062	24
E	72.00 ±0.083	1705
E	36.00 ±0.062	1705



a. 19-Rod Cluster, Type B Fuel, No Housings, 0.597-inch Triangular Rod Pitch; 9.33-inch Triangular Lattice Pitch



b. 19-Rod Cluster, Type B Fuel, No Housings, 0.597-inch Triangular Rod Pitch; 11.5-inch Square Lattice Pitch

Figure I-1 <u>SE Buckling Measurements as Function of Lattice Temperature</u>

SECTION II

AECL IN-CORE FLUX MONITORS

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Reactor Technology Section
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INTRODUCTION

An irradiation test of in-core flux monitors is being made in one of the Savannah River Plant reactors to determine the life characteristics of a selection of flux detectors and of the mineral insulation used in their construction. Self-powered flux detectors are relatively new; therefore, confidence in their use hinges to a great extent on proven performance at large integrated exposures. The chief points of interest are 1) integrity of the conductors and sheath during life, 2) life of insulation, and 3) sensitivity. The higher flux density available at SRP (vis-à-vis Chalk River) will shorten the irradiation time for a given exposure and should also show whether or not any new high intensity effects appear.

SUMMARY

Fabrication and installation of the detector rod in the reactor has been completed and testing is in progress.

DISCUSSION

The dimensions and characteristics of the three detectors being tested are:

Emitter Material	Emitter Diameter (inches)	Emitter Length (cm)	Est. Output (Amp) at 10^{15} n/cm^2-s	Response (half-life of capture product)	Est. Burnup Rate at 10^{15} n/cm^2-s
Vanadium	.040	20	3×10^{-6}	3.8 m	1.2%/month
Cobalt	.060	20	2×10^{-6}	prompt	10%/month
Zircaloy	.062	20	8×10^{-7} (gamma)	prompt	0

A rhodium detector with a chromel-alumel thermocouple junction attached to the emitter element was scheduled for this test, but damage to the cables resulted in its loss.

In the vanadium detector, the output current is due to the beta activity of the capture products,and the response time is directly proportional to its half-life. The cobalt detector produces an output current due to photo and Compton electrons ejected by the high energy gamma associated with neutron capture. It is a true neutron detector and the response is prompt. The Zircaloy detector is mainly gamma sensitive, the output coming mostly from photo and Compton electrons. Such a detector has prompt response and may be used where gamma radiation is considered a satisfactory measure of reactor power.

The electrical resistance of the insulation in the detector and the in-core section of the connecting cable is important because it determines the maximum practical input impedance. Two sets each of alumina, magnesia, and beryllia insulations are being tested.

The detector and cable subassembly were inserted into a perforated aluminum thimble and charged to an instrument position in K reactor in May 1966. The detector and cables are connected to instrumentation in a nonradiation zone where data can be taken during reactor operation. A slow speed recorder is used to obtain a continuous record of the output current from each detector and cable. The output from an SRP gamma thermometer is being used as a reference for power and flux. Facilities are provided for current measurements with a variable resistor in series with the cable and detectors. A high speed recorder will be provided to record the time response of the detectors to rapid changes in flux level.

Irradiation testing of the AECL neutron detector rod in the Curium II reactor has been initiated satisfactorily. The following measurements have been made:

- Electrical output of the three chambers at constant power.
- Electrical output of the six test cables at constant power.
- Fast response test using ΔK rods to increase and decrease neutron flux.
- Test of output from each detector during reactor startup and during a controlled shutdown.
- Noise measurements from each detector and from selected cables at constant reactor power.
- Leakage resistance measurements for each cable at exposure intervals of about 1×10^{21} n/cm^2.

Results

The following results are preliminary in nature because:

- The test period is not complete.

- Not much analysis of the data has been done. Most of the time has been spent in setting up the tests, running them, and collecting data.

Life Tests

The cables and detectors have been irradiated for four months in Curium II cycles which operate at a flux of about 10^{15} n/cm^2-sec. It is planned that the test will continue until the end of the Curium II irradiation period.

