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Evaluation of Metal Volumetric Standards Used in the Measurement of Liquid Hydrocarbons: A Report of a U. S. National Bureau of Standards and American Petroleum Institute Research Associate Project.

D. J. Hine
Research Associate

Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

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FOREWORD

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D. J. Hine*

ABSTRACT. Weights and measures jurisdictions and the petroleum industry have, for many years, used metal volumetric standards in the measurement of petroleum liquid hydrocarbons. As a result of several surveys, it was learned that a need existed to establish uniform application procedures and investigate measurement accuracy. To answer this need, a joint project under the Research Associate Program of the U. S. National Bureau of Standards was established with the American Petroleum Institute as the sponsoring agency. Equipment and techniques were evaluated and the program resulted in an equipment specification, a recommended procedure for inspection, and a recommended procedure for the calibration of metal volumetric standards used by weights and measures jurisdictions and the petroleum industry.

Key words: accuracy, design analysis, equipment specification, field standard, gravimetric calibration, liquid retention or clingage tests, precision, prover, Research Associate Program, Standards inspection procedure, test measure, test measure evaluation, temperature correction, "To Contain", "To Deliver", volumetric calibration.

*Research Associate, assigned to NBS Office of Weights and Measures and sponsored by the American Petroleum Institute.

1.0 INTRODUCTION. In 1914 a weights and measures inspector, responsible for testing the accuracy of gasoline dispensers, devised a container with a graduated neck to replace the "slicker-plate" style measure that was normally used. Within a few years that container evolved to be the more acceptable field standard due to the ease of application or use. Available records reflect calibration of a graduated neck measure by NBS as early as 1919. The details of that and subsequent early calibrations were not found. There are no records concerning any evaluation of the device for suitability and/or accuracy other than prototype examinations in 1972 by NBS Office of Weights and Measures. In 1972 two graduated neck measures were examined and judged to be in compliance with NBS Handbook 105-3, Specifications and Tolerances for Metal Volumetric Standards. [1]*

During the mid-1960's the American Petroleum Institute Division of Marketing conducted an engineering survey of practices in the operation and testing of petroleum measurement systems. The objectives were: (1) evaluate factors influencing system accuracy; and (2) investigate the accuracy potential or capability of these systems.

The investigators in the project used the criteria in API Standard 1101, "Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter", to judge the suitability and acceptability of provers utilized in the survey. Only 5 of 24 provers

*Numbers in brackets refer to List of Reference listing inspected were considered to completely comply with the chosen specifications. The results of the survey revealed non-uniformity of prover design employed by the petroleum industry and weights and measures jurisdictions. The inspections disclosed many serious fabrication defects in existing volumetric prover equipment. The report of the survey cited the lack of concise standards for the construction and maintenance of provers. The absence of uniform test procedures was also reported to be a serious deterrent to meter accuracy evaluation.

At the 1953 National Conference on Weights and Measures a report was presented of a study conducted by the National Bureau of Standards entitled "Performance of Inspectors and Gasoline Pumps". This study also demonstrated the need for a research program to study prover designs and performance.

The API Division of Marketing and NBS agreed to a cooperative research project and on April 15, 1970 a Research Associate was assigned to work with the Office of Weights and Measures (OWM) at NBS under the sponsorship of API.

The API sponsored Research Associate Program is one of 23 projects and 66 Research Associates that are being sponsored at NBS by private industry and trade and professional organizations. Under the Research Associate Program, a representative from the sponsoring organization works at NBS on specific problems that are of mutual interest to his sponsoring organization, to the industry, and to the Bureau. The Research Associate Programs, initiated by NBS in 1965, provide a valuable information exchange mechanism and promote technology development.

