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MEASUREMENT OF RESPONSE TIME AND DETECTION OF DEGRADATION IN PRESSURE SENSOR/SENSING LINE SYSTEMS*

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TO:

TWELFTH WATER REACTOR SAFETY RESEARCH INFORMATION MEETING

NATIONAL BUREAU OF STANDARDS

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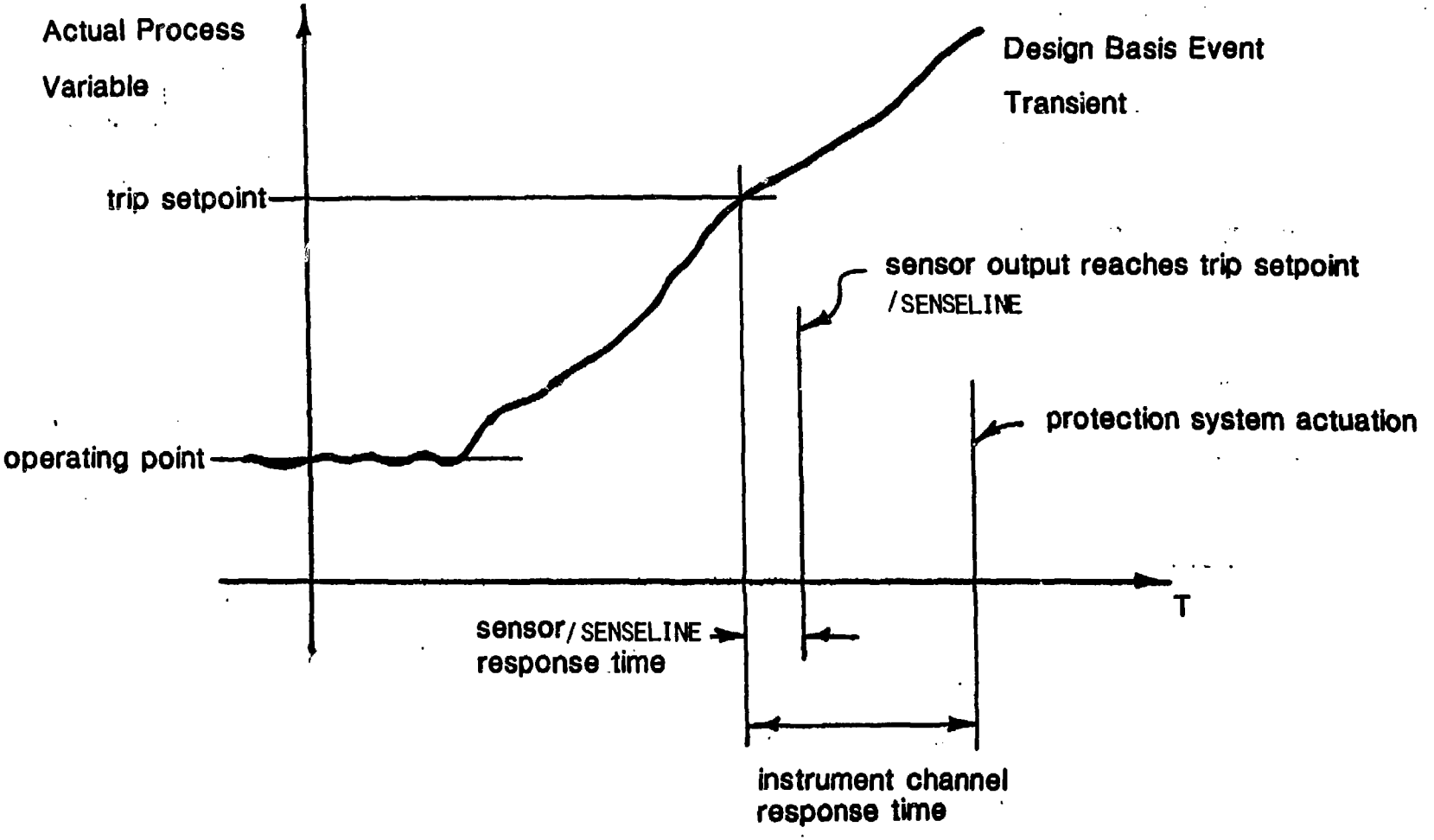
OVERVIEW OF RESEARCH

- HISTORICAL COMMENTS
- REGULATORY ISSUES
- NEED FOR RESEARCH
- MAJOR TEST RESULTS



Definition of response time

ORNL EVALUATED SEVERAL METHODS

TRANSMITTER

- REMOTE (OFF-ON) TEST FOR FORCE BALANCE SENSORS--TESTS ONLY ONE TYPE SENSOR AND DOESN'T TEST OTHER PRESSURE SYSTEM COMPONENTS