- The Zircaloy detector, or its cable failed in May. It may have been defective when charged; however, continuity measurements at that time indicated that the equipment was satisfactory. The failure was indicated by unstable positive and negative currents.

- The vanadium and cobalt detectors are operating satisfactorily.

- Of the six cables charged, one gives erratic current readings; however, the resistance of all the cables, lead to sheath, has not changed appreciably. A reproducible current is obtained from five of the cables -- the current increases and decreases with flux, but not proportionately.

- The initial current output for each detector and cable is given below.

Type Detector	Test Cable Insulation	Actual Current* Microamperes	Predicted Current** Microamperes
Cobalt		3.00	2
Vanadium		3.70	3
Zircaloy		0.15	0.8
	MgO	0.16	0.01
	MgO	0.16	0.01
	Al_2O_3	0.40	0.01
	Al_2O_3	0.42	0.01
	BeO	0.10	0.01
	BeO	0.04	0.01

*Measured current normalized to a fuel flux of 1 x 10^{15} n/s/cm^2

**Calculated by AECL personnel based on flux of 1 x 10^{15} n/s/cm^2

The currents at the present time are approximately the same as above, except for the Zircaloy chamber. Its current is erratic.

Response to Reactor Startup

Detector and cable responses to reactor startup are compared to the response of a compensated ion chamber and of an axial power monitor in the following table.

Detector	Cable Insulation*	Per Cent Increase in Signal for a Reactor Power Increase of 40-60%	60-80%	80-90%	90-100%
Cobalt	-	47	33	15	14
Vanadium	-	22	38	18	14
Zircaloy	-	**	**	**	**
	MgO	100	48	28	17
	Al_2O_3	**	89	47	26
	BeO	66	38	21	13
SRP CIC	(HLFM)	58	33	20	20
SRP APM	***	47	30	18	13

*Only data for one of the two cables of each set are given.
**Instrument difficulties, or failure.
***Nearest APM chamber to AECL detector rod.

ΔK Rod* Test

The time response of the detectors and three cables was measured during a ΔK rod* test. The results are given below.

Detector or Cable	Response Time, Time after ΔK Rod* Change, seconds
SRP CIC	0.5
Cobalt	0.3
Vanadium	**
Zircaloy	0.4
HC0201 Cable (MgO)	0.3
HC0203 Cable (BeO)	0.4
HC0205 Cable (Al_2O_3)	0.3

*The ΔK rod is a gas operated sleeve and cruciform made of alternating aluminum and cadmium. The ΔK rod can produce a step change of about 5% of full power.
**The vanadium was not measured during this test. Its response time is about 3.5 minutes.

Response to Controlled Shutdown

Figure II-1 illustrates the behavior of the vanadium and cobalt detector during a slow reactor shutdown. These responses are compared to an SRP axial power monitor response. A typical response from a cable, the MgO cable, is also included. As expected, the 3.8 minute half-life of the vanadium detector, compared with the prompt response of the cobalt, causes the chamber response to lag.

Noise Measurements and Leakage Resistance

Detector or Cable	Output Variation %	Calculated Leakage Resistance, ohms Original	Present
Cobalt	±1	1.75×10^7	4.08×10^7
Vanadium	<0.5	1.0×10^7	4.15×10^6
Zircaloy	-	2.3×10^6	-
MgO	±1	1.5×10^7	3.2×10^7
MgO	±1	1.5×10^7	2.5×10^7
BeO	-	3.8×10^7	3.48×10^7
BeO	±1.5	2.8×10^7	5.0×10^7
Al_2O_3	<0.5	1.8×10^7	1.68×10^7
Al_2O_3	<0.5	2×10^7	1.66×10^7

PROGRAM

The following measurements will continue.

- Resistance measurements of cables.
- Current outputs of detectors and cables.

In addition, the following tests will be repeated:

- Noise measurements.
- ΔK rod, fast response, tests.
- Startup and slow shutdown.