2.0 PRELIMINARY RESEARCH ASSOCIATE STUDIES. With the arrival of the Research Associate, an outline was prepared to establish the guidelines under which the project would proceed. The outline was approved by both API and NBS. The approved outline was as follows:

I. Program Objectives

  A. Develop primary test measure design

    1. Design criteria

    2. Industry comments, opinions, and suggestions

    3. Analytical design analysis

    4. Calibration procedures evaluation

      a. Methods

      b. Human factors

      c. Physical data

    5. Accuracy limits

      a. Existing

      b. Required or desired

      c. Attainable

    6. Test measure size evaluation

      a. Scale or model evaluation

        (1) 1 gallon

        (2) 5 gallon

        (3) 10 gallon

        (4) Larger sizes

  B. Design specifications

C. Application procedure

II. Testing Program

A. Structural testing

1. Material thickness

2. Reinforcing bands

3. Weld finishing requirements

B. Internal finish investigation

1. Material finishes

a. Metal

b. Non-metal

2. Clingage tests

a. Surface finish

b. Coated surface

C. Conical section evaluation

1. Angle optimization

a. Critical

b. Non-critical

III. Program Terminal Report NBS-API

A. Distribution

1. A.P.I.

2. Government

a. Federal

b. States

B. Complete test measure specification

1. Material

2. Geometric

3. Fabrication

4. Auxiliary permanent hardware

5. Finish

    a. Internal

    b. External

6. Inspection recommendations

C. Application procedure

1. Laboratory

To launch into a program of this type it was necessary to first determine what information was available that might be applicable to the project. Various reports and standards were studied with the result being that a complete specification was non-existent and procedural write-ups were too general to establish uniform practices.

In an attempt to obtain needed material and information, a meeting was held September 14, 1970 at NBS. Following are the minutes of that meeting.

MEETING HELD SEPTEMBER 14, 1970, AT 11:00 A.M.
IN DINING ROOM C

NATIONAL BUREAU OF STANDARDS
GAITHERSBURG, MARYLAND

Attending the meeting were:

R. F. Aubrey - Marathon Pipe Line Co.

Ken Challenger - F. H. Maloney Co.

P. R. DeBruyn - NBS

Stephen Hasko - NBS-OWM

D. J. Hine - (Phillips Petroleum Co.) API Research Associate

B. C. Keysar - NBS-OWM

R. P. Layton - Gulf Refining Co.

H. L. Lewis - Sinclair Pipe Line Co.

R. M. Mills - NBS-OWM

R. C. Primley - Cities Service Co.

Howard Siebold - Liquid Controls Corp.

Dick Southers - API

T. M. Stabler- NBS-OWM

R. H. Tolson - Texaco, Inc.

H. F. Wollin - NBS-OWM

W. C. Waterman - Shell Oil Co.

W. H. Yancey - American Oil Co.

This meeting was conducted by D. J. Hine in an attempt to obtain answers to certain questions concerning the API-sponsored Research Associate Program on Primary Standard Volumetric Test Measures.

The meeting opened with a brief resume of the investigations performed thus far in the program by Hine. The program has begun with Clingage

Investigations and Calibration Witnessing. Although the clingage test data is limited in quantity, it has become evident that procedure will be of paramount importance in the overall evaluation. The calibration witnessing is to be a continuing program in order to fully evaluate human factor dependence and must be based on as large a sample as possible.

T. M. Stabler then gave a summary of the historic background leading up to the current Research Associate Program. He included areas of operation of the Office of Weights and Measures with emphasis on the current responsibility to furnish state offices with "New State Standards".

At this point in the meeting, Mr. Hine began a presentation of questions that had been developed from an "API Standard Test Measure Research Program" outline previously furnished to all persons present.

Question: What fluids should be considered in establishing test measure load design criteria? Beyond water. What gravity range?

The answers ranged from LPG to asphalt; however, the majority consensus was that water must be the fill fluid of primary concern in design calculations. The need for data at least to No. 2 Fuel Oil (approx. API Gravity of 34°) is badly needed.

Question: Do you have a written, strictly adhered to detailed calibration procedure on primary standard use? Is it available so that it could be submitted for evaluation?

Most answers to this question were "API 1101". There are very few documents that will directly answer this question, due to the limitation of detailed rather than generalized procedure. Whatever may be available within the companies represented in this meeting will be searched out and submitted.

