Tennessee Valley Authority, Post Office Box 2000, Spring City, Tennessee 37381-2000

October 27, 2000

TVA-WBN-TS-00-06 10 CFR 50.90

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555

Gentlemen:

In the Matter of)
Tennessee Valley Authority) Docket No. 50-390

WATTS BAR NUCLEAR PLANT (WBN) - TECHNICAL SPECIFICATION (TS) CHANGE NO. 00-06 - INCREASE UNIT 1 REACTOR POWER TO 3459 MWt - TVA PRESENTATION TO NRC ON LEFM TEST RESULTS SEPTEMBER 7, 2000 (TAC NO. MA9152)

As recently requested by the NRC, the enclosure to this letter provides the presentation materials distributed to NRC staff and discussed at NRC headquarters during a September 7, 2000, meeting between TVA, NRC, and TVA's LEFM vendor, Caldon, Inc. The presentation addressed the principles of operation of Caldon's LEFM and the results of hydraulic laboratory testing of the WBN LEFM Check system. TVA believes this information to be complete and accurate based on information provided by Caldon, Inc.

Should you have any questions, please call me at (423) 365-1824.

Sincerely,

P. L. Pace,
Manager, Licensing and Industry Affairs

Enclosures

Subscribed and sworn to before me
on this 27th day of October 2000.

Notary Public

My Commission
Expires June 27, 2001

cc (See Page 2)

D030

Printed on recycled paper

cc (Enclosure):

NRC Resident Inspector
Watts Bar Nuclear Plant
1260 Nuclear Plant Road
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Caldon, Inc.
1070 Banksville Avenue
Pittsburgh, PA 15216
412-341-9920 Tel
412-341-9951 Fax
www.caldon.net

10/23/00

Mr. James Maddox
Manager of Engineering
Tennessee Valley Authority
Watts Bar Nuclear Power Plant
EQB-1A
P.O. Box 2000
Spring City, TN 37381

Subject: Transmittal of September 7, 2000 NRC Meeting Presentation Materials

Dear Mr. Maddox:

This letter formally transmits the presentation materials distributed to members of NRC staff and discussed at the September 7 meeting between TVA and the NRC. These materials describe the principles of operation of Caldon's LEFM and outline the results of hydraulic laboratory testing of the Watts Bar LEFM Check system. As we stated during the meeting, the results of the hydraulic laboratory testing outlined in the enclosed materials have been prepared and reviewed by Caldon engineers and are found to be true and accurate.

Please contact me if you have any questions about the enclosed information.

Sincerely,

Mr. Ernest Hauser
President, Caldon Nuclear

Enclosure

cc: J. Thompson, TVA

PRESENTATION
to
USNRC

September 6, 2000

PR310

CALIBRATION TESTS OF THE WATTS BAR LEFM✓
Impact on In-Plant Accuracy and Margin

I. Principles of Operation

II. Sources of Uncertainty

III. Calibration Tests of the Watts Bar Spool Piece

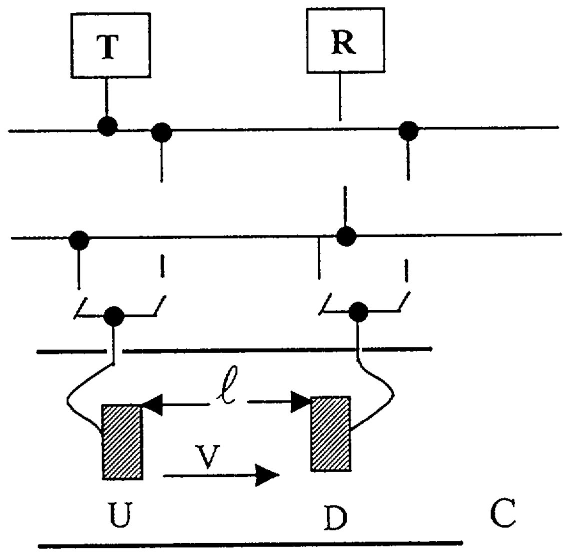
IV. Uncertainty in the Profile Factor of the Watts Bar Spool Piece

V. Impact of Reduced Profile Factor Uncertainty on Margin

I. PRINCIPLES OF OPERATION

- 4 Path Chordal LEFM Check

a. Velocity, Path Length, and Transit Time



$$t_{UD} = \frac{\ell}{c+v} + \tau \,;\; t_{DU} = \frac{\ell}{c-v} + \tau$$

$$\Delta t \equiv t_{DU} - t_{UD} = \frac{\ell(c+v) - \ell(c-v)}{(c+v)(c-v)} = \frac{2\ell v}{c^2 - v^2}$$

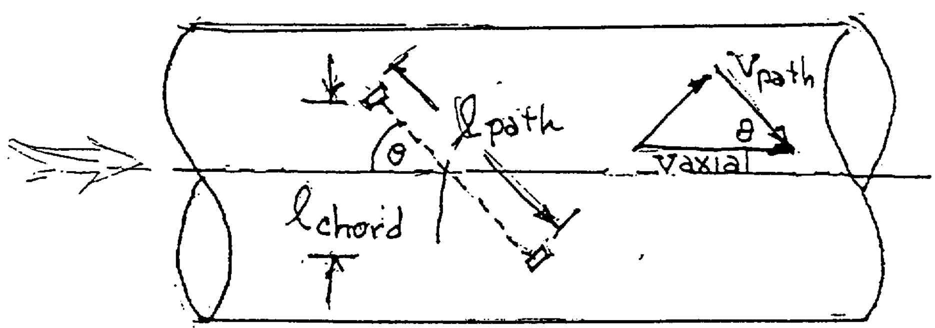
$$(t_{UD} - \tau)(t_{DU} - \tau) = \frac{\ell^2}{c^2 - v^2}$$

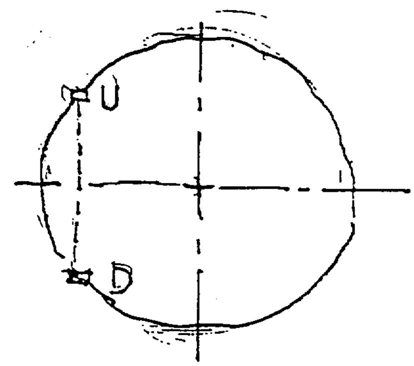
$$\therefore\ \ell v = \frac{\ell^2}{2} \quad \frac{\Delta t}{(t_{UD} - \tau)(t_{DU} - \tau)}$$

I. PRINCIPLES OF OPERATION

- 4 Path Chordal LEFM Check

b. Axial Velocity and Chordal Trigonometry





$$V_{PATH} = V_{AXIAL} \cos\theta$$

$$\ell_{PATH} = \frac{\ell_{chord}}{\sin\theta}$$

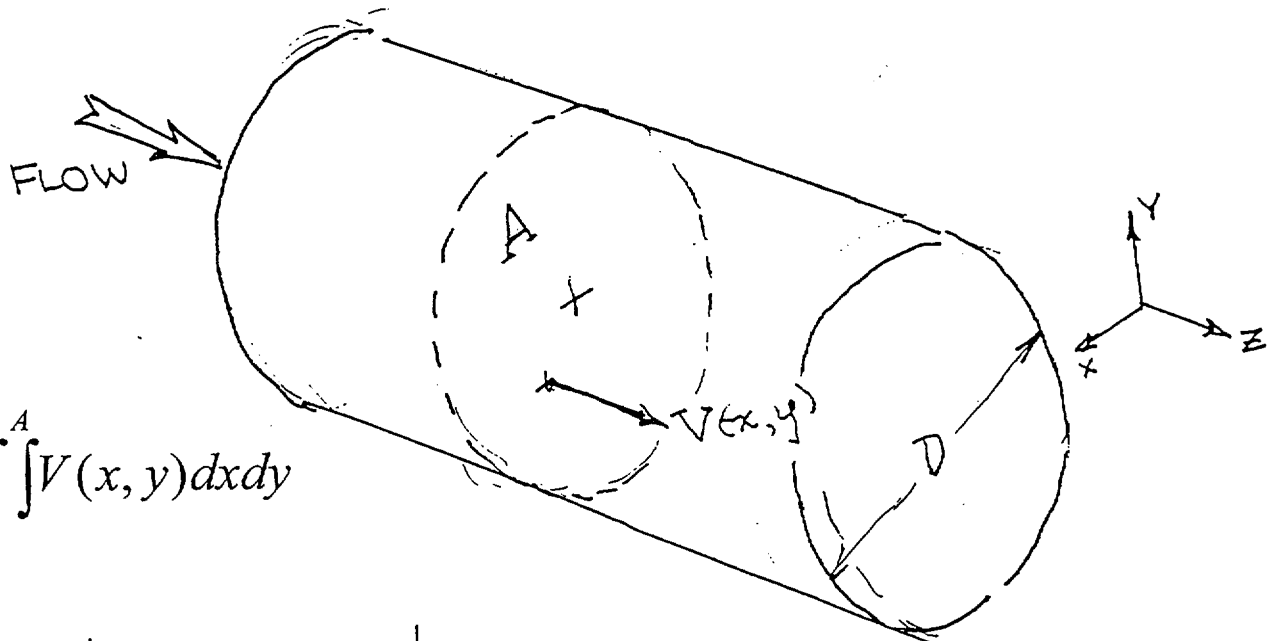
$$V_{axial}\,\ell_{chord} = V_{PATH}\,\ell_{PATH}\tan\theta$$

$$V_{axial}\ell_{chord} = \ell_{PATH}^{\;2}\tan\theta\,\frac{1}{2}\,\frac{\Delta t}{(t_{UD}-\tau)(t_{DU}-\tau)}$$

I. PRINCIPLES OF OPERATION

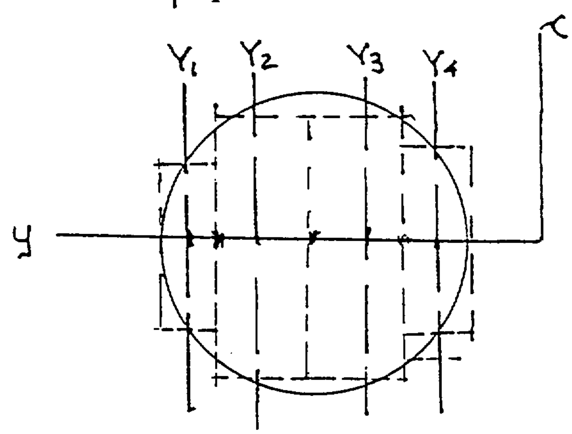
- 4 Path Chordal LEFM Check

c. Numerical Integration of Chord Velocity Products



$$Q = \iint^{A} V(x,y)\,dx\,dy$$

$$\int V(x)\,dx\Big|_{Y_1} = \mathrm{v}_{axial}\,\ell_{chord}\Big|_{Y1}$$



$\Delta Y_1 = w_1 D$, $\Delta Y_2 = w_2 D$, $\Delta Y_3 = w_3 D$, $\Delta Y_4 = w_4 D$

$$Q \cong \sum_{i=1}^{4} w_i D (V_{axial}\ell_{chord})_i = \sum_{i-1}^{4} w_i D \frac{\ell^2{}_{PATH\,i} Tan\,\theta_i}{2} \frac{\Delta ti}{(t_{UD\,i} - \tau)(t_{DU\,i} - \tau)}$$

I. PRINCIPLES OF OPERATION

- 4 Path Chordal LEFM Check

d. Meter Factor, Profile Factor, Geometry Factor

$$Q = (PF)(GF) * F_A(T) \cdot \frac{D}{2} \sum_{\ell=i}^{4} w_i \frac{\ell^2{}_{PATH\,i} Tan\theta_i}{(t_{UD\,i} - \tau)} \frac{\Delta ti}{(t_{DU\,i} - \tau)}$$

$F_A(T)$ ≡ Expansion Factor, accounts for expansion of spool from conditions of calibration

$F_A(T)$ ≅ $1 + 3\alpha\,(T(c) - To)$

GF = Geometry Factor, accounts for small bias in 4 path Legendre integration of a circular area and measured departures of actual path locations from those specified by Legendre.