The following test has not received full authorization:

- Scram test from full power.

Instrumentation is available for this latter test.

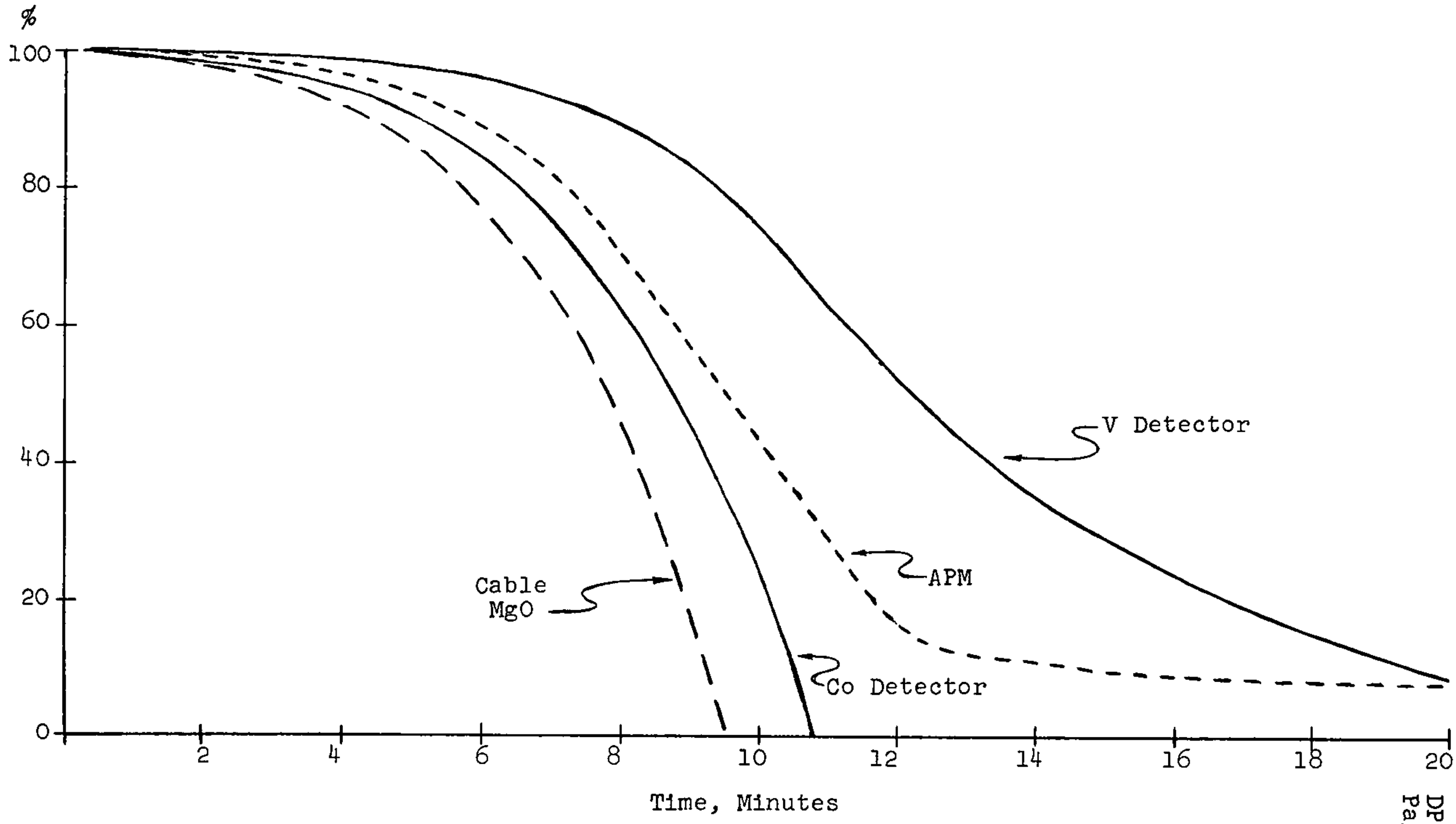

Figure II-1 Signal Response to Slow Shutdown

SECTION III

SIEVE TRAY TEST

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Separations Technology Section
Savannah River Plant