  -- TEST PERFORMED REMOTELY BY SIMPLY TURNING AC POWER TO TRANSMITTER OFF AND BACK ON AND RECORDING RESPONSE OF SENSOR

SENSING LINE

- PRESSURE PERTURBATION METHOD TO TEST SENSING LINES

  -- MOVEMENT OF SMALL VOLUMES OF FLUID IN SENSING LINE TO MEASURE ITS DYNAMIC RESPONSE

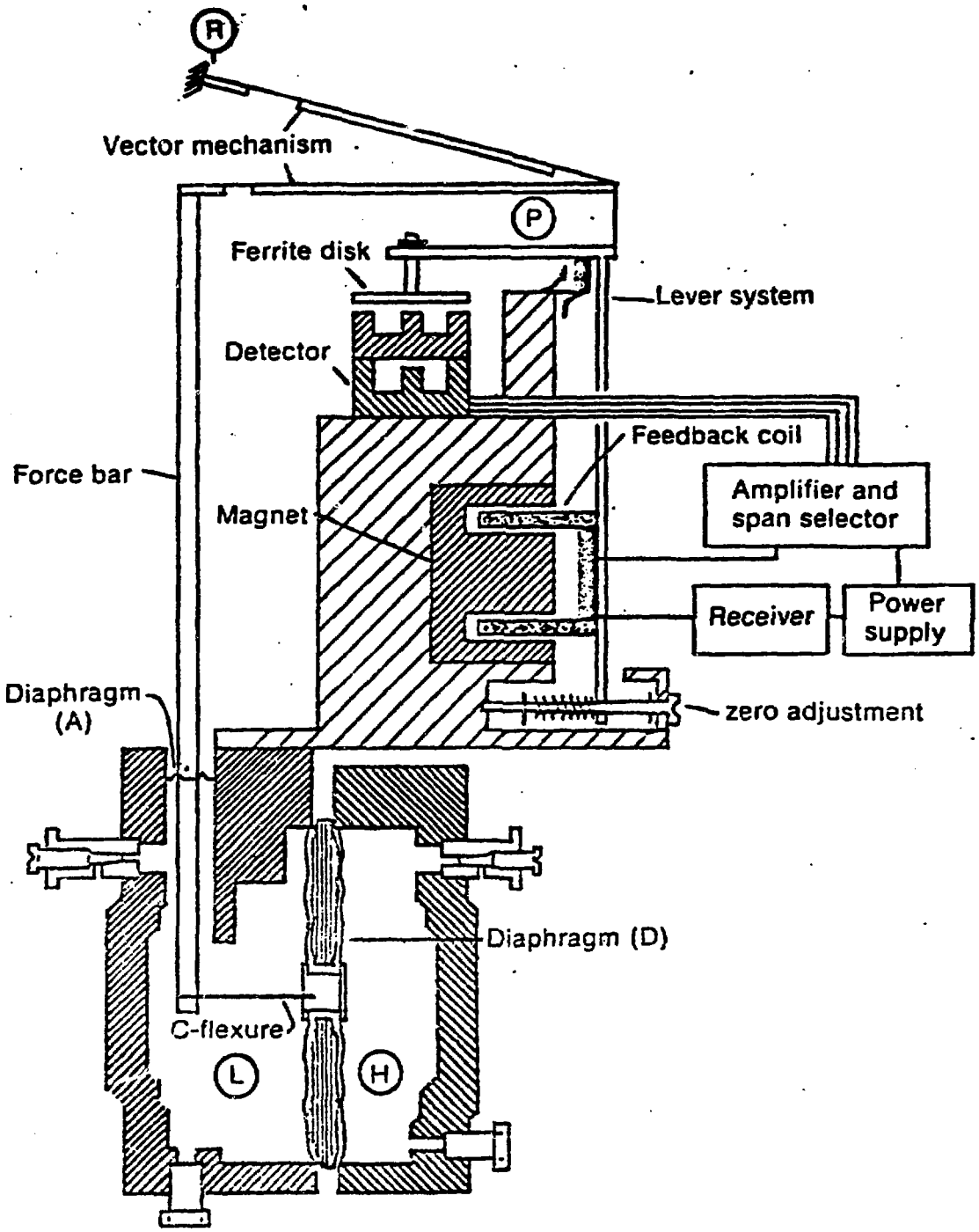
INSTRUMENT CHANNEL

- NOISE ANALYSIS FOR DETECTION OF DEGRADATION IN THE OVERALL SYSTEM RESPONSE TIME

  -- EVALUATION OF PRESSURE MEASUREMENT SYSTEM RESPONSE BY SPECTRAL ANALYSIS OF NOISE ON PRESSURE SIGNAL

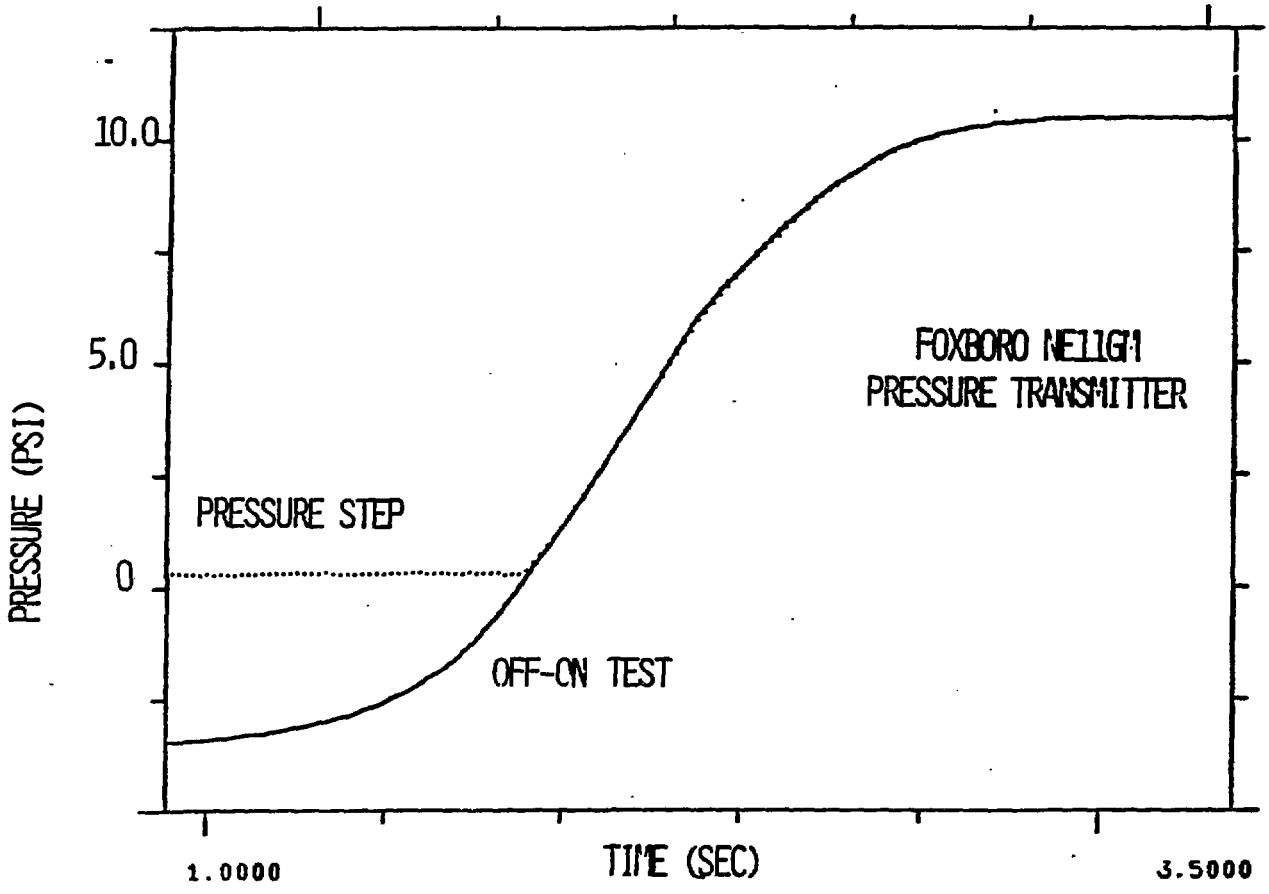
REMOTE (OFF-ON) TEST RESULTS

- SENSOR ONLY MOMENTARILY REMOVED FROM SERVICE
- DOES NOT REQUIRE PERSONNEL TO ENTER CONTAINMENT
- REMOTE TESTS YIELD RESULTS EQUIVALENT TO THAT OBTAINED FROM THE RAMP TEST CURRENTLY USED FOR RESPONSE TIME MEASUREMENT OF PRESSURE SENSORS
- ONLY APPLICABLE TO FORCE-BALANCE (FOXBORO) SENSORS