[If geometry is ideal, GF = 0.9940].

PF = Profile Factor, accounts for bias in the numerical integration with the in-plant hydraulic profile.

PF typically between 1.000 and 1.004.

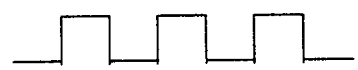
The objective of the calibration test is the measurement of PF.

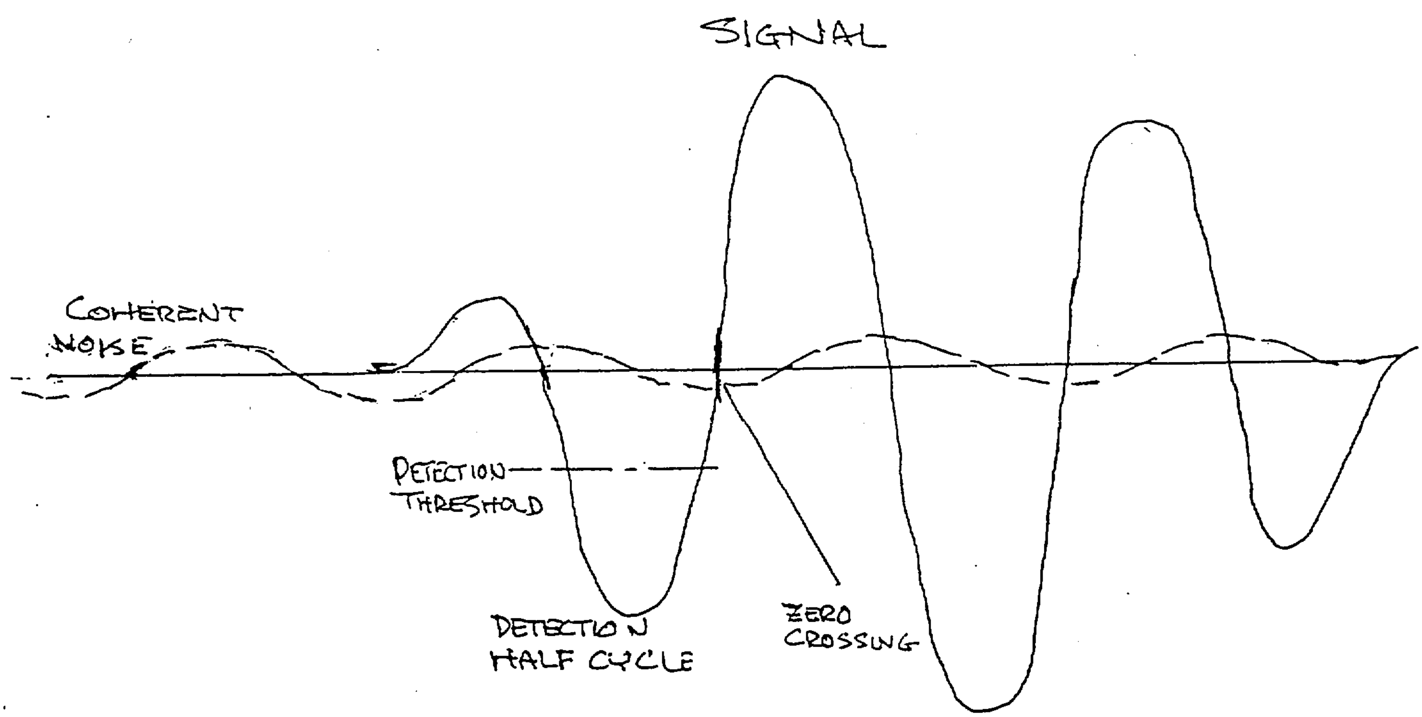
II. SOURCES OF UNCERTAINTY

VOLUMETRIC FLOW MEASUREMENTS WITH THE LEFM CHECK

- FROM THE ALGORITHM

a. **Δt**

- Non reciprocal delay in the non fluid path ≤ 1 nsec
- Clock
- Clock pulse resolution 
- Signal to random noise ratio
- Signal to coherent noise ratio ≤ 1 nsec



II. SOURCES OF UNCERTAINTY

VOLUMETRIC FLOW MEASUREMENTS WITH THE LEFM CHECK

- FROM THE ALGORITHM

b. t and τ

- Errors that affect Δt also affect t but they are negligible because

$$t \gg \Delta t$$

- Largest source of uncertainty in t due to the non fluid delay τ

- τ

1. Calculated "bottom up" from
   - Measured electronics delay
   - Measured "half cycle" delay
   - Measured cable length
   - Measured thickness of housing windows and speed of sound in stainless steel

2. Measured in the field by "triple bounce"

3. Measured using long and short path lengths and times of flight
   - Also used, in service to confirm τ remains constant

II. SOURCES OF UNCERTAINTY

VOLUMETRIC FLOW MEASUREMENTS WITH THE LEFM Check

- FROM THE ALGORITHM

c **Dimensions – Path Lengths, Path Angles, Path Spacings, Internal Diameter**

- If the spool piece profile factor is measured in a calibration facility, dimensional errors are imbedded in Profile Factor.

- Only errors owing to changes in the field need be accounted

  - Erosion corrosion of ID
  - Changes in path length (monitored by comparing path sound velocities)
  - Field alignment
  - Uncertainty in thermal expansion

a) As measured dimensions are used to determine geometry factor

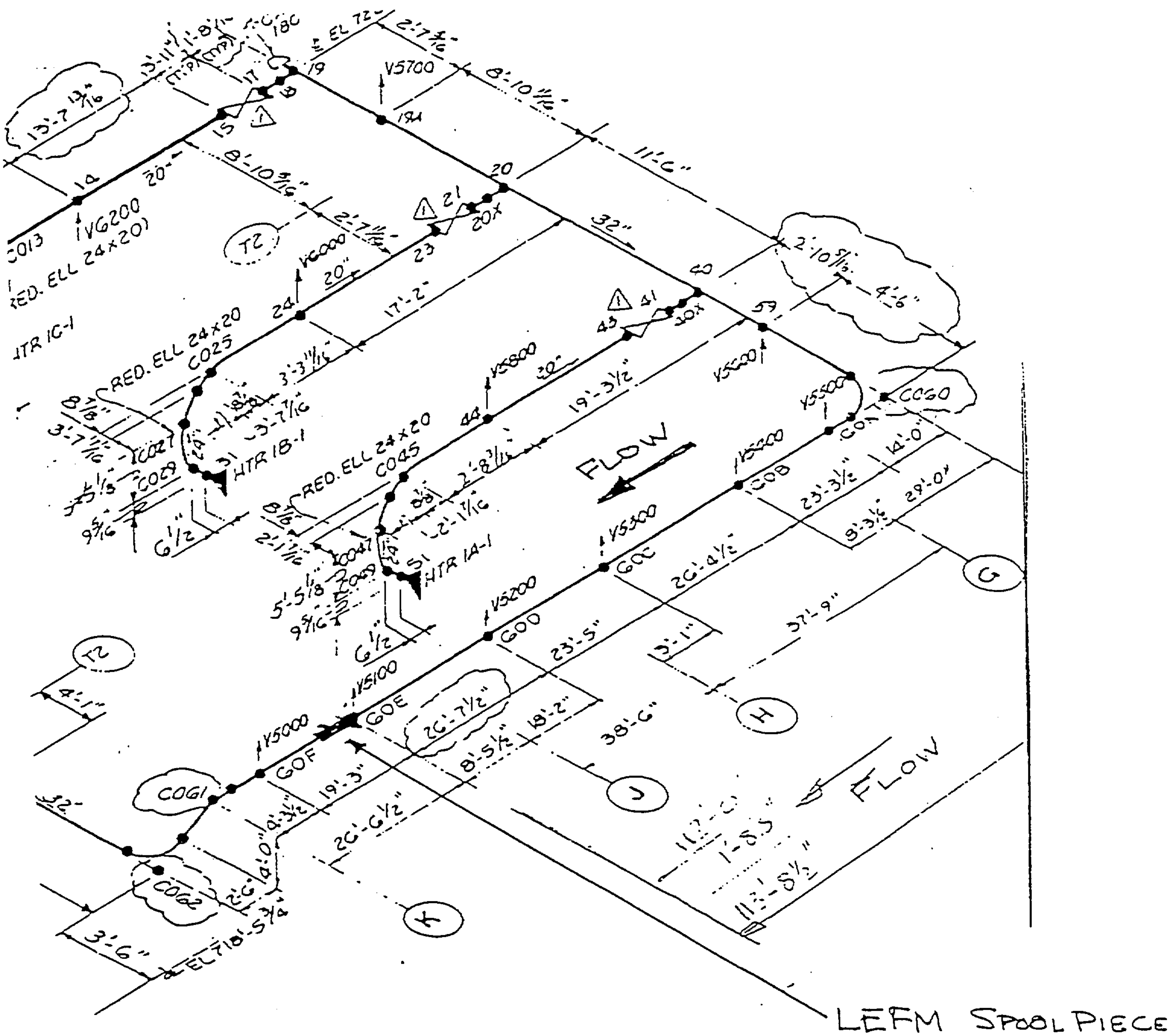
- Allows separation of hydraulic and geometry effects
- Permits comparison with data for other spools

b) As measured path lengths and their uncertainties are important to sound velocity (temperature) determination