INTRODUCTION

The maximum fluid handling capacity of sieve trays enters into comparisons of future power costs for various types of nuclear reactors through its effect on the projected cost of heavy water. In 1963 an expenditure of $230,000 was authorized to modify equipment and evaluate the capacity of sieve trays in one of the idle GS units at the Savannah River Plant.

To reduce construction and operating costs, the test unit was interconnected with and limited by the pressure in the existing GS Plant. While these modifications were in progress, GS Plant pressure was reduced from 275 psig to 225 psig (at the proposed point of interconnection) until the extent of external corrosion of carbon steel equipment could be determined.

SUMMARY

Preliminary tests at 225 psig, initially with segmental downcomers and finally with downpipes, were completed in July 1964. GS Plant pressure, at the point of test facility interconnection, was increased to 275 psig early this year and sieve tray capacity tests, with downpipes, were completed this month. At 225 psig, operation with an L/G of 0.50 at 34°C (GS cold tower conditions) was simultaneously limited by tower flooding and blower capacity to a maximum F-factor* of about 1.65. At 275 psig tower flooding limited stable operation to a maximum F-factor of 1.80.

DISCUSSION

Test work at 275 psig was completed and the unit was shut down and depressurized in early August. During two duplicate runs at GS cold tower conditions (L/G = 0.50) with 1 ppm silicone in the feedwater, the sieve trays were stable at F-factors of 1.81 and 1.77** and flooded at F-factors of 1.87 (blower capacity) and 1.83**. (The difference in these runs was within the accuracy of measuring F-factor.) Pressure drop data for the first run were shown last month and data for the second run are shown in Figure III-1.

*All F-factors in this test are based on 31.9 sq ft of free area in the 6'-6"-diameter tower. $F = \mu\sqrt{\rho}$ μ = gas velocity, ft/sec ρ = gas density, lb/ft^3

**Preliminary data given in July's report. F-factors shown here are the most accurate.

During a run with gas flow held constant at an F-factor of 1.82* and an increasing liquid flow, stable operation was maintained up to a liquid flow of 148 gpm (L/G = 0.47) and flooding began at a liquid flow of 152 gpm (L/G = 0.50). Pressure drop data for this run are shown in Figure III-2.

Figure III-3 shows pressure drop data for a run with liquid flow held constant at 170 gpm and increasing gas flow. Stable operation was maintained up to an F-factor of 1.67 (L/G = 0.59) and flooding began at an F-factor of 1.71 (L/G = 0.58).

Figure III-4 shows maximum stable F-factors obtained during the test period. The wide variation in flooding point is attributed to changing feedwater quality. Sporadic moderate to severe carryover, indicative of poor feedwater quality, was experienced in the GS Plant while these tests were in progress.

PROGRAM

Approximately $229,000 has been expended. Preparation of a final report is in progress.

*Preliminary data given in July's report. F-factors shown here are the most accurate.