Question: What references are currently used by the companies or organizations represented here to determine temperature-pressure corrections? Specifically, thermal expansion coefficient for water and test standard material and water compressibility.

The majority reflects almost total dependence upon the table presented in API 1101. It was pointed out that ISO is attempting to present a correction table that may be applicable. (This will be acceptance of ASTM-IP Petroleum Measurement Tables.) There remains a dire need for data standardization for all factors used which might in any way effect the standard test measures.

Question: What accuracy limits are reasonable for standard test measures? Is it necessary to go beyond the existing 0.02%?

Those present verified that improved accuracy was the omnipresent goal in measurement. The suggested accuracy to be investigated was 0.01%. However, the procedure recommended was to perform a statistical analysis starting with the requirements of Handbook 44 for meters and working backward to the test measure in order to judge the compatibility of the two accuracies. If the analysis indicates that improved accuracy was necessary for test measures, NBS divisions performing the calibrations will be contacted in an attempt to make an estimate of the increased cost of calibration. It is feasible that only by changing calibration procedures can the 0.01% accuracy be achieved.

Question: Is there a preference between gravimetric or volumetric calibrations? Currently, calibration of test measures includes both, but is it really necessary to absorb the cost?

This question prompted questions regarding the capability of the facilities at the Bureau of Standards. A direct answer to the stated problem hinges on whether there is any purpose to dual calibrations and how they are compared. Load cell linearity as well as ambient conditions measurement are of significant relevance in gravimetric calibration procedures. If dual calibrations improve the accuracy they are likely warranted.

Question: Keeping in mind that the Research Associate Program is for a stipulated time, when the 1, 5, and 10 gallon primary test measures have been evaluated, what size is of primary interest to industry?

Agreement was reached that certainly the 50 gallon and probably the 100 gallon size test measures must be included if at all possible, since these sizes constitute a great majority of test measures in field use.

Question: In view of the findings from the limited amount of testing thus far, either an extended drain-down time or a restrictive procedure may be the resultant solution to repeatability (precision) of a given test measure. Do you have a preference?

It seems that a well-defined procedure would be preferable, if not overly restrictive in application. An extended drain-down time might be difficult to sell to all the various agencies involved.

Question: In view of recent interest by several manufacturers, an opinion is needed regarding the requirements for a "field" test measure that would not be calibration quality. It would be another generation removed from standard.

Wollin indicated that some states are contemplating dropping routine checking, and in so doing will transfer the liability for accuracy to the service station operator or owner and perform only investigative sampling. This would certainly encourage the operator or owner to purchase a test measure which would make the availability of a low-cost measure desirable.

It was generally agreed that the availability might be warranted but the market was not a receptive one. The market will exist only if and when the inspecting jurisdictions make it necessary.

SERAPHIN TEST MEASURE CLINGAGE HARDWARE PROPOSAL

(See Drawing)

Question: Are top and bottom angles sufficiently representative?

It was agreed that possibly an angle less than 15° should be included. The top and bottom designs could be made identical by eliminating the 4" top neck and installing a coupling instead. This minor change would allow the angles to serve as either top or bottom depending on how installed.

Question: Does testing with this type of device have any merit?

Since it would facilitate possibly optimizing prover and test measure design, it has definite potential significance.

Question: What liquids should be used for the tests?

It would be desirable to include Kerosene and/or No. 2 Fuel Oil.

Question: Where, if testing with other than water?