III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

- Measuring Profile Factor and Bounding its Uncertainty

a. The Spool Piece in the Plant



III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

- Measuring Profile Factor and Bounding its Uncertainty

b. The Plant Hydraulic Geometry

- A long straight pipe
- Vortices decay in ~30 diameters

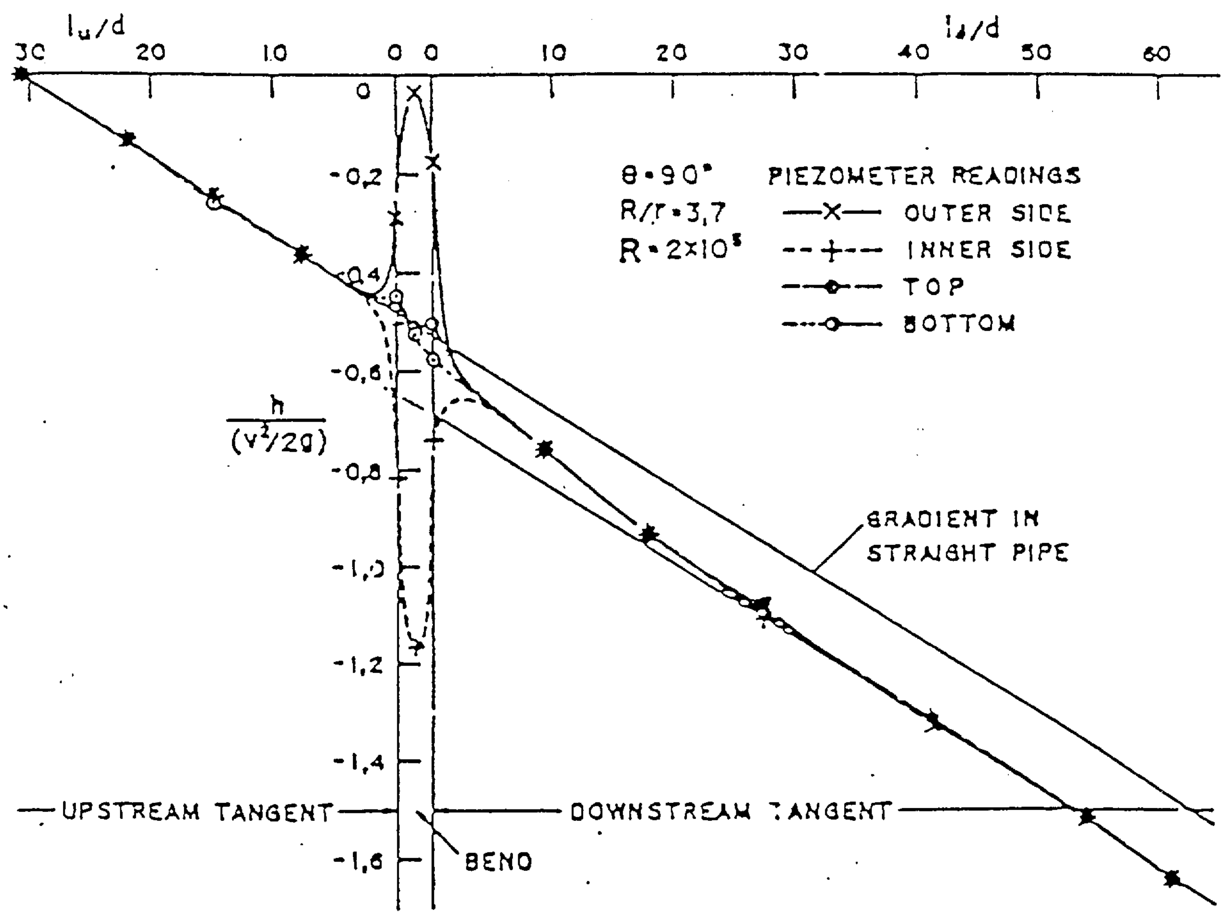


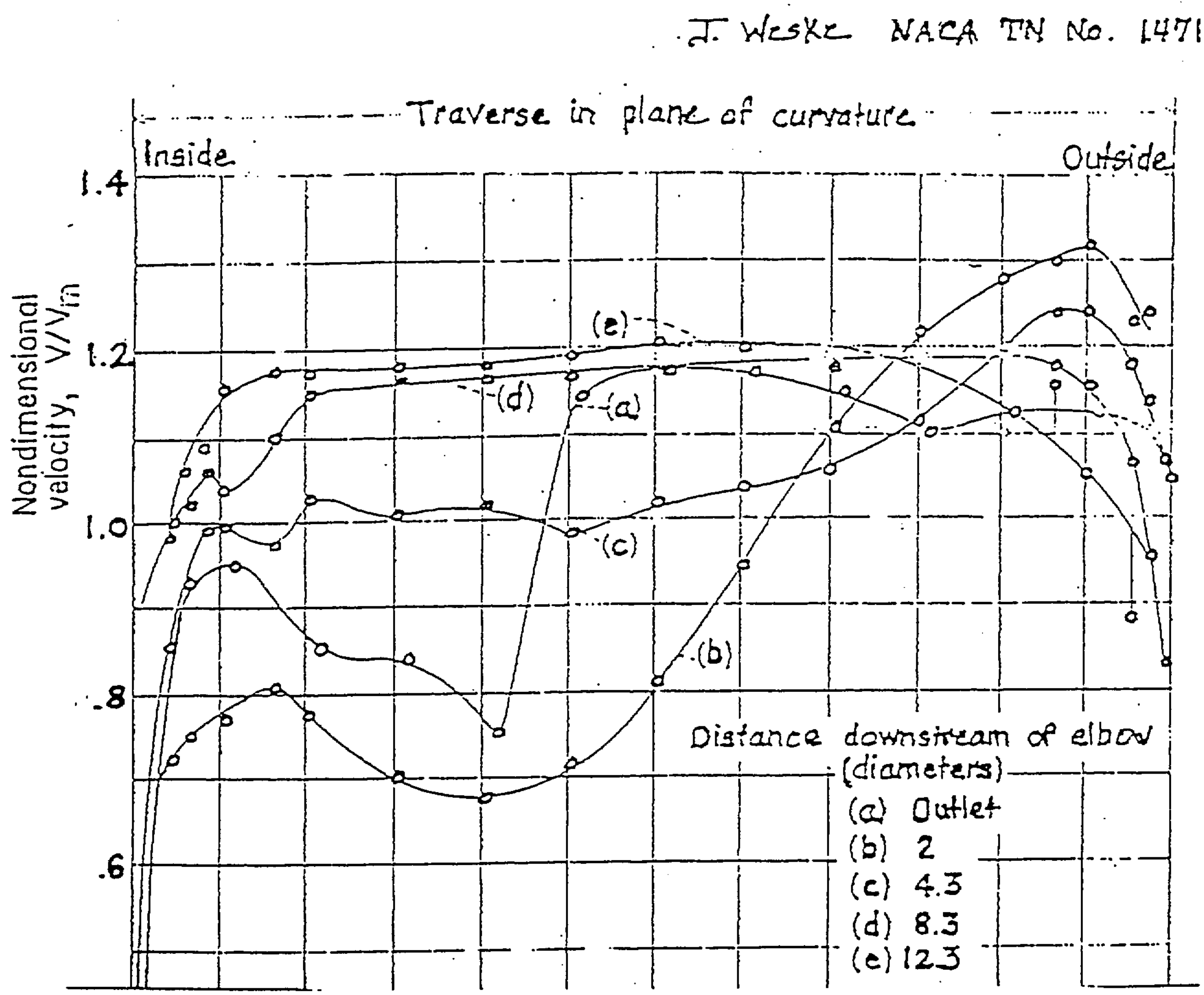
Fig. 3 Pressure distribution along pipeline containing a 90-deg pipe bend (R/r = 3.7)

III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

- Measuring Profile Factor and Bounding its Uncertainty

c. The Plant Hydraulic Geometry

- A long straight pipe
- Axial distortion decays in ~12 diameters

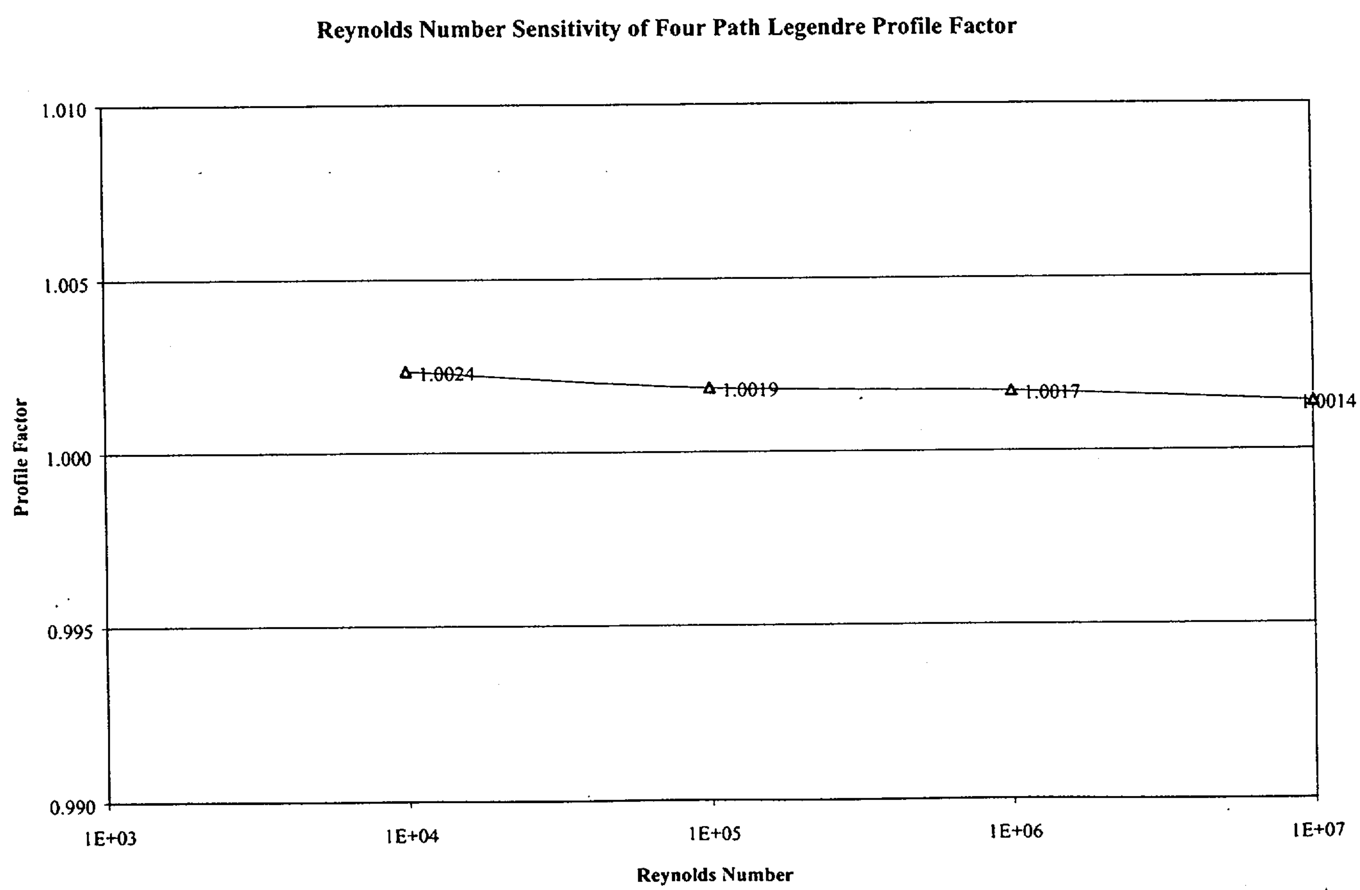


III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

- Measuring Profile Factor and Bounding its Uncertainty

d. Performance of 4 Path Chordal Flow Meters in Straight Pipe

- Calculations based on Nikardse Data for fully developed profiles show that Profile Factor is insensitive to Reynolds Number