Conditions
Temperature 36°C
Pressure 279 psig
L/G 0.49
Data Points every 30 min

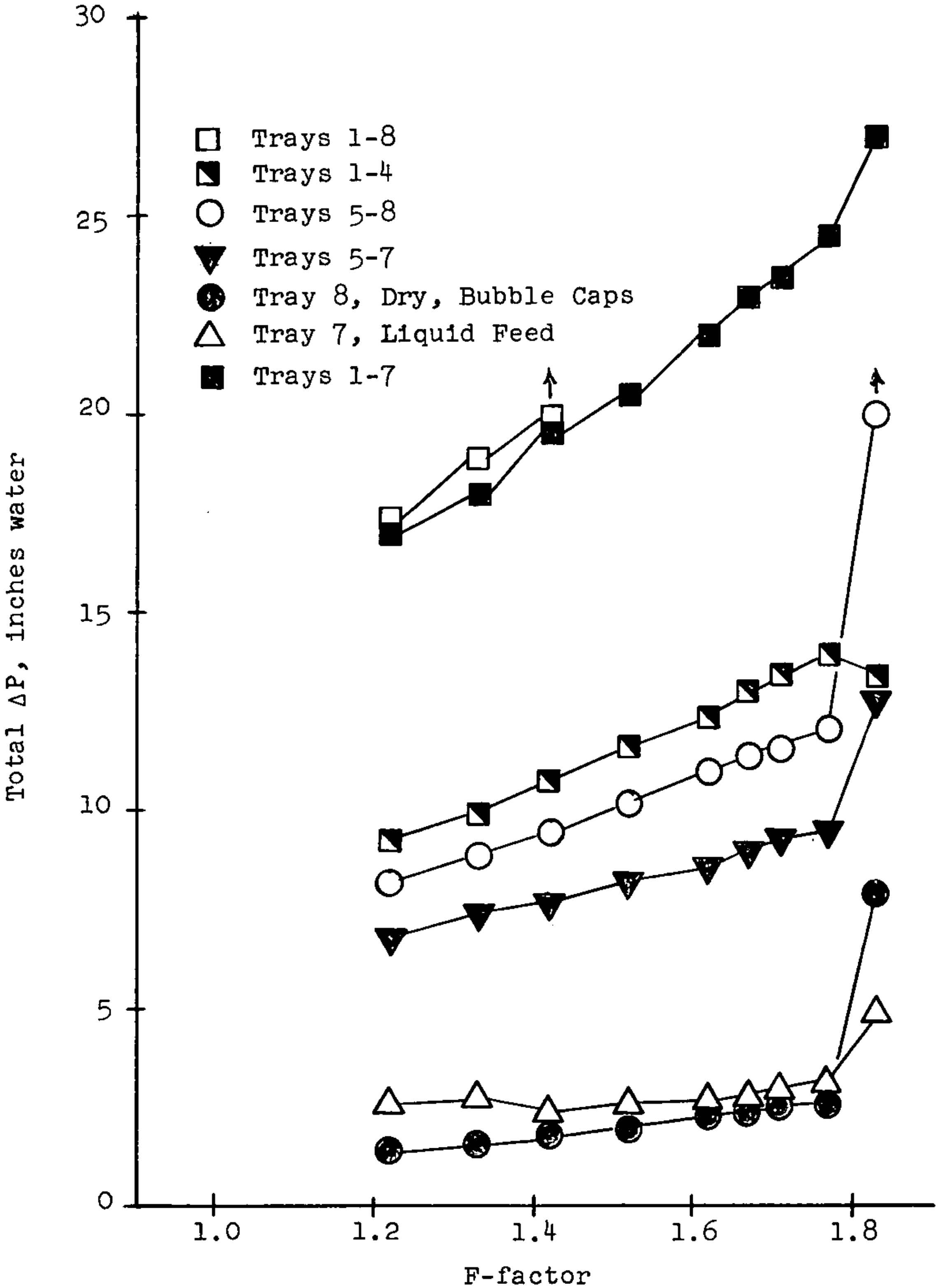

Figure III-1 Performance of Sieve Trays at Cold Tower Conditions: Silicone in Feedwater

Conditions
Temperature 36°C
Pressure 281 psig
F-factor 1.82
Data points every 30 min