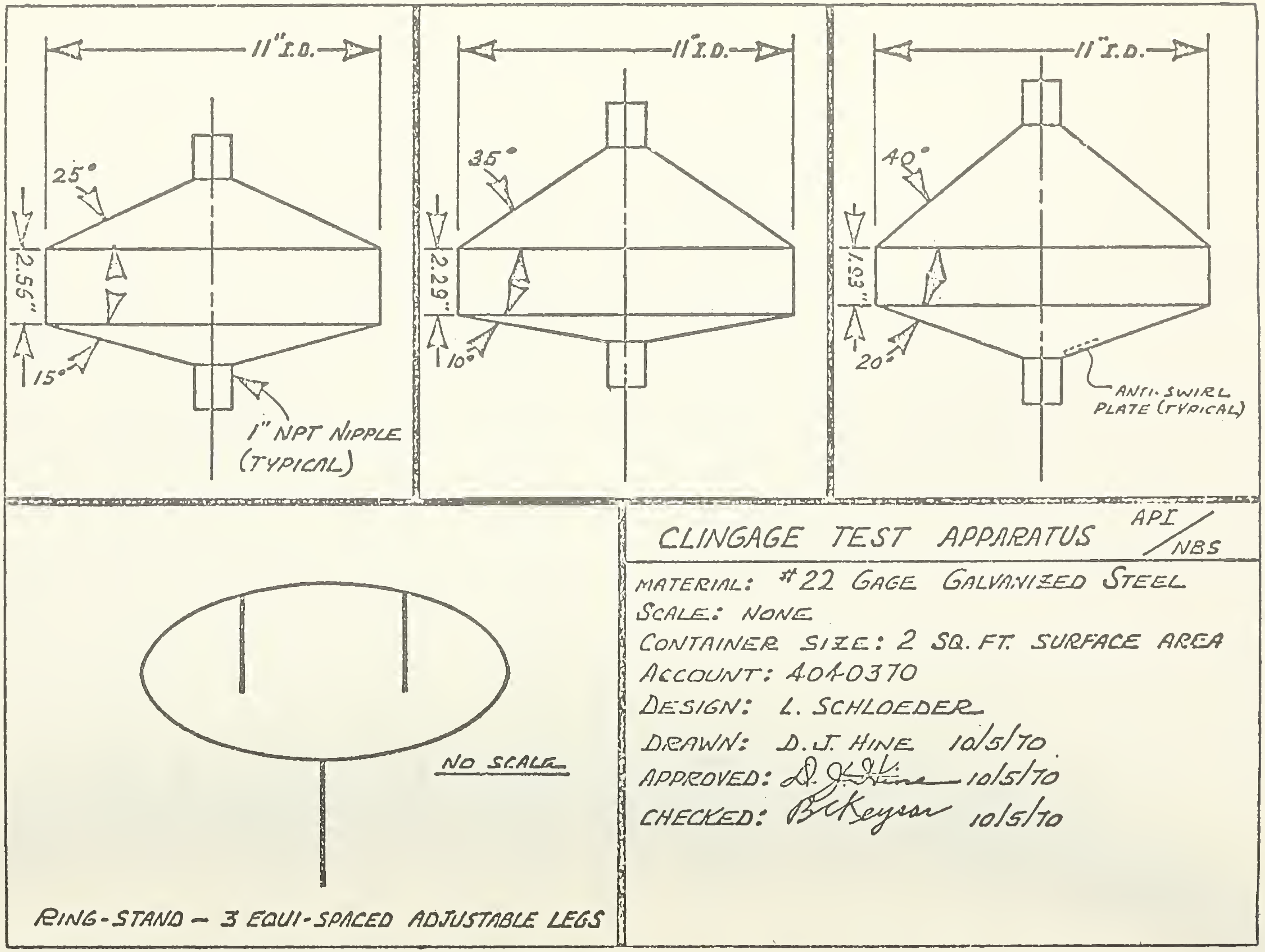
Mr. DeBruyn pointed out that the Hazards Laboratory here at the Bureau might be made available. This possibility will be investigated.

Additional items brought up during the meeting were as follows:

1. Need for a Measurement Terminology Standard.

2. Interpolation procedure is needed for extending a "Water Calibrated" test measure to other fluids. No. 2 Fuel Oil is of particular interest.