FOXBORO PRESSURE TRANSDUCER MODEL E13DM

NUCLEAR GRADE TRANSMITTER RESPONSE TO OFF-ON TEST
AGREES WITH RESPONSE TO ACTUAL PRESSURE CHANGE



FOXBORO TRANSMITTER REMOTE TEST RESULTS

Transmitter Type	Response Time (ms) Direct	Remote
E11DM	140	160
E11DM	107	160
E11DM	139	143
E11DM	121	156
E11DM	155	182
E11DM	154	189
E11DM	205	135
E11DM	177	172
NE11GM	360	411
E13DM	321	287
Differential E13DM	492	382
Differential E13DM	438	346
Differential E13DM	412	331
Differential E13DM	392	450
Differential E11GM	179	146
Absolute E11GM	155	203
Absolute E13DM	180	156
Differential		

TWO METHODS HAVE BEEN EVALUATED FOR DETECTION OF BLOCKAGE OR VOIDS IN SENSING LINE:

- PRESSURE PERTURBATION METHOD
- NOISE ANALYSIS METHOD

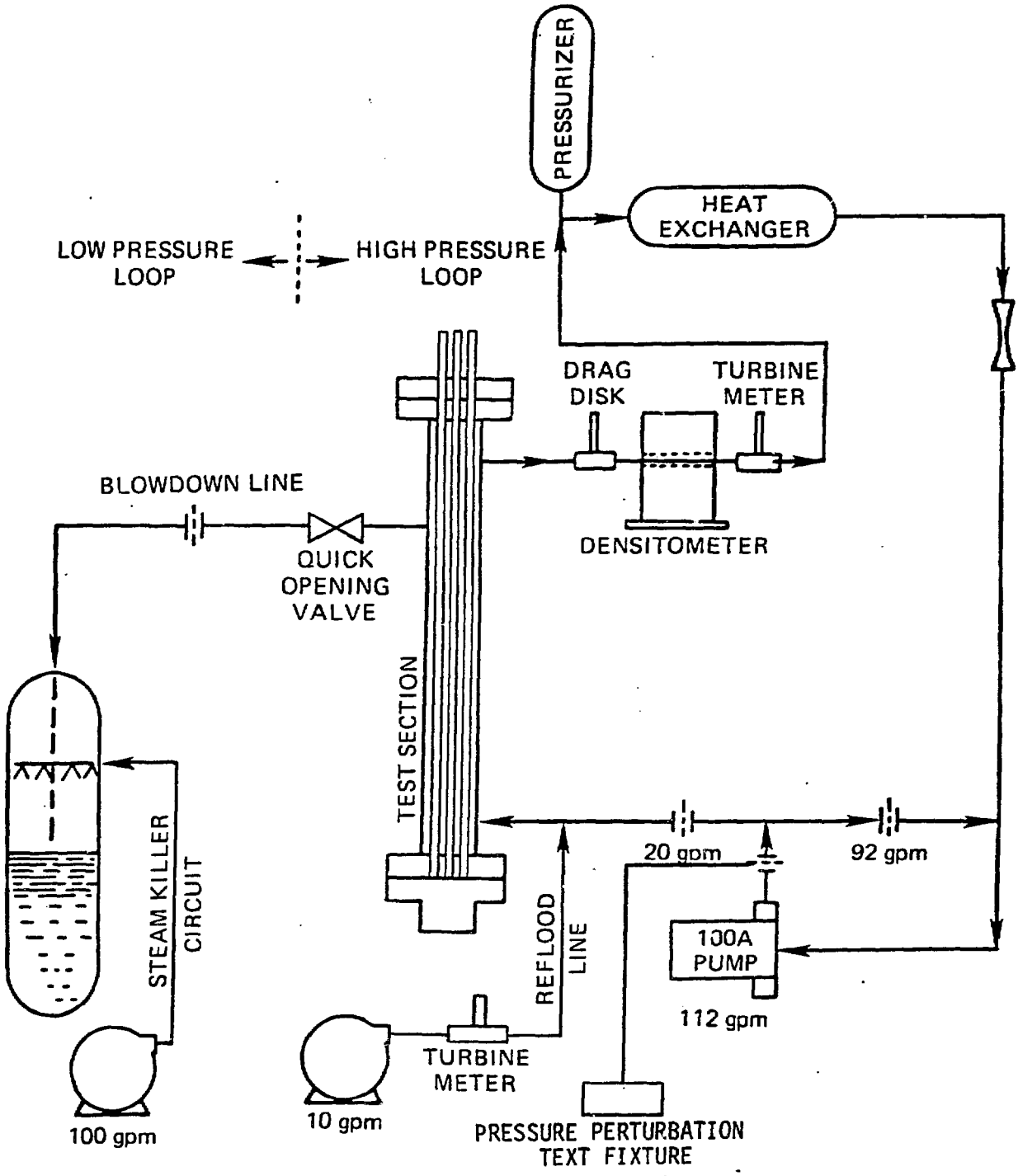
- PRESSURE PERTURBATION METHOD

  --VERY SENSITIVE FOR QUANTITATIVE MEASUREMENT OF SMALL RESPONSE TIMES

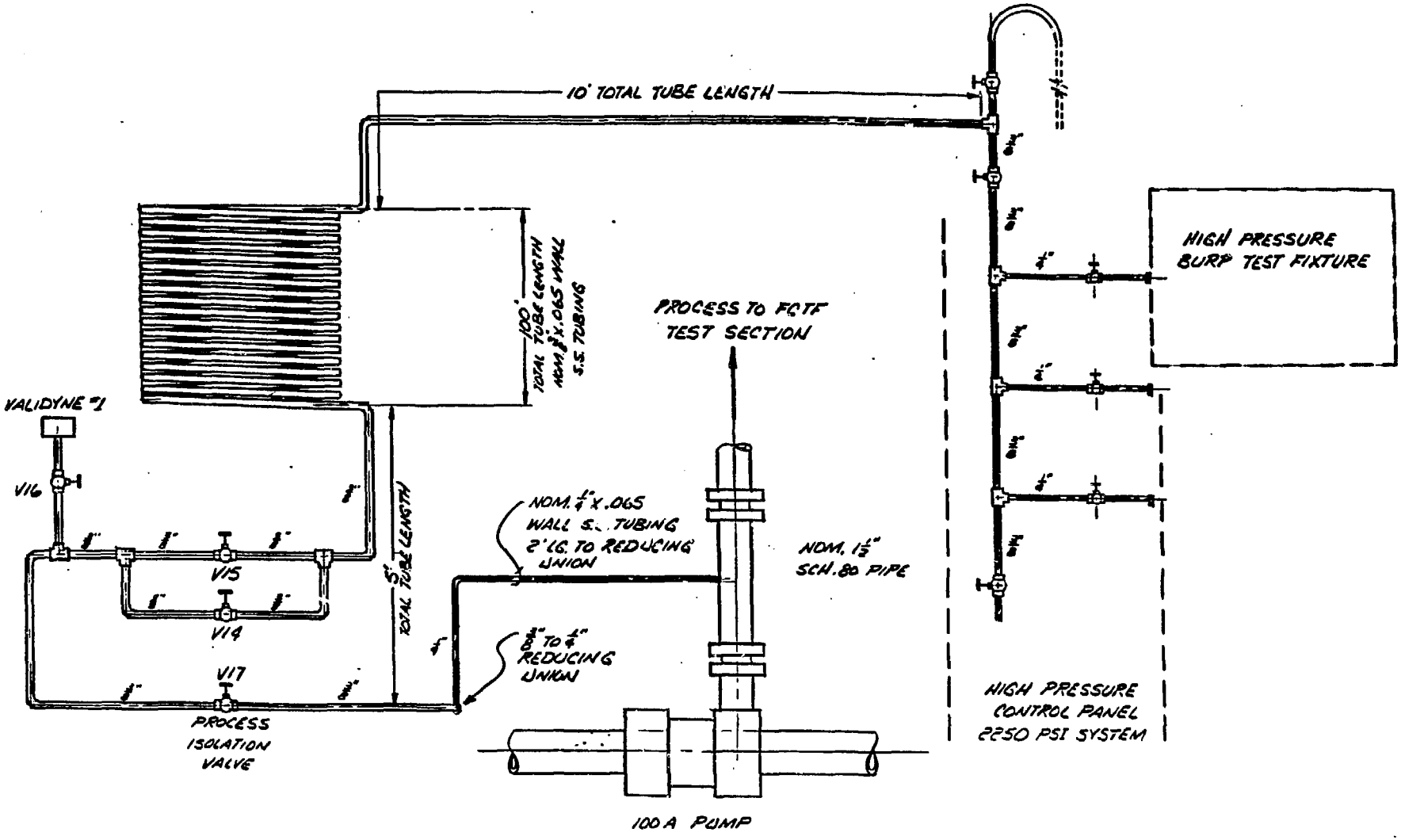
  --CAN DETECT LARGE BLOCKAGE OR VOIDS BUT MAY NOT YIELD QUANTITATIVE MEASURE OF RESPONSE TIME FOR THESE CONDITIONS