III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

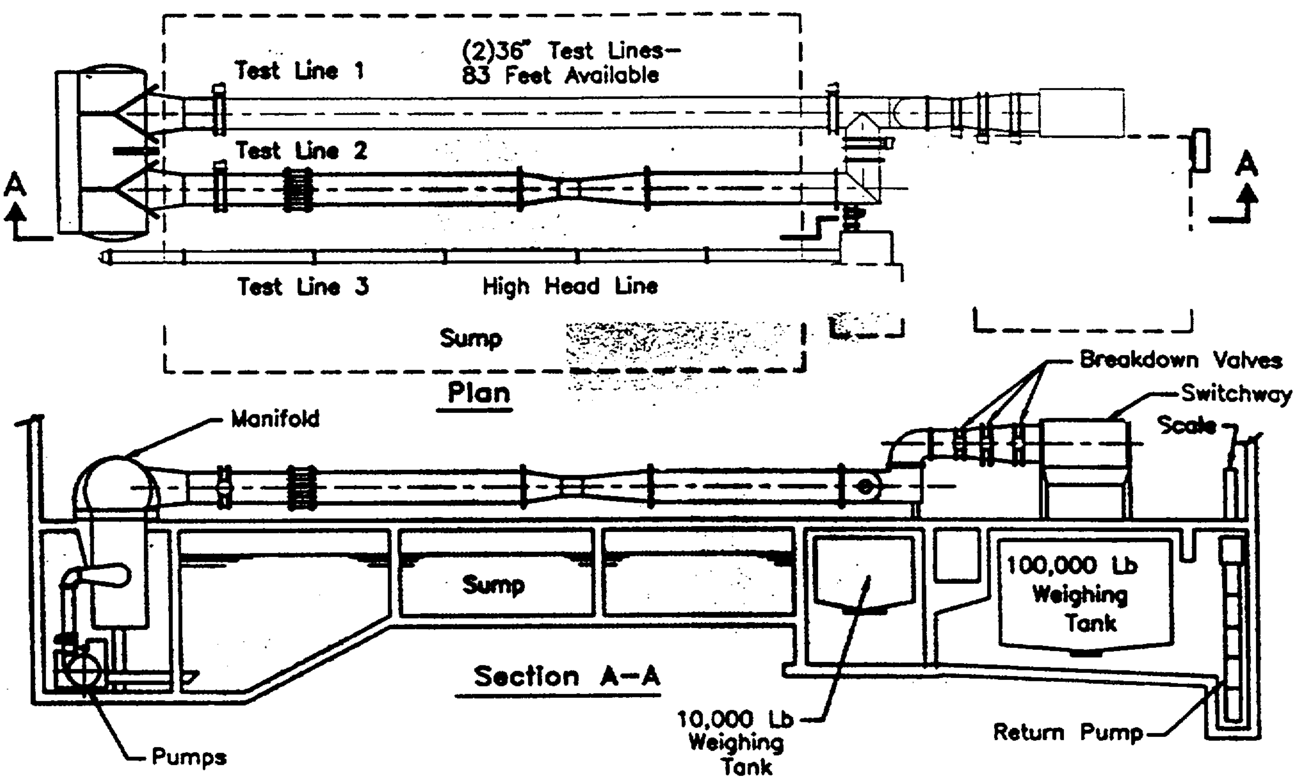
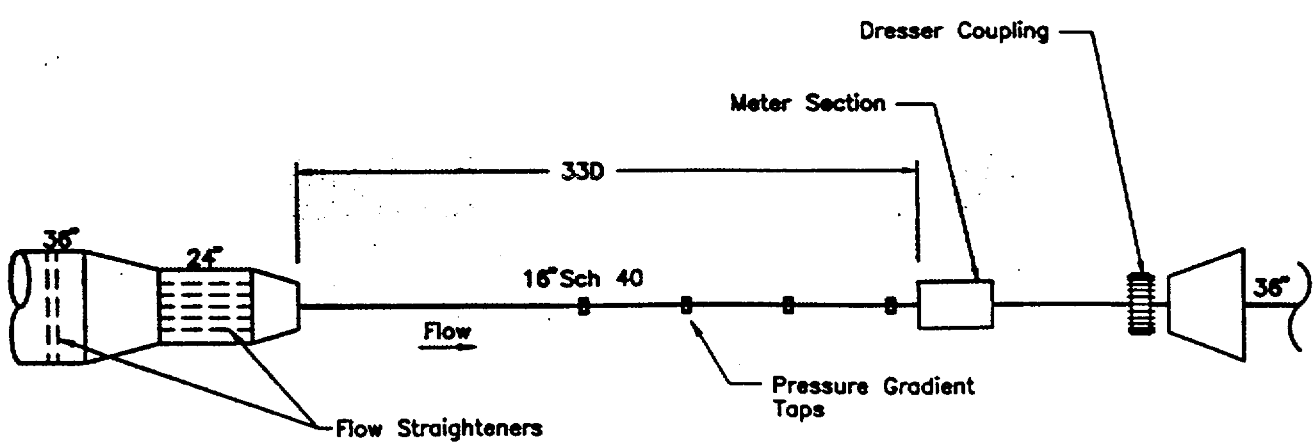


Figure 4. Alden Laboratory Test Loop



III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

- Measuring Profile Factor and Bounding its Uncertainty

e. Calibration Data for 9 other Spools match the calculated Profile Factor for Straight Pipe

Greater than 15 Inch Diameter; Reynolds Numbers: 1 million to3 million

Nominal Pipe Internal Diameter, inches	Application	Date of Calibration Tests	Measured Profile Factor*
24	Nuclear feedwater	Feb., 1979	1.0009
18	Nuclear feedwater	May, June, 1979	0.9998
16	Nuclear feedwater	Sept., 1983	1.0026
16	Nuclear feedwater	Sept., 1983	1.0006
16	Nuclear feedwater	Sept., 1983	1.0014
16	Nuclear feedwater	Nov., 1983	1.0025
16	Nuclear feedwater	Nov., 1983	1.0011
16	Nuclear feedwater	Nov., 1983	1.0006
26	Test program for nuclear feedwater	July, 1978	1.0017

Mean Profile Factor **<u>1.0012</u>**

Uncertainty in the Mean, 95 % confidence limits **± 0.0020**

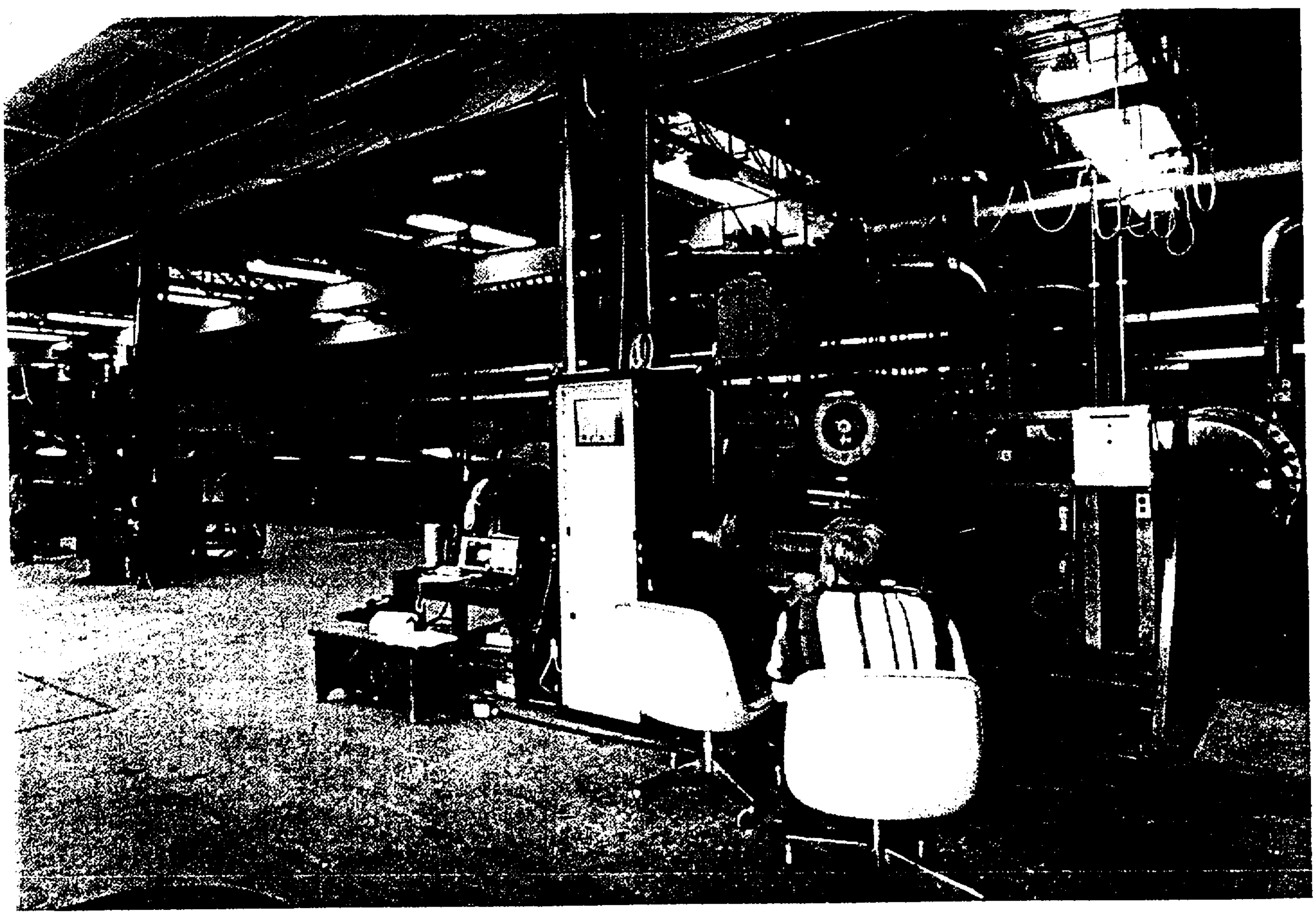
Profile Factor for Fully Developed Velocity Distribution @ $R_N = 3 \times 10^6$ **<u>1.0017</u>**

* Original data include the effects of both velocity and geometry. The original data have been multiplied by a nominal (ideal) geometry factor of 1.0060 to obtain the listed profile factors.