3. The need for standardization of recalibration intervals



11" I.D.
25°
15°
2.56"
1" NPT NIPPLE (TYPICAL)
11" I.D.
35°
10°
2.29"
11" I.D.
40°
20°
1.93"
ANTI-SWIRL PLATE (TYPICAL)
NO SCALE
RING-STAND — 3 EQUI-SPACED ADJUSTABLE LEGS
CLINGAGE TEST APPARATUS
API/NBS
MATERIAL: #22 GAGE GALVANIZED STEEL
SCALE: NONE
CONTAINER SIZE: 2 SQ. FT. SURFACE AREA
ACCOUNT: 4040370
DESIGN: L. SCHLOEDER
DRAWN: D.J. HINE 10/5/70
APPROVED: 10/5/70
CHECKED: 10/5/70

for test measures and prover tanks.

4. Larger capacity (non-inverted) measures are calibrated with nipple-elbow-pipe combination attached to the drain valve, whereas in application, field calibrations are rarely performed with a similar flow restriction. The effect of the restrictions on clingage should be investigated.

5. Incremental scale maximum allowance may be too lax at 5 cubic inches. In the interest of improved accuracy, the maximum allowable division might be reduced to 2 cubic inches.

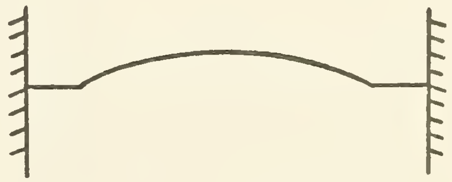
The answers to at least some of these questions could feasibly be a residual benefit of the Research Associate Program as it is now outlined. Attention will be given to these and additional questions as the program progresses.

Meeting adjourned - 3:00 P.M.

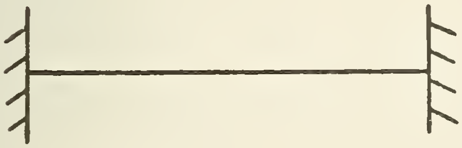
The answers and discussions of questions did not yield direct solutions to the defined problem areas presented but did provide information concerning the areas of interest where additional research is required. The meeting provided additional indication that standard test procedures and equipment specifications are virtually non-existent and the concensus of those in attendance was that they are badly needed.

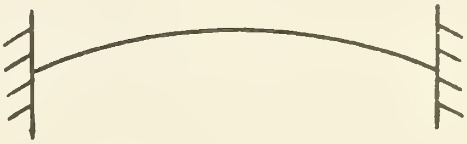
3.0 DESIGN ANALYSIS. An analysis was performed to theoretically predict the performance of two specific areas of a test measure. The areas of interest were the lateral or cylindrical sides and the bottom of a measure. The dimensions required for the calculations were assumed to equal the minimum values appearing in NBS Handbook 105-3, Specifications and Tolerances for Metal Volumetric Field Standards. [1]

3.1 TEST MEASURE BOTTOM ANALYSIS. A literature search was conducted in an attempt to find an appropriate mathematical model that could be used to calculate the maximum predicted deflection and the surface stress on the formed measure bottom. The model being sought was for a shape with an appearance as:



It was discovered that such a model was not included in the available literature. The nearest models found were for a flat-plate and a dished plate which appeared as follows:





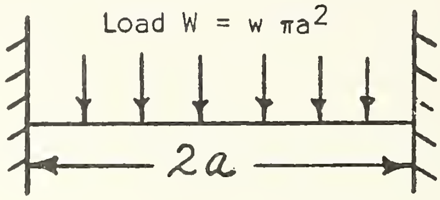
An exact model could not be found. The worst case between the two models would be the flat plate which would present the worst potential case for maximum deflection of the bottom plate of the test measure. The model, equations used, and results are as follows:

PROBLEM: Determine the deflection of a circular flat plate with a uniform load over the entire area.

GIVEN: Load to consist of 5 gallons of water.