  --MAY BE EXTREMELY DIFFICULT TO PERFORM UNDER PLANT CONDITIONS

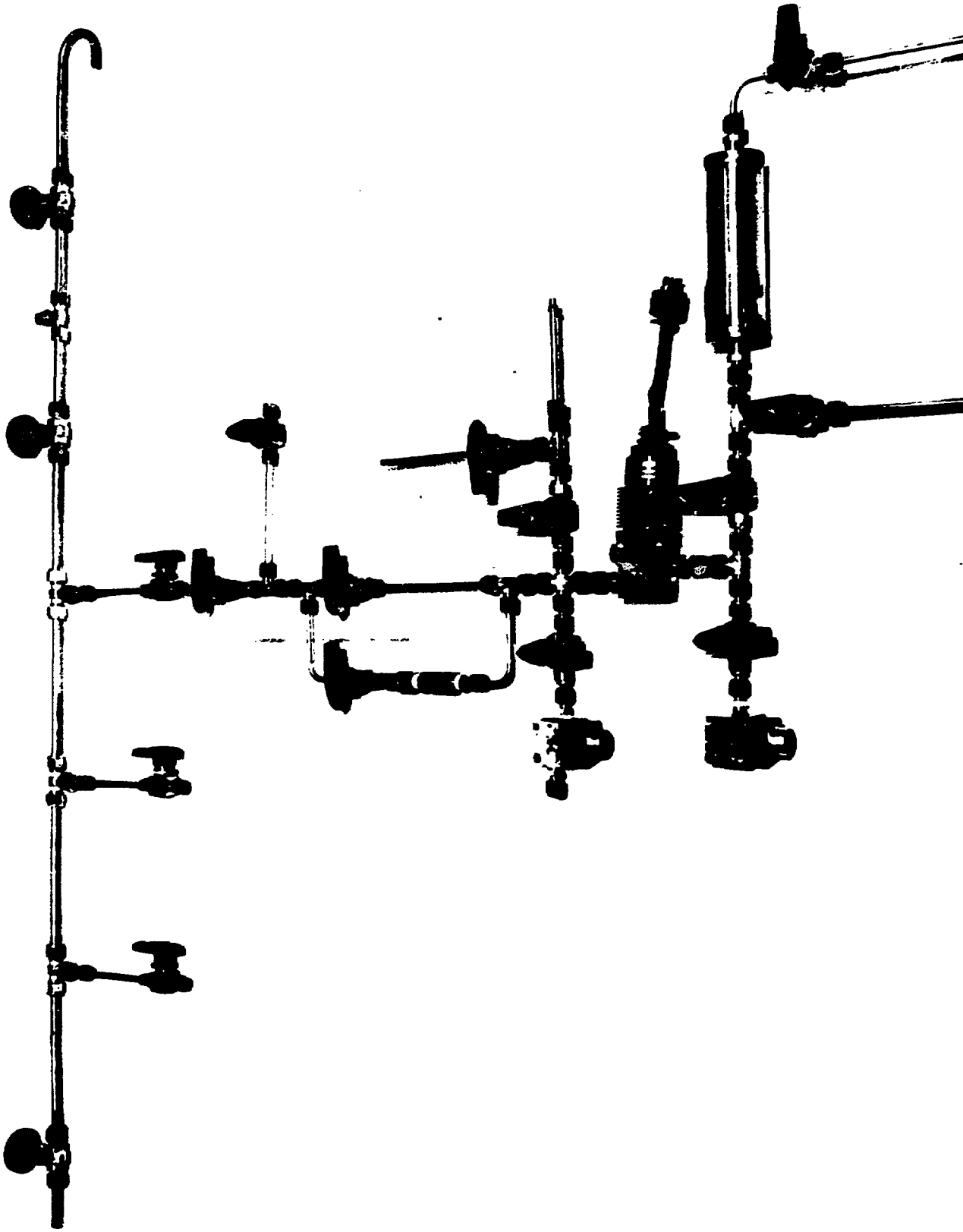
  --NOT A CONTINUOUS MEASUREMENT

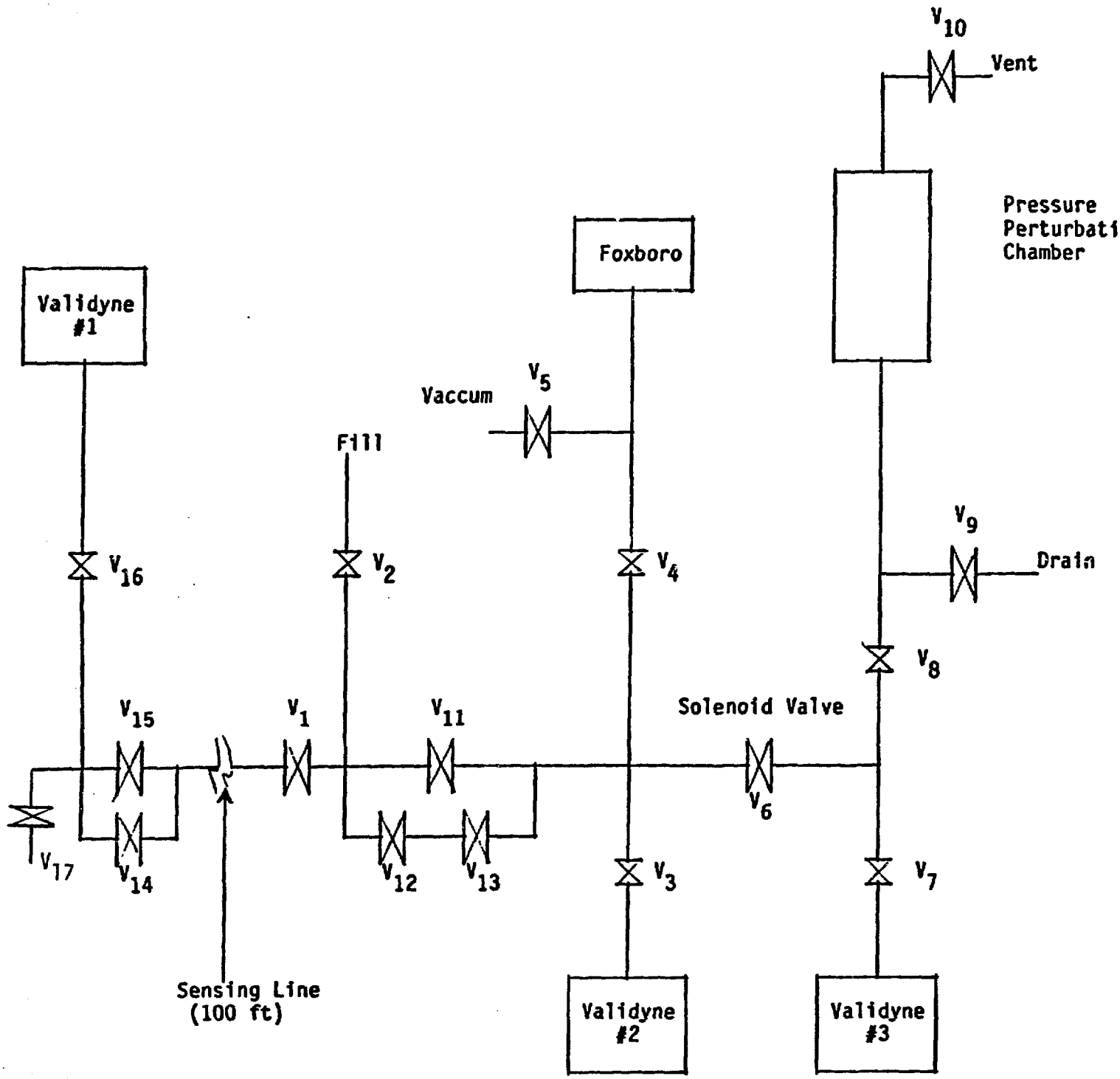


FORCED CONVECTION TEST FACILITY



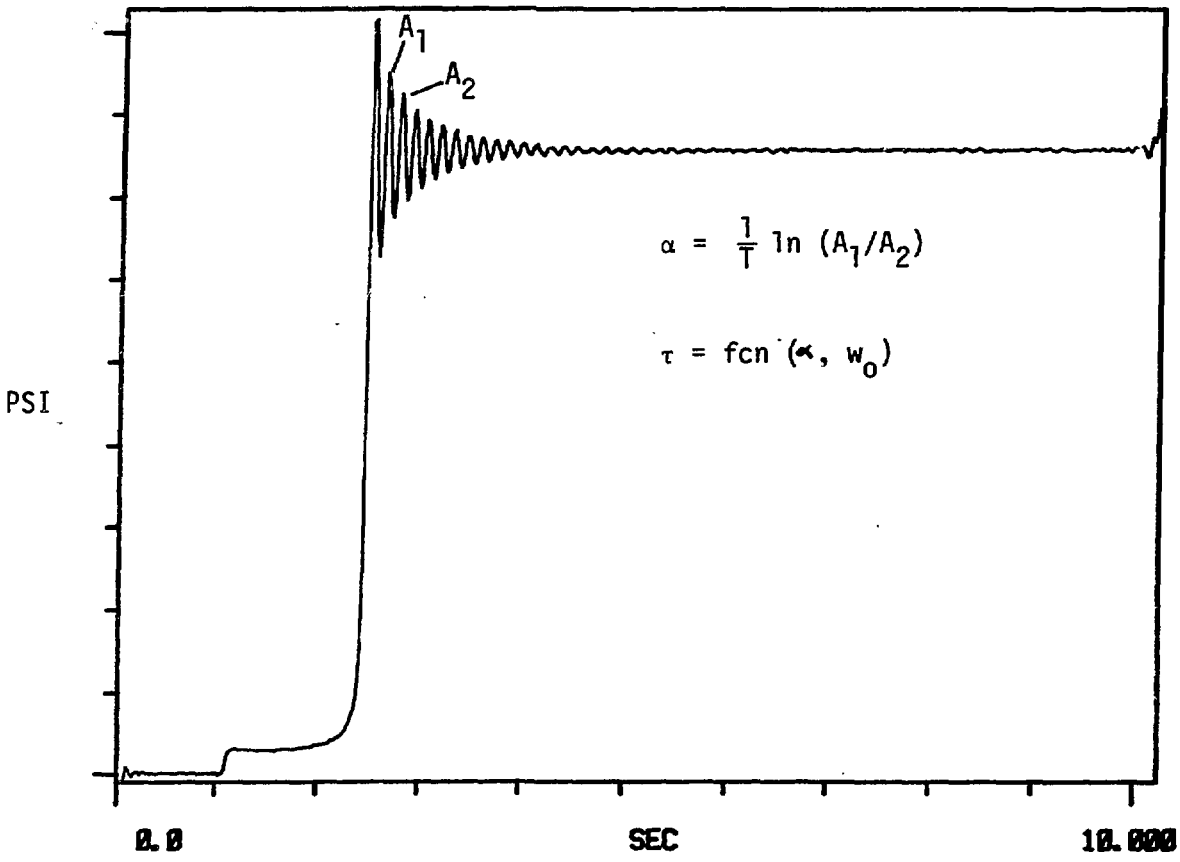
ORNL HIGH PRESSURE PERTURBATION TEST CONFIGURATION





SCHEMATIC OF ORNL HIGH PRESSURE PERTURBATION TESTS

TYPICAL HIGH-PRESSURE PERTURBATION TEST RESPONSE



PRESSURE PERTURBATION TESTS FOR SEVERAL VALUES OF LINE RESISTANCE

VALVE CONDITION (TURNS OPEN)	ASYMPTOTIC RAMP DELAY TIME
2	4.6 MS
3	2.6
5	2.7
7	3.7
FULL OPEN	2.7

SENSING LINE RESPONSE TIMES FOR SEVERAL SIMULATED LINE RESTRICTIONS AT THE ORNL HIGH PRESSURE TEST FACILITY

VALUE CONFIGURATION*	TRANSPORT DELAY TIME (MS)
V_{14} 1/16 T OPEN	1300
V_{14} 1/4 T OPEN	230
V_{14} 1/2 T OPEN	100
V_{14} 1 T OPEN	45
V_{15} FULL OPEN	30