III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

- Measuring Profile Factor and Bounding its Uncertainty

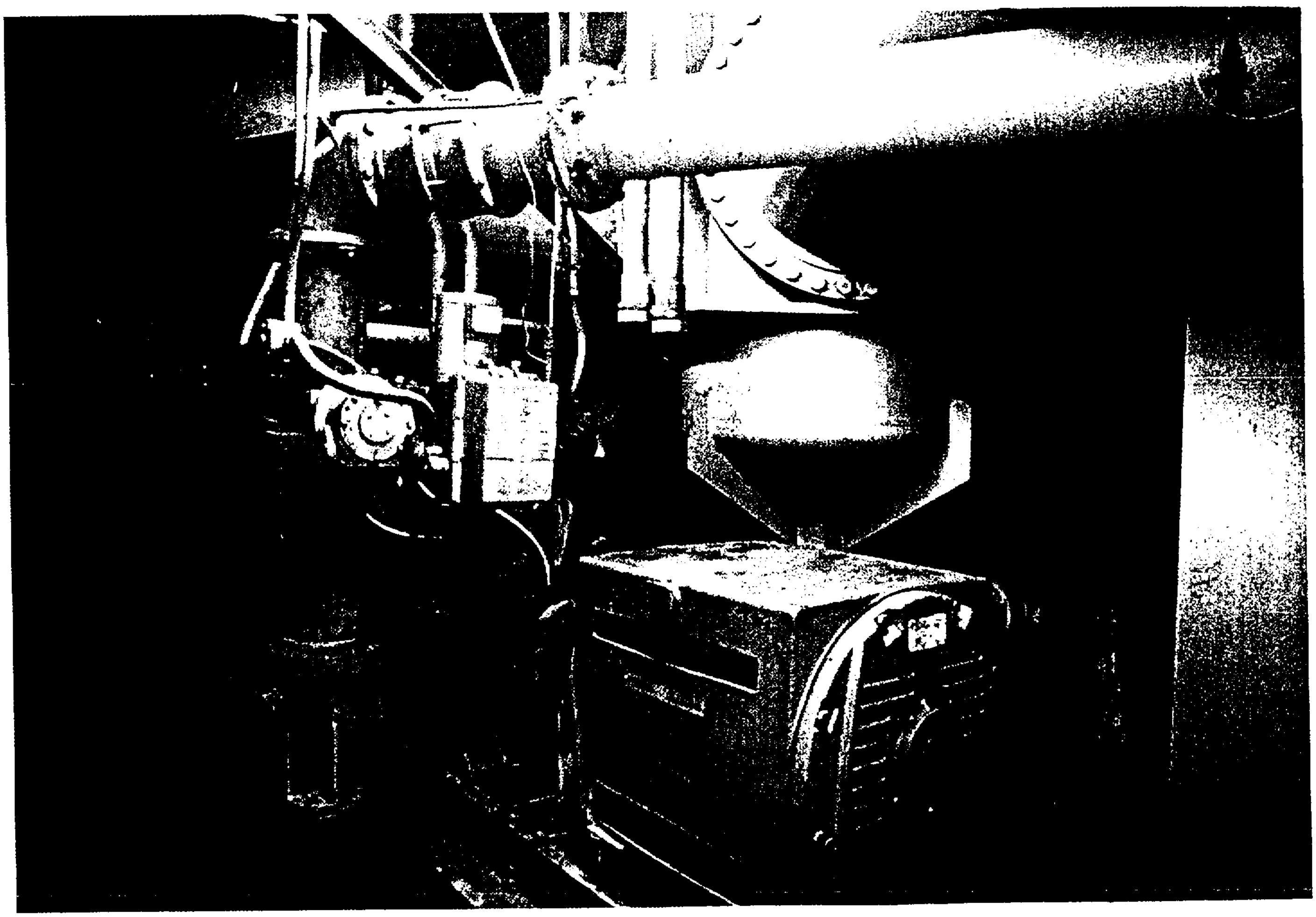
f. The Alden Calibration Facility



III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

- Measuring Profile Factor and Bounding its Uncertainty

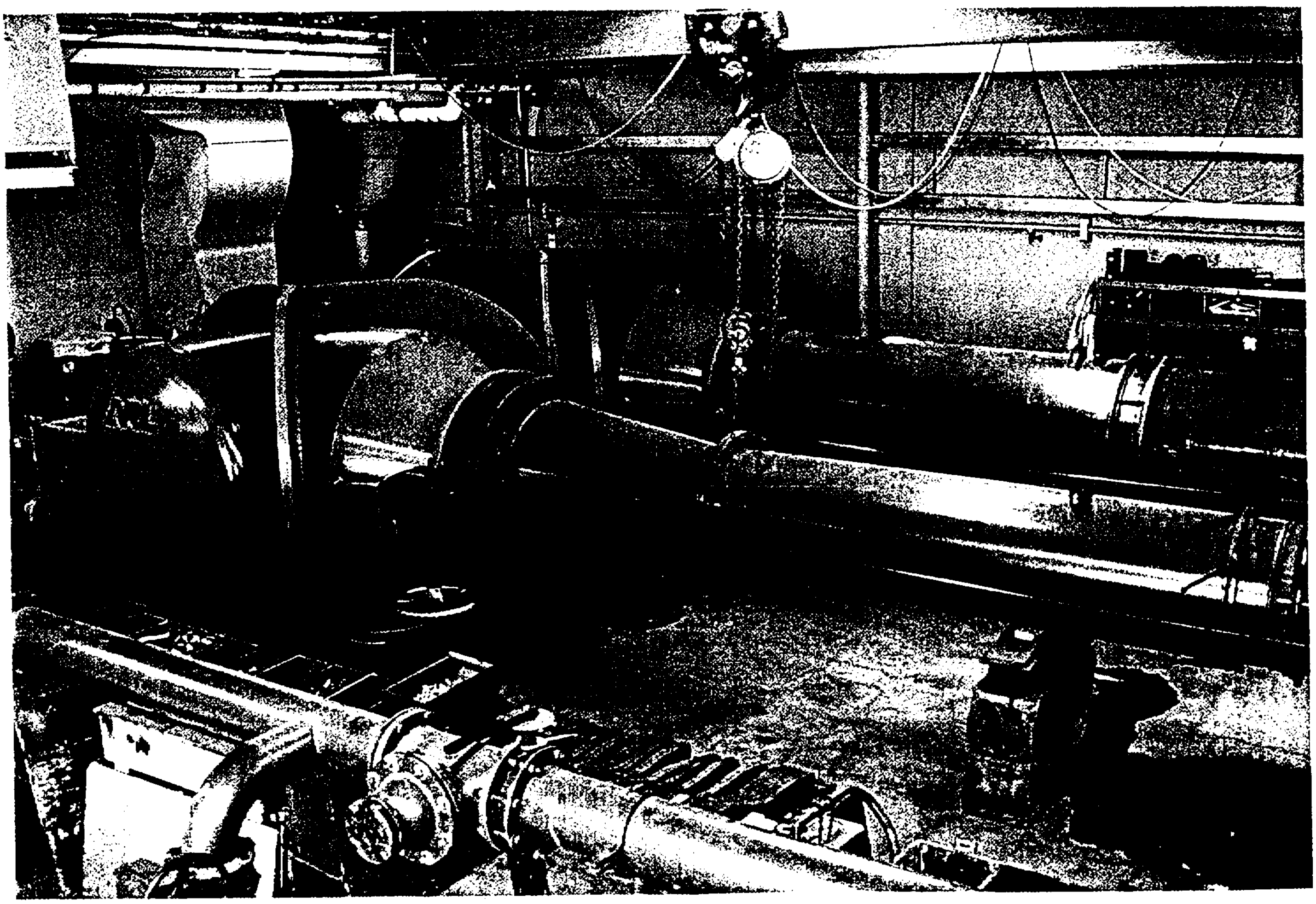
g. The Watts Bar Test Setup



III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

- Measuring Profile Factor and Bounding its Uncertainty

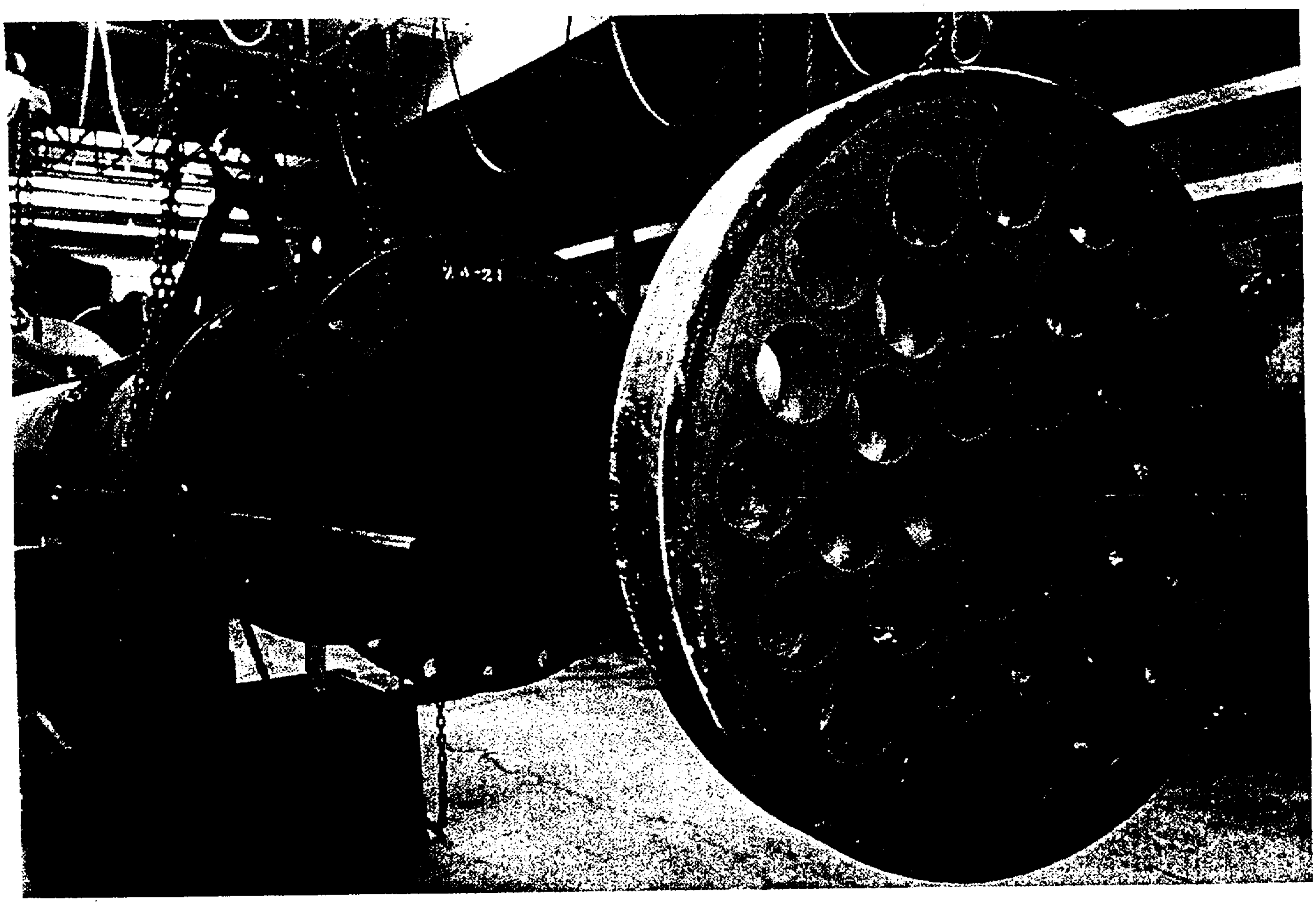
The Watts Bar Test Setup



III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

- Measuring Profile Factor and Bounding its Uncertainty

The Watts Bar Test Setup



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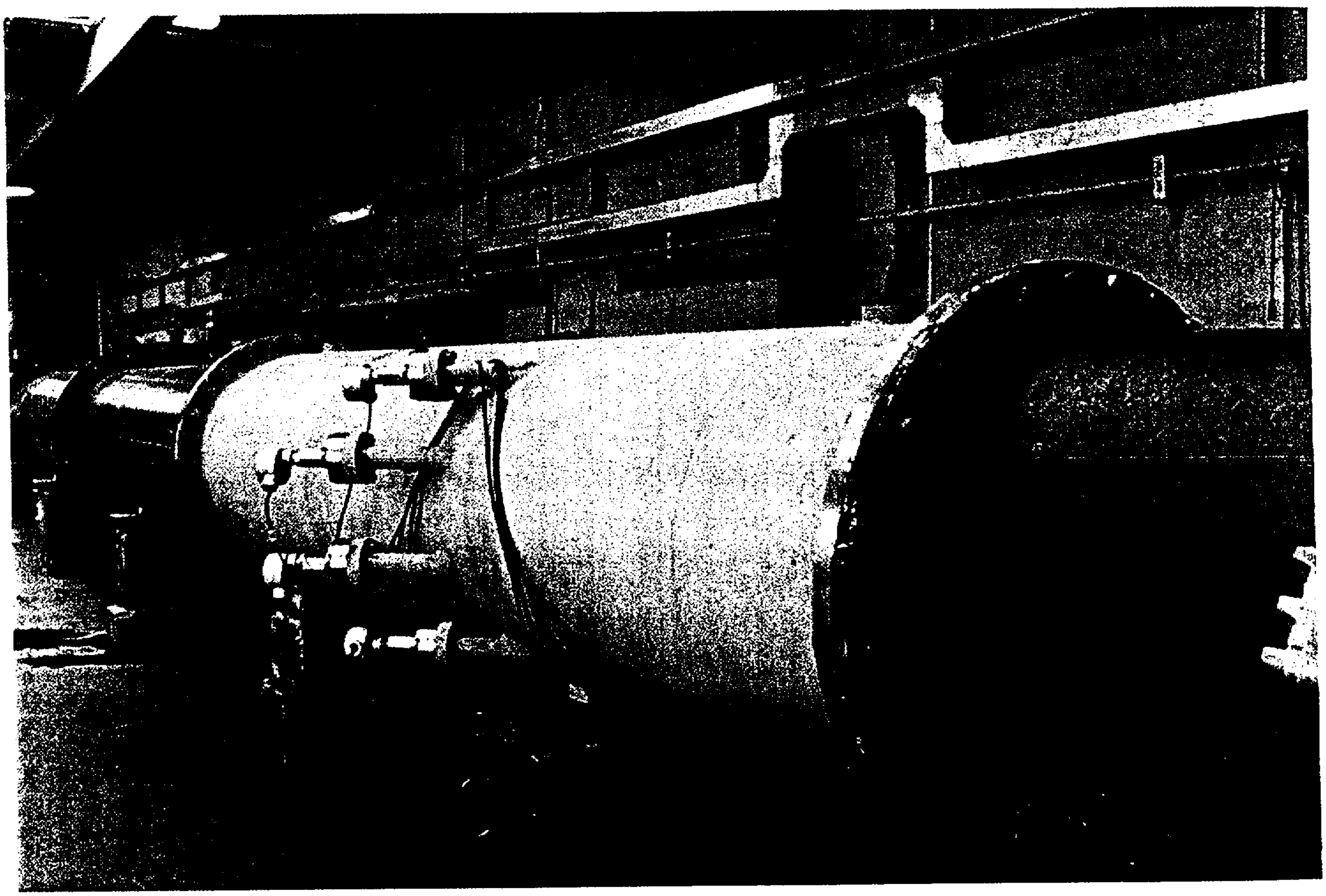
- Measuring Profile Factor and Bounding its Uncertainty