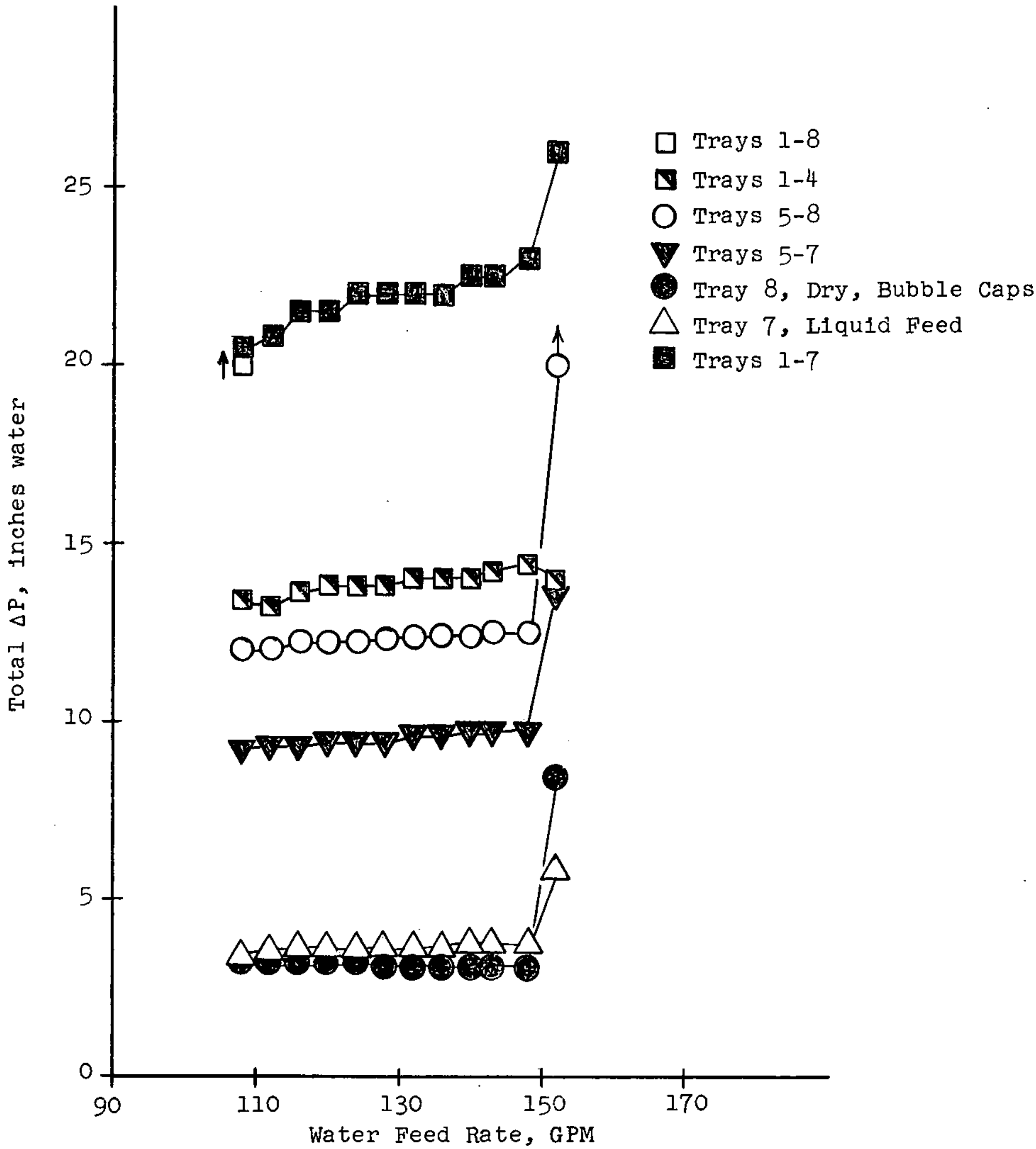

Figure III-2 Performance of Sieve Trays at Constant Gas Flow and Increasing Water Flow; Silicone in Feedwater