*NINE TURN NEEDLE VALVE

- NOISE ANALYSIS METHOD USING TWO SENSORS

  --MEASURES TRANSFER FUNCTION

  SENSING LINE
  PROCESSOR SENSOR

  --QUANTITATIVE RESULTS EASILY OBTAINED

  --RESULTS ARE NOT SUBJECTIVE AND VERY ACCURATE

  --COULD REPLACE CURRENT RAMP TEST

  - EASIER TO PERFORM

    MAY REQUIRE CONTAINMENT PENETRATION

  --REQUIRES INSTALLATION OF A SECOND SENSOR IN LINE

- NOISE ANALYSIS METHOD USING ONLY ONE SENSOR

  -- SMALL CHANGES IN RESPONSE TIMES WERE DETECTABLE

  -- MEASUREMENTS CAN BE MADE CONTINUOUSLY AND REMOTELY

  -- MAY BE PERFORMED WITH MINIMAL ADDITIONAL INSTRUMENTATION

  -- QUANTITATIVE RESULTS ARE AVAILABLE, BUT NOT EASILY OBTAINABLE

  -- SUCCESS DEPENDS ON

     PROCESS CONDITIONS

     ADEQUATE INSTRUMENTATION

     PROPER ANALYSIS

  -- REQUIRES BASELINE MEASUREMENT UNDER NORMAL CONDITIONS

ASYMPTOTIC

TIME DELAYS (MS) ESTIMATED FROM NOISE ANALYSIS

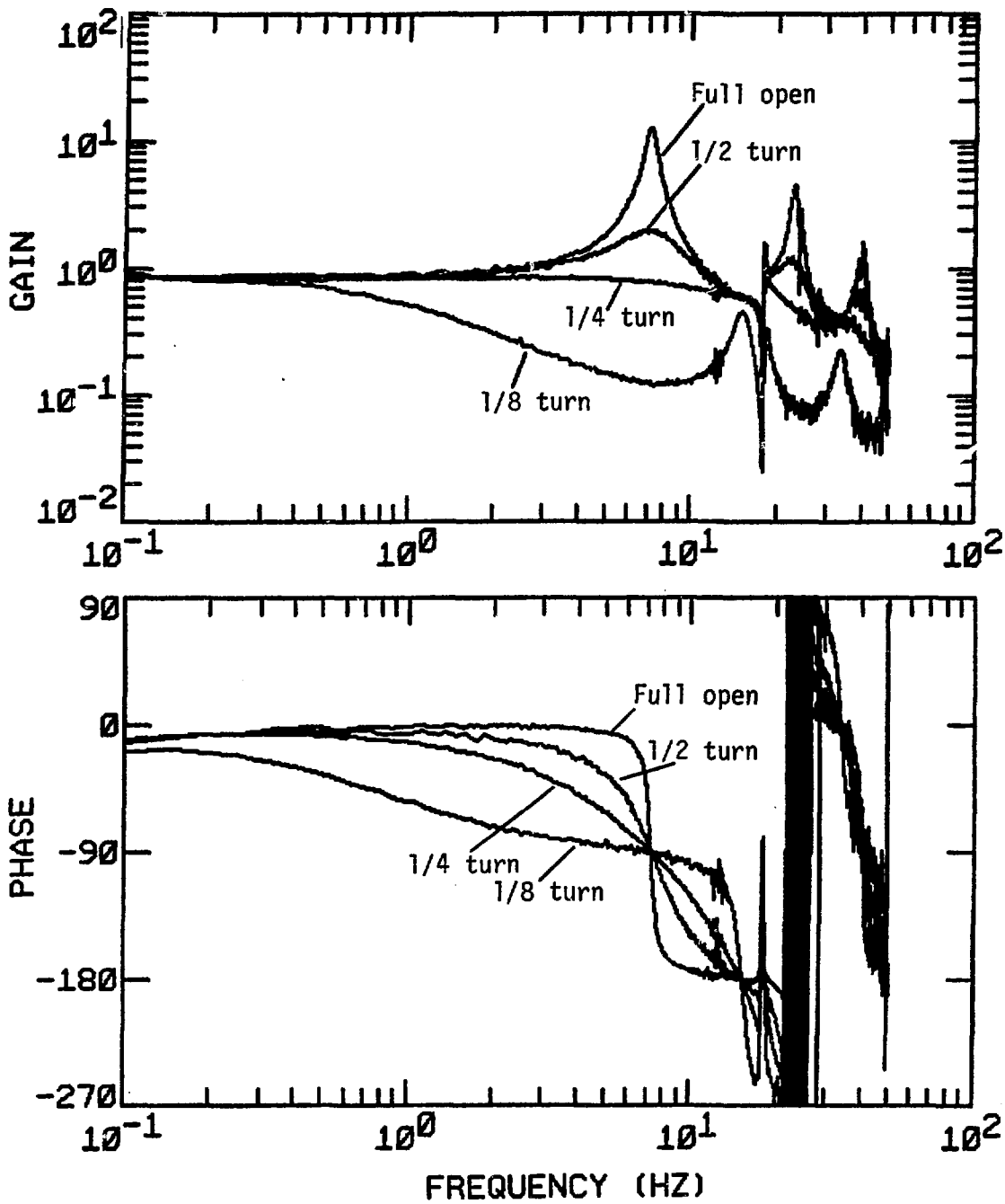
METHOD	VALVE POSITION*			
	OPEN	1/2 TURN	1/4 TURN	1/8 TURN
TRANSFER FUNCTION NONLINEAR FIT[A]	1.8	10.5	13.0	215.1
TRANSFER FUNCTION[A] -45 DEGREES FREQUENCY	23.2	28.9	45.5	227.4
VALYDINE PSD:[B] NONLINEAR FIT	2.6	14.7	28.8	212.5
VALYDINE PSD:[B] RMS VALUE	--	42.0	96.0	425.0
FOXBORO PSD:[B] NONLINEAR FIT	3.1	12.7	24.3	240.8
FOXBORO PSD:[B] RMS VALUE	--	6.0	225.0	>500