The Watts Bar Test Setup



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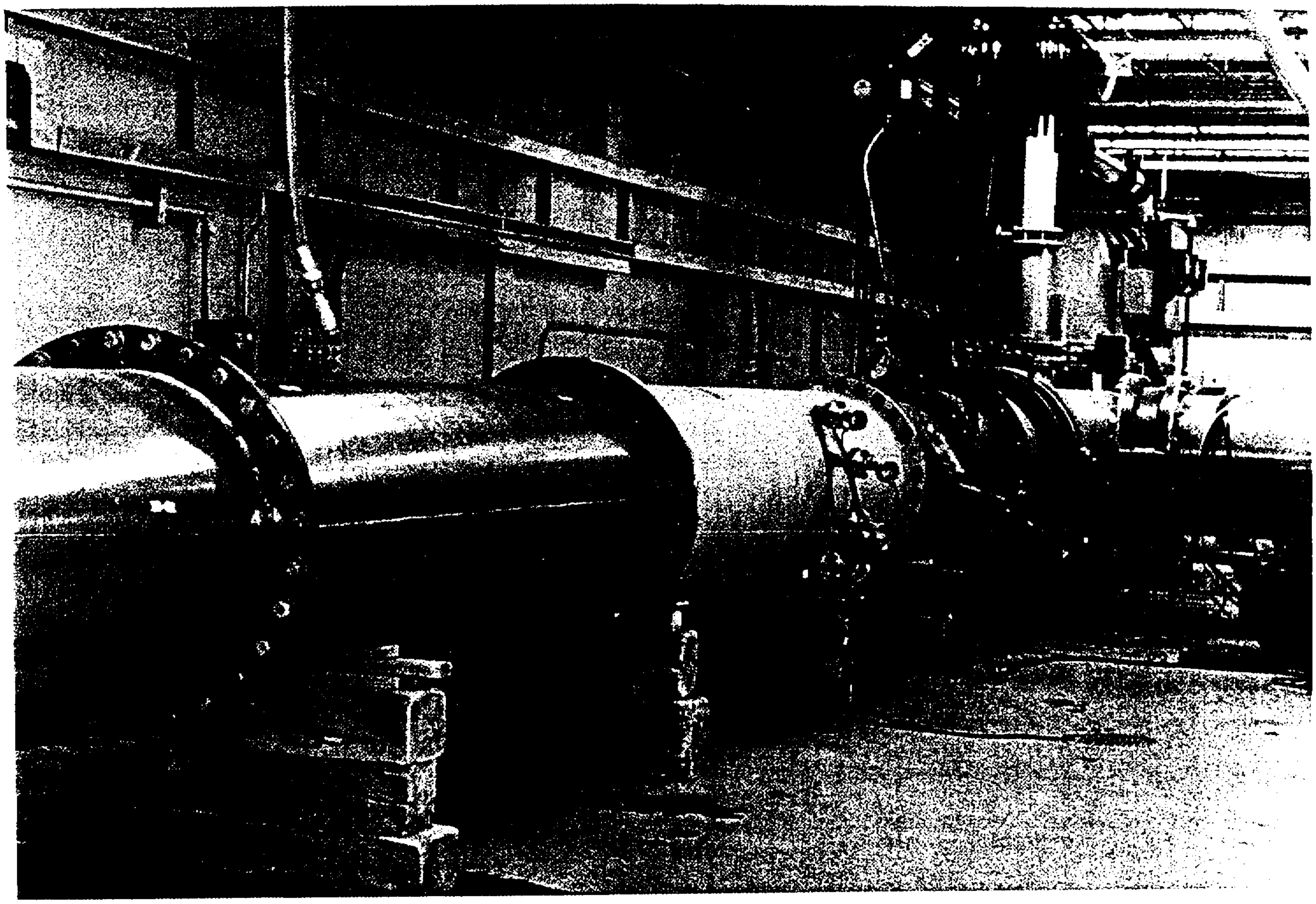
- Measuring Profile Factor and Bounding its Uncertainty

The Watts Bar Test Setup



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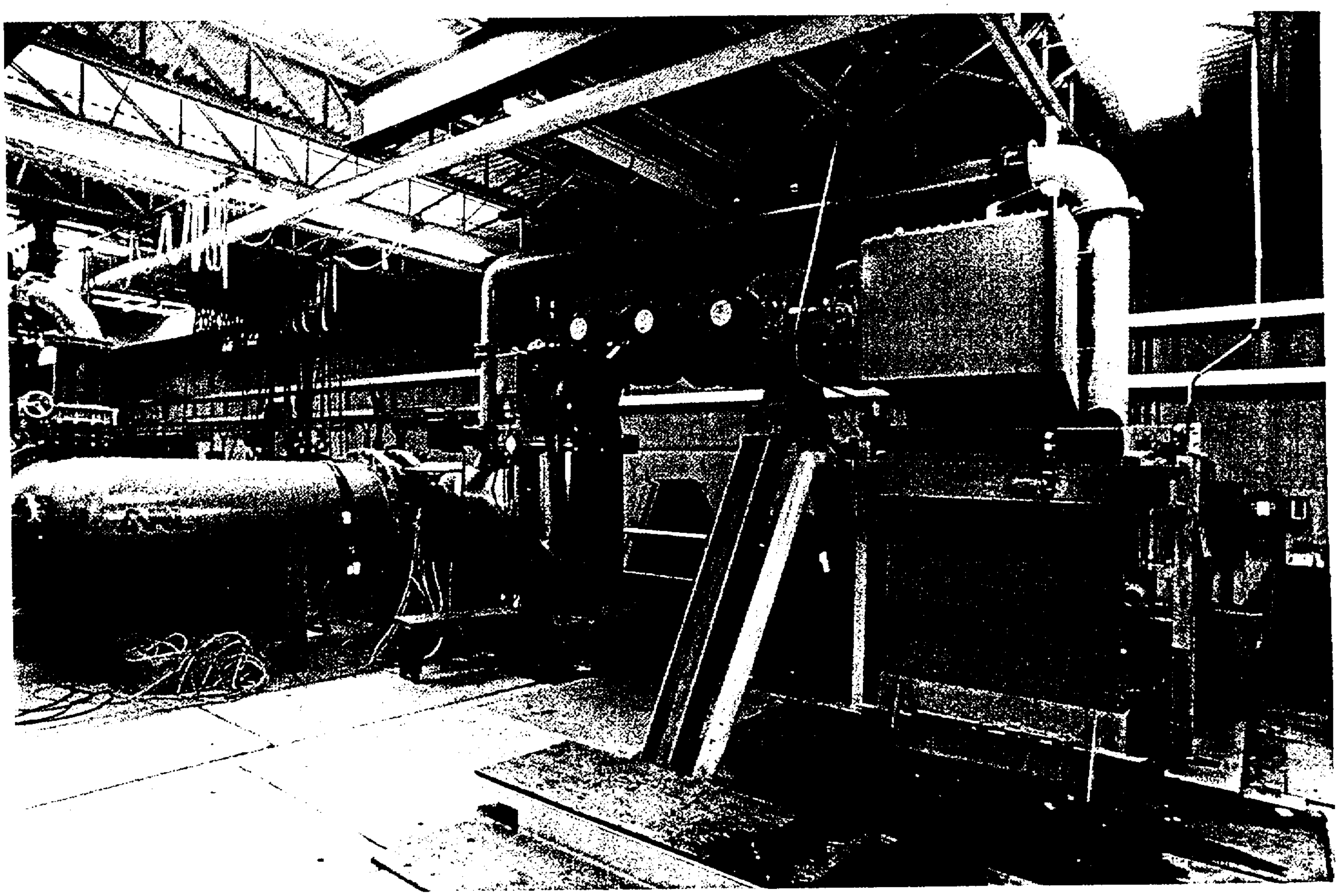
- Measuring Profile Factor and Bounding its Uncertainty

The Watts Bar Test Setup



III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

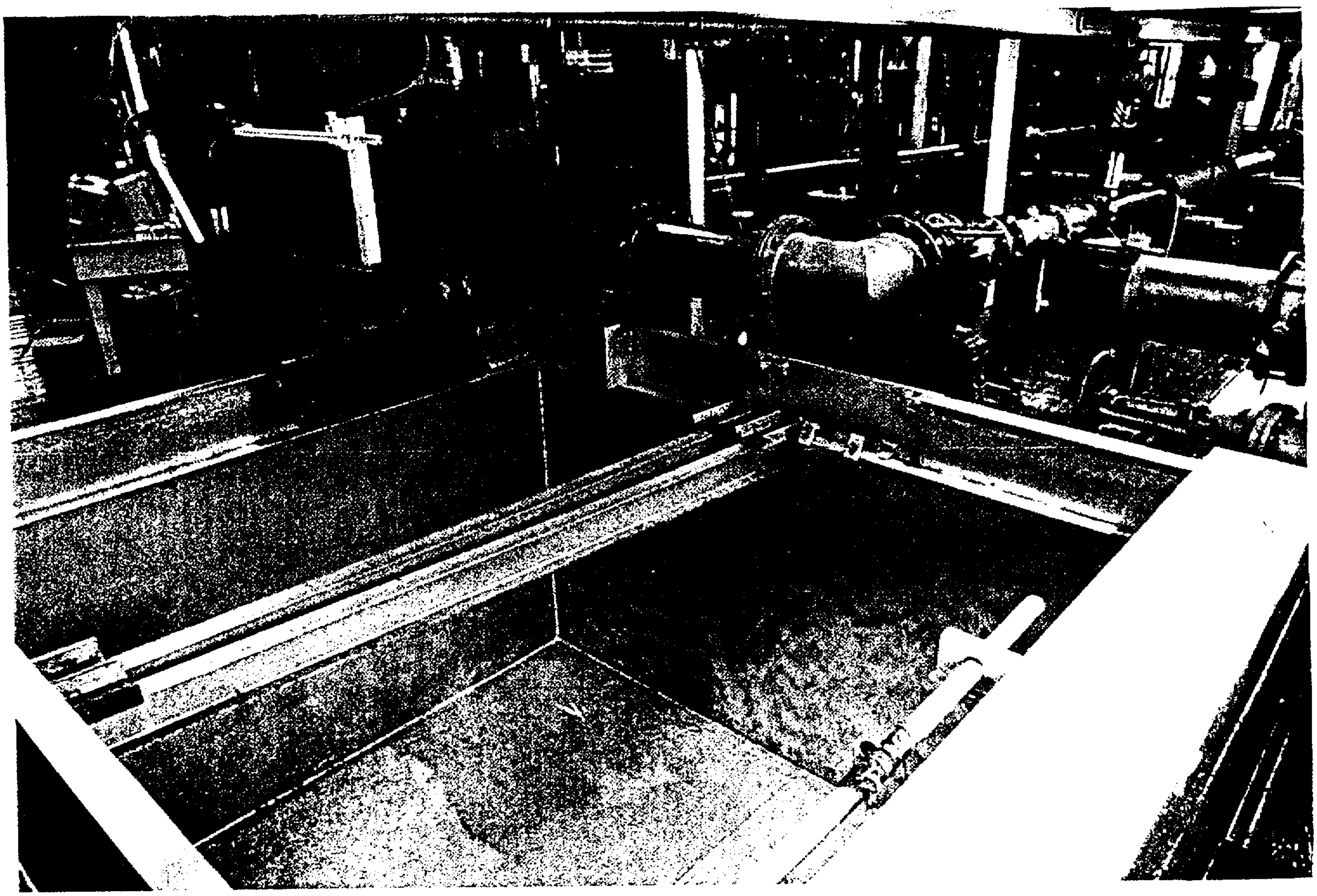
- Measuring Profile Factor and Bounding its Uncertainty