Conditions
- Temperature 37°C
- Pressure 281 psig
- Water flow 170 gpm

Data points every 30 min

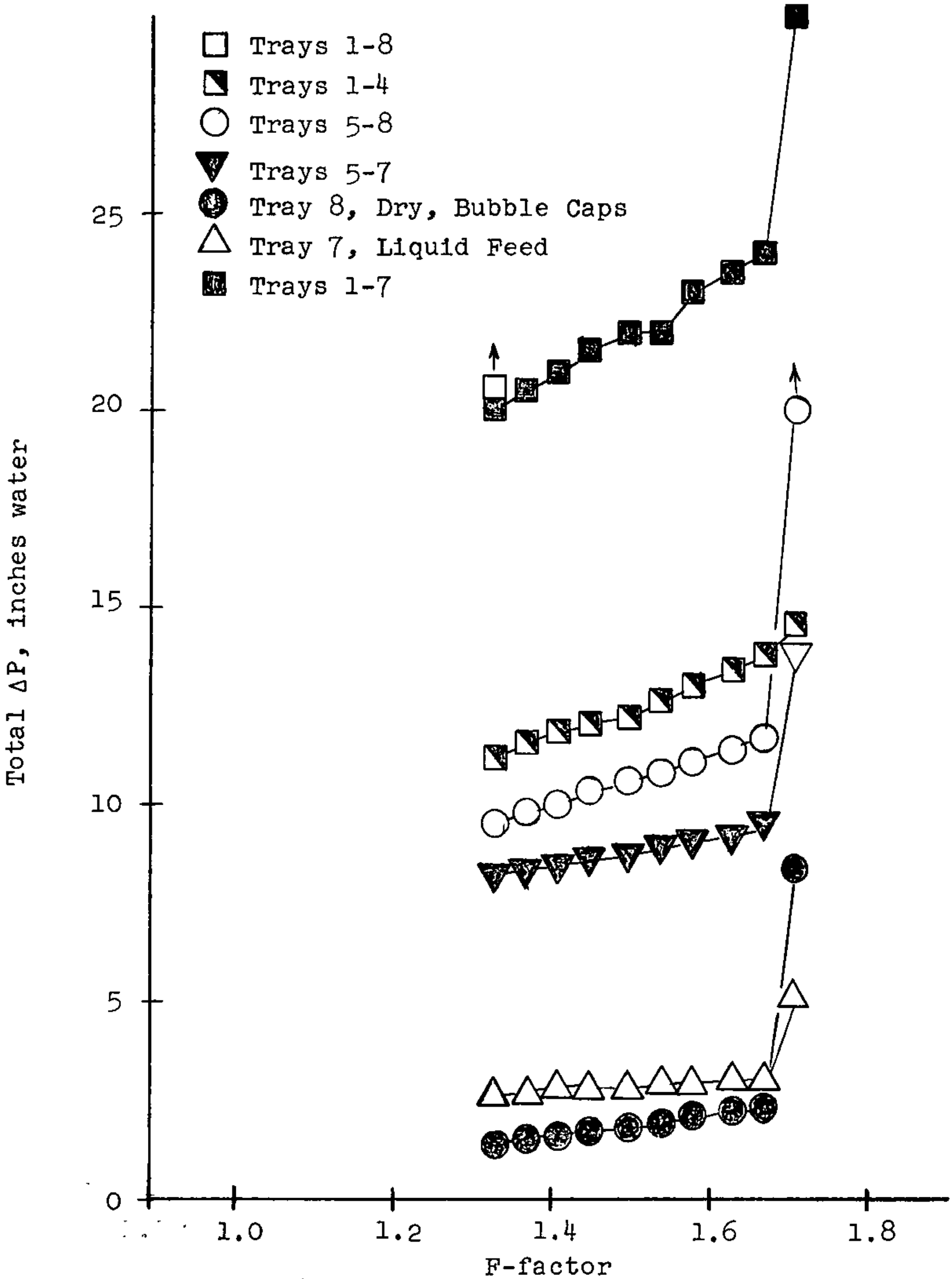

Figure III-3 <u>Performance of Sieve Trays at Constant Water Flow and Increasing Gas Flow; Silicone in Feedwater</u>