*NINE TURN NEEDLE VALVE

[A]OPEN LOOP

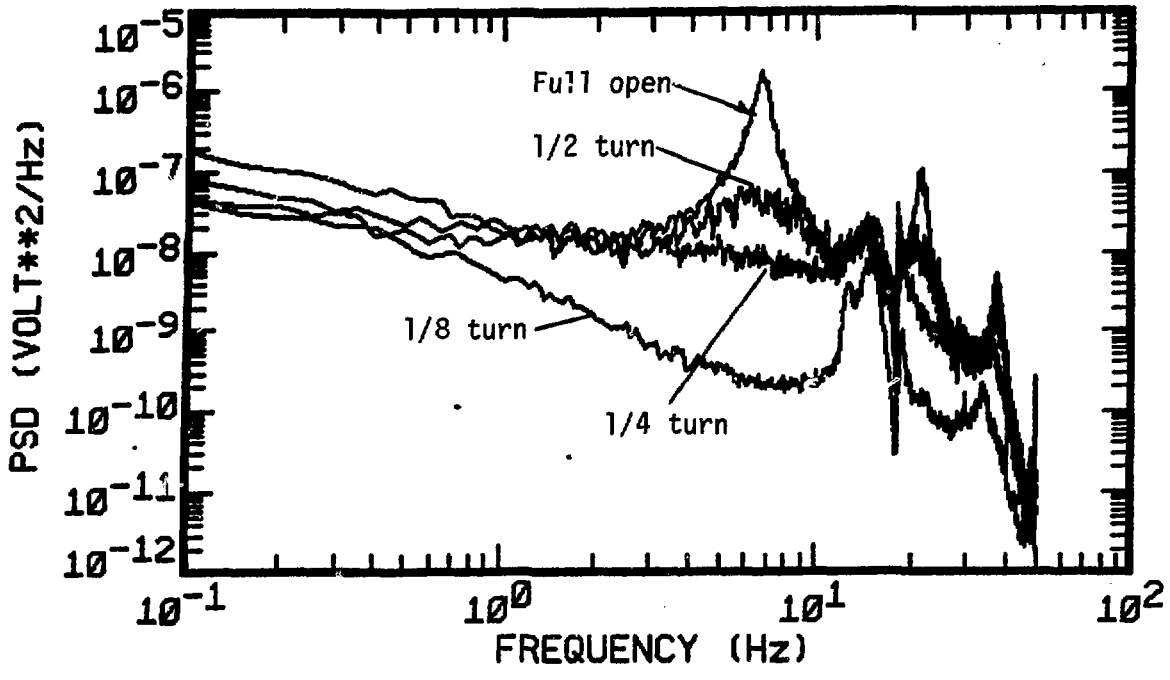
[B]CLOSED LOOP

SENSING LINE TRANSFER FUNCTION PARAMETRIC IN SENSING LINE RESISTANCE

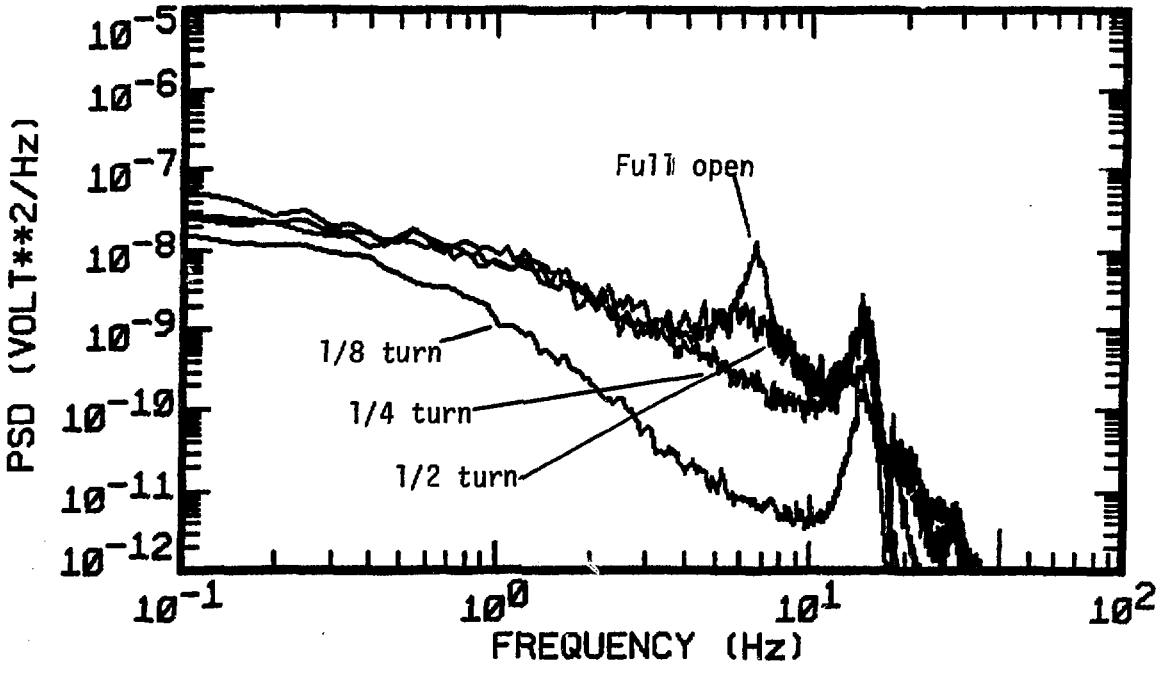


POWER SPECTRAL DENSITY PARAMETRIC IN SENSING LINE RESISTANCE

VALYDINE



FOXBORO



CONTRIBUTION OF SENSING LINE TO PRESSURE MEASUREMENT RESPONSE TIME

- MODEL PREDICTIONS AND LABORATORY TESTS WITH PROTOTYPICAL SENSING LINES INDICATE THAT NORMAL SENSING LINE MAKES A NEGLIGIBLE CONTRIBUTION TO RESPONSE TIME (<10 ms)

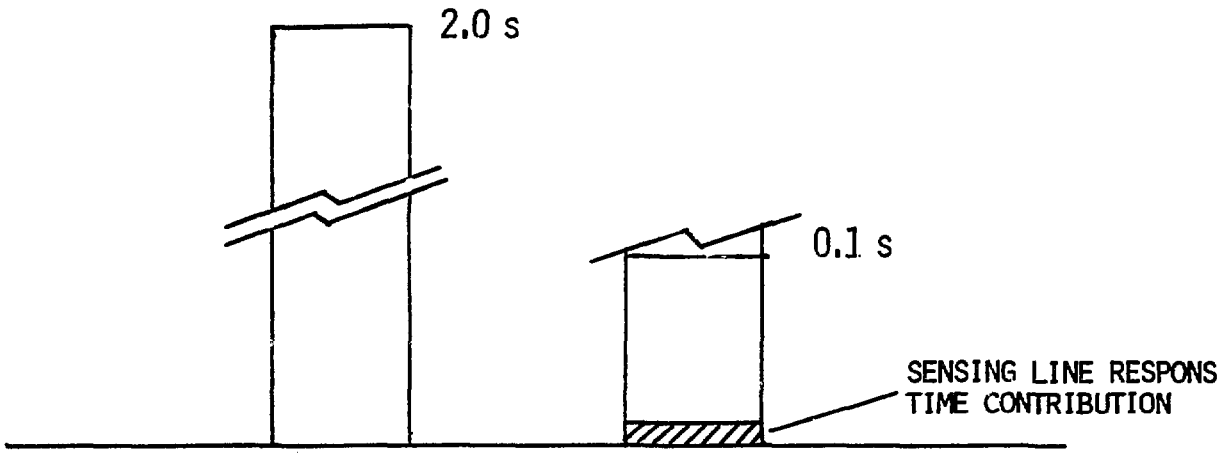
HOWEVER,

- A SEVERELY BLOCKED LINE CAN AFFECT THE OVERALL RESPONSE TIME
  -- LINE MUST BE ALMOST TOTALLY BLOCKED (>99% BLOCKED)

- LARGE QUANTITIES OF VOID IN A SENSING LINE MAY ALSO DEGRADE RESPONSE TIME - UP TO ~ 150 ms at 2300 psi (EFFECT IS LARGER AT LOW PRESSURE)

RELATIVE RESPONSE TIMES OF THE

SENSING LINE AND PRESSURE CHANNEL INSTRUMENT



IN SUMMARY, RESEARCH HAS RESULTED IN:

- IMPROVED UNDERSTANDING OF THE DYNAMICS OF PRESSURE SENSORS AND SENSING LINES

- A REMOTE METHOD FOR MEASURING RESPONSE TIME OF FORCE-BALANCE SENSORS