The Watts Bar Test Setup

III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

- Measuring Profile Factor and Bounding its Uncertainty

The Watts Bar Test Setup



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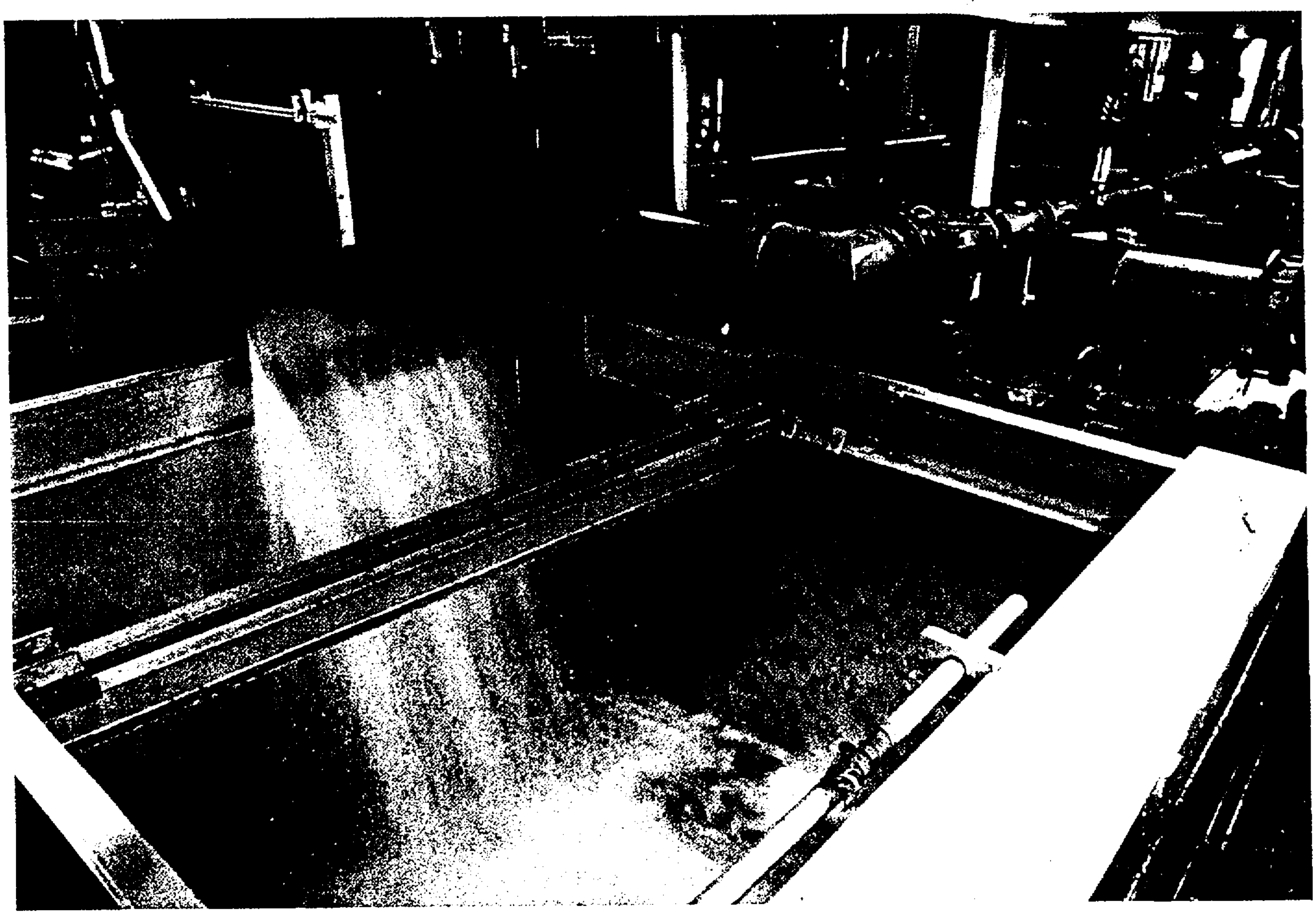
- Measuring Profile Factor and Bounding its Uncertainty