Conditions

Temperature	35°C
L/G	0.50
Pressure	280 psig

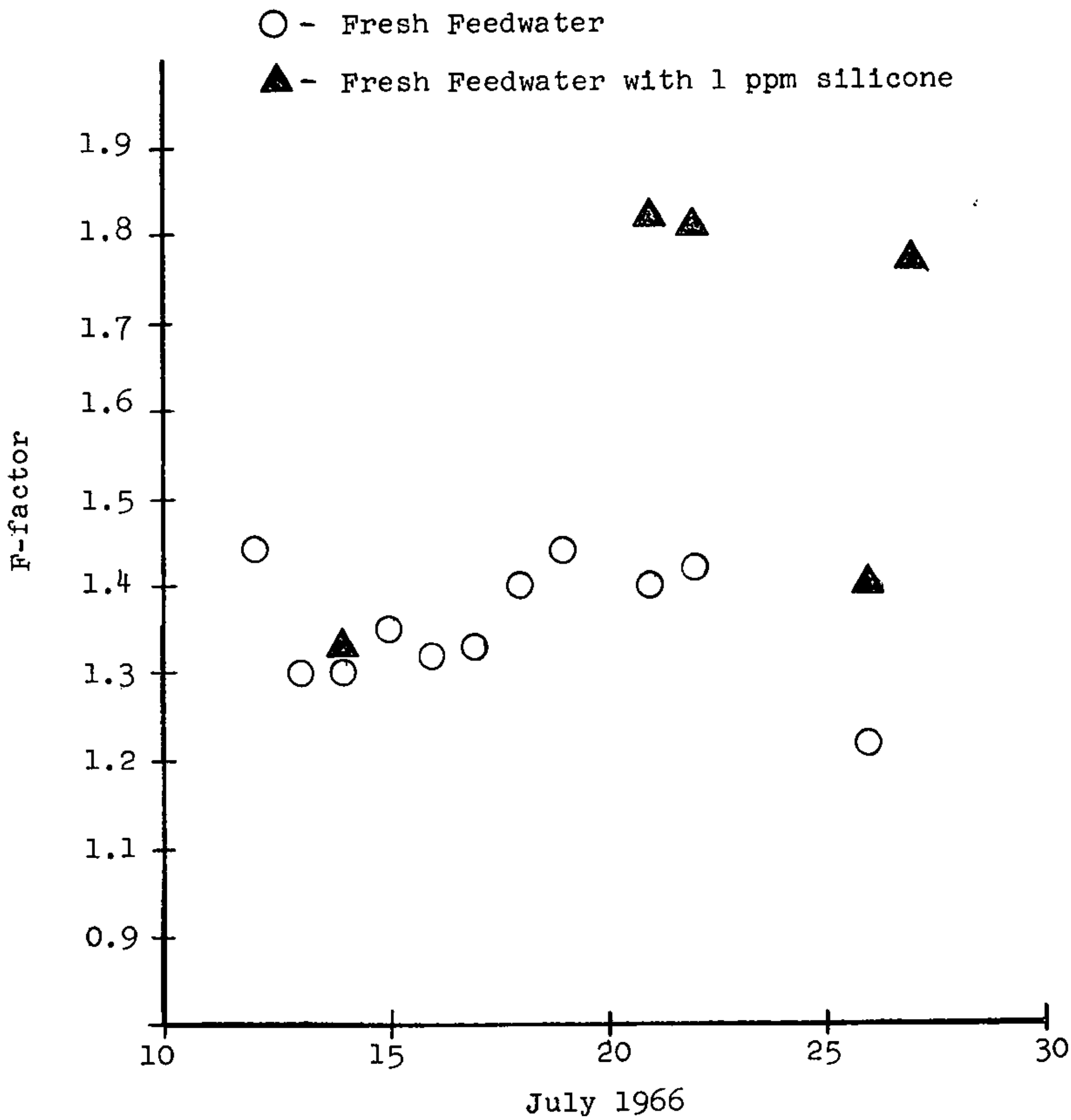

Figure III-4 Maximum Stable Flows

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