- REMOTE METHODS FOR DETECTION OF BLOCKAGES OR VOIDS IN PRESSURE SENSING LINES

RESPONSE TIME MEASUREMENTS OF THE FOXBORO PRESSURE TRANSMITTER AT THE ORNL HIGH PRESSURE TEST FACILITY

TYPE OF INPUT	RESPONSE TIME, S
POSITIVE STEP	.39
POSITIVE STEP	.40
POSITIVE STEP	.32
POSITIVE STEP	.32
NEGATIVE STEP	.11
NEGATIVE STEP	.15
NEGATIVE STEP	.12

COMPARISON OF MODEL CALCULATIONS WITH PRESSURE PERTURBATION TRANSIENT TEST RESULTS

Quantity compared	Test used	Measured value	Calculated value
Standing wave frequency, Hz	ORNL, cold	10	10.1
Helmholtz frequency, Hz, with Rosemount present without Rosemount	UT, low pres. UT, low pres.	1.04 1.08	1.08 1.16
Helmholtz frequency, Hz	ORNL, cold	6.4	5.6 to 7.3
Line length effect on resonance, $F_0(32')/F_0(101')$	UT, low pres.	1.60	1.63
Chamber volume effect on resonance, F_0 (50 cc)/ F_0 (100 cc)	UT, low pres.	1.43	1.41
Accumulator air volume effect on resonance, F_0 (.87 FT^3)/F_0 (1.86 FT^3)	UT, low pres.	1.00	1.0005
Blockage valve turns T effect on K, $\Delta K(9T \rightarrow 3T)/\Delta K(3T \rightarrow 1T)$	UT, high pres.	.18	.16
Pressure effect on resonance F_0 (25 psia)/F_0 (45 psia)	UT, low. pres.	.54	.54