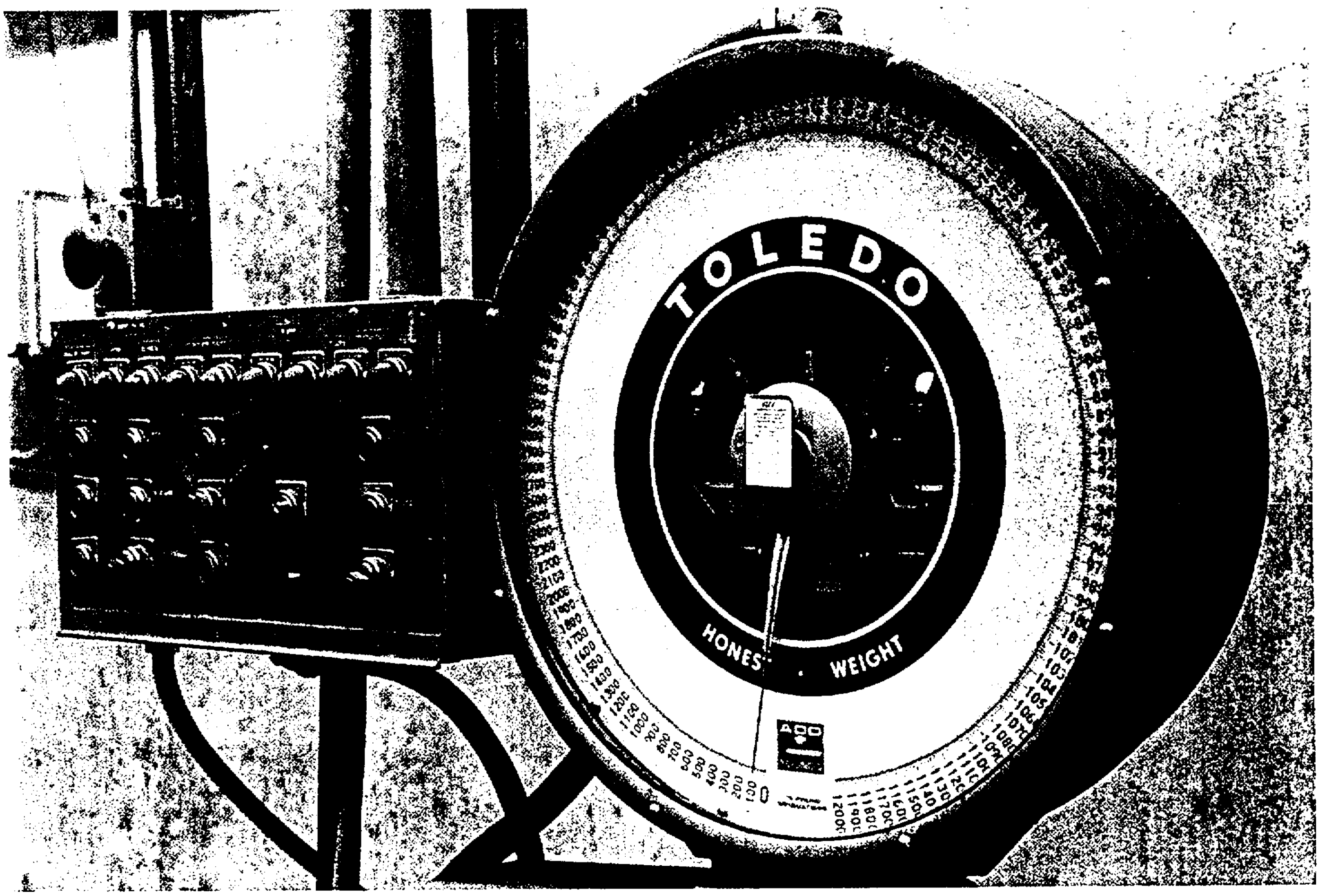
The Watts Bar Test Setup



III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

- Measuring Profile Factor and Bounding its Uncertainty

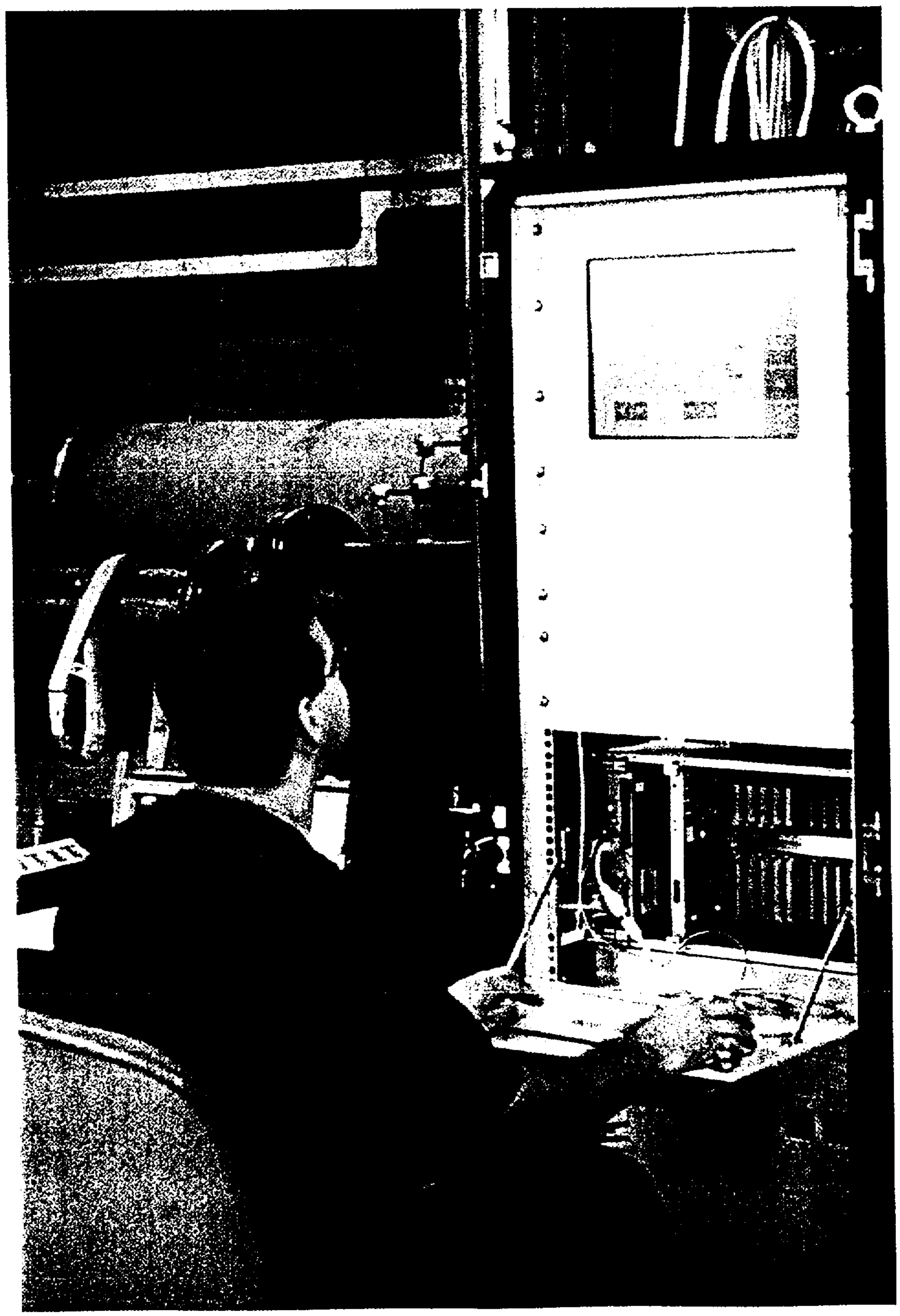
The Watts Bar Test Setup



III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

- Measuring Profile Factor and Bounding its Uncertainty

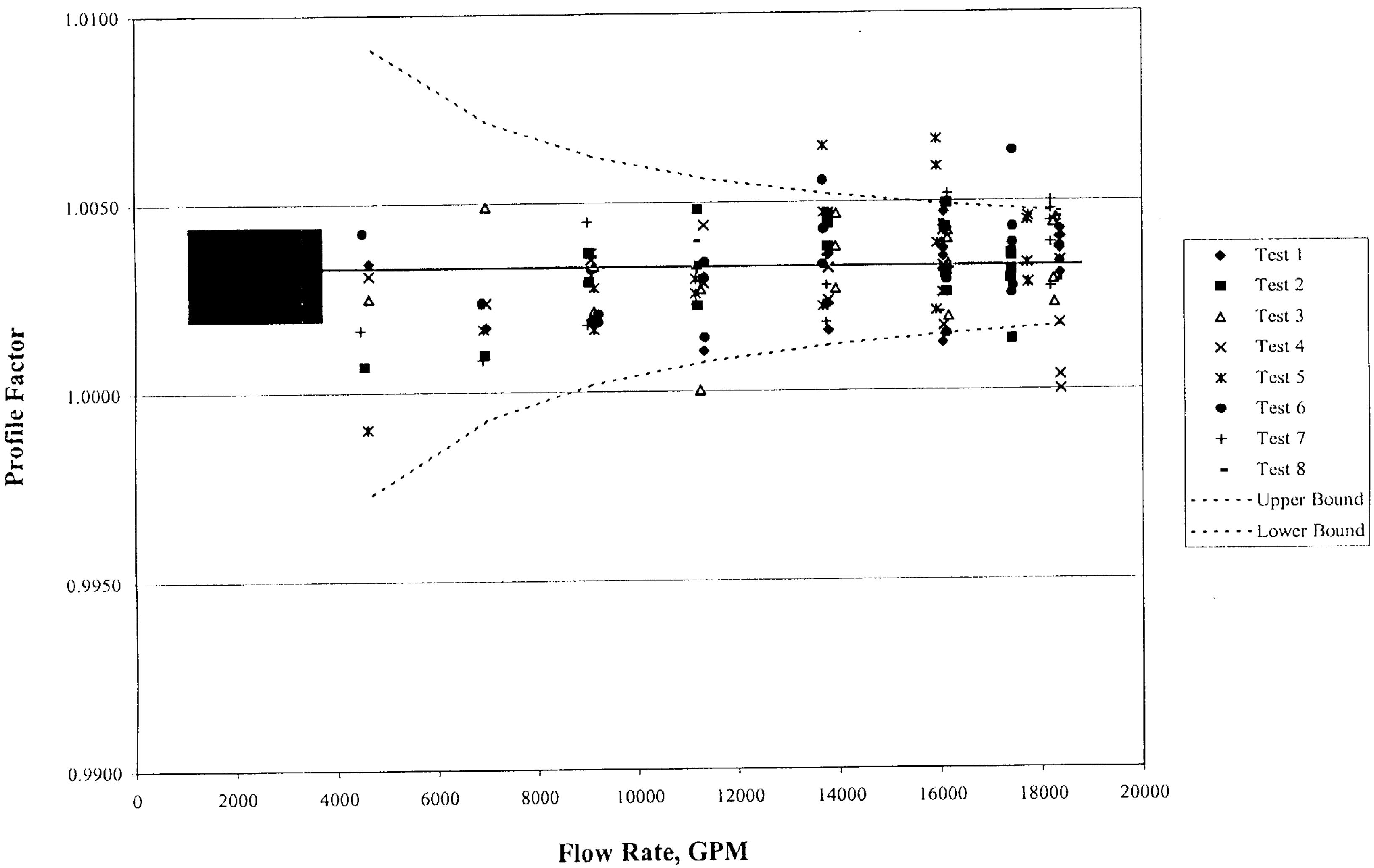
The Watts Bar Test Setup



III. CALIBRATION TESTS OF THE WATTS BAR SPOOL PIECE

- Measuring Profile Factor and Bounding its Uncertainty

h. Calibration Data for the Watts Bar Spool Piece



IV. UNCERTAINTY OF THE PROFILE FACTOR FOR THE WATTS BAR SPOOL PIECE

a. Profile Factor Uncertainty

Facility	± 0.15%	Budgeted and conservative; ARL certifies ± 0.12% for this test
Test LEFM Check Measurement Uncertainty	± 0.11%	See Table following
R_N (Reynolds Number) Extrapolation	± 0.00%	Theory and experiment show profile factor decreases slightly with R_N
Hydraulic Model	± 0.03%	2σ of the mean profile factor for all tested configurations
Observational Uncertainty	± 0.03%	2 σ of the mean for all 144 weigh tank runs
RMS Total	**± 0.19%**	Root Sum Square of Above

Profile Factor Uncertainty Budgeted in ER 80P ± 0.40%

IV. UNCERTAINTY OF THE PROFILE FACTOR FOR THE WATTS BAR SPOOL PIECE

b. Measurement Uncertainties of the Test LEFM

Path Sources	Random/ Pipe	Systematic/ Pipe	Combined % of max flow	Combined % of mean flow
Delta T	0.05%	0.04%	0.06%	0.08%
Tdown	0.05%	0.06%	0.08%	0.08%
Spool Piece Sources				
Profile Factor	0.00%	0.00%	0.00%	0.00%
Thermal Expansion	0.00%	0.01%	0.01%	0.01%
RMS Total – Including Path Weightings			**0.10%**	**0.11%**

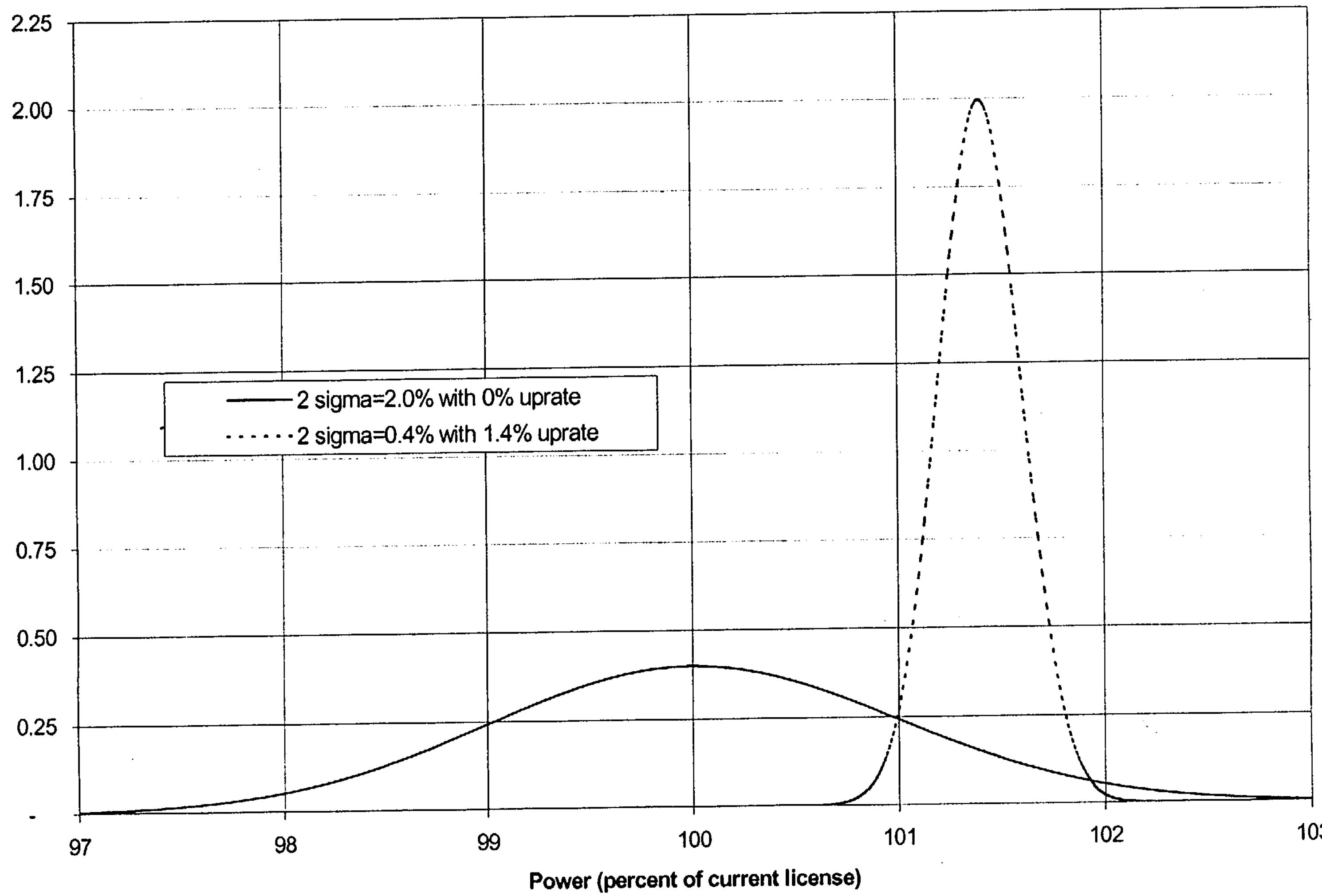
V. IMPACT OF REDUCED PROFILE FACTOR UNCERTAINTY ON MARGIN

a. Estimate of As-Installed Watts Bar LEFM CHECK Uncertainty VS. The Budgeted Uncertainties in the Topical Report (ER-80P)

	Watts Bar as Commissioned LEFM Check (estimated)	Topical Report ER 80P
Hydraulic	0.19%	0.40%
Geometry	0.12%	0.16%
Time	[0.09%]	0.20%
Volumetric Flow Rate	0.24%	0.47%
Density & Enthalpy	[0.18%]	0.23%
Steam Enthalpy	0.11%	0.21%
Moisture Carryover	0.21%	0.21%
Other Gains & Losses	0.10%	0.07%
Total Power	**[0.40%]**	**0.61%**

V. IMPACT OF REDUCED PROFILE FACTOR UNCERTAINTY ON MARGIN

b. PROBABILITY DENSITY FUNCTION



3411 **3459** **3479 MWt**

V. IMPACT OF REDUCED PROFILE FACTOR UNCERTAINTY ON MARGIN

c. Self Testing Features of the LEFM Check Ensure Margin is Maintained

ALL PARAMETERS THAT MIGHT PLAUSIBLY CHANGE ARE MONITORED

- **Profile Factor**

  Changes in the fluid velocities of each acoustic path are checked relative to the mean; Alarmed if variations exceed normal.

- **Dimensions**

  Path lengths are monitored by checking individual path sound velocities against the mean, using commissioning data as reference. Alarmed if variations exceed normal.

  ID is monitored by checking spool piece wall thickness periodically, as part of ISI.

V. IMPACT OF REDUCED PROFILE FACTOR UNCERTAINTY ON MARGIN

c. Self Testing Features of the LEFM Check Ensure Margin is Maintained (continued)

- **Time Measurements**

  Self test feature checks clock against an independent reference.

  Signal quality is monitored by checking signal strength and signal/noise ratio against commissioning data. Alarmed if quality falls below design basis.

  Reciprocity of time delays checked by self test feature.

  Non fluid time delay checked by long path-short path transit time comparisons.

- **Computation**

  Operation of computer checked by monitoring RMS turbulence of measured flows.