ASSUMPTIONS: Plate thickness 0.050 inches (18 gage)
Water Density - 8.34 pounds per gallon (60°F in Vacuum)
Modulus of Elasticity - 30 X 10^6 psi

SOLUTION:



Maximum Deflection: $$y = \frac{3W(m^2 - 1)a^2}{16 \pi E m^2 t^3}$$

where m = 1/Poisson's ratio = 1/0.3 = 3.333

a = radius of circular flat plate = 5.5 inches

E = 30 X 10^6 psi

t = thickness = 0.05 inches

y = 0.018 inches

Surface Stress: $$S = \frac{-3W(m + 1)}{8 \pi m t^2}$$

$= - 2585$ psi

CONCLUSIONS: The calculated maximum deflection of the plate can be assumed negligible. The deflection would increase the volume by approximately 0.6 cubic inches and this volume increase would be essentially constant with water application. If the liquid providing the loading was only 0.65 Specific Gravity, the deflection would be 0.012 inches and the volume increase would be 0.4 cubic inches. The net change for the example comparing a water-calibrated device when used to measure a 0.65 gravity liquid is 0.2 cubic inches. For a gasoline application, (assuming 0.7 specific gravity) the volume change would be approximately 0.2 cubic inches. With a 7.0 cubic inch tolerance the volume change of 0.2 cubic inches would represent approximately 3 percent of the total tolerance.

3.2 CYLINDRICAL SHELL ANALYSIS. For the shell analysis, a cylindrical tank with uniform wall thickness was assumed. Strength contribution from any reinforcing bands was not considered except the bottom was assumed to be constrained.

The radial expansion near the bottom was calculated by

$$w = \frac{-\gamma(d-x)a^2}{Et}$$

where w = radial expansion

γ = water density (lbs/in^3)

d = water height (assumed 12 inch)

x = height of radial hoop (taken as zero)

a = radius = 5.5 inches

E = modulus of elasticity

t = shell thickness

The theoretical deflection was calculated to be 0.000014 inches. The shearing force was also calculated and was found to be less than 1 psi. The shearing force was determined by the relation:

$$Q_a = \frac{adt}{12(1-\upsilon^2)} \, 2\beta \, \frac{1}{d}$$

where Q_a = shearing force

υ = Poisson's Ratio (assumed 0.3)

β = constant calculated from the equation $\beta^4 = \frac{3(1-\upsilon^2)}{a^2h^2}$

This examination was performed to determine if the elastic limit of the material was approached or exceeded. Theoretically, it will not be approached with normal use.

4.0 <u>CALIBRATION PROCEDURES EVALUATION</u>. The purpose of including this segment in the research project was to compare existing calibration procedures and investigate the possibility of developing an optimum procedure. From many inquiries, it was discovered that formal written procedures were virtually non-existent in either industry or calibrating agencies. The lack of any procedures prompted a series of calibration witnessings in order to evaluate the procedures being used. As a result of witnessing calibrations performed at the Bureau of Standards, a procedure was written to reflect the actual method used. The observed procedure is as follows:

NBS GRAVIMETRIC/VOLUMETRIC CALIBRATION PROCEDURES

(1, 5, and 10 Gallon Measures)

The test measures are thoroughly cleaned by the following process:

1. Rinse with degreasing solvent to remove any soldering flux or other foreign residue.
2. Rinse with alcohol.
3. Wash with hot water and a bio-degradable glassware detergent. Rinse with clear water until detergent is removed.

4. Rinse with alcohol.

5. Air dry.

During the cleaning, the test measures are examined for leaks or any visible defects.

The test measures are then weighed on an Equal Arm Balance. This is a five-step procedure as follows:

	Left Side Load	Right Side Load	Records Made
1.	Weights of unknown quality & quantity	Test Measure w/cover	None
2.	Weights of unknown quality & quantity	Standard Weights	Total load, turning points, relative humidity & temperature, barometric pressure & balance enclosure temperature.
3.	Weights of unknown quality & quantity	Test Measure w/cover	Turning points
4.	Weights of unknown quality & quantity	Test Measure w/cover plus sensitivity weight	Turning points, relative humidity & temperature, barometric pressure & balance enclosure temperature.
5.	Weights of unknown quality & quantity	Standard Weights plus sensitivity weight	Turning points

Following the dry weighing, the test measure is filled to about zero on the neck scale (plus or minus 5 in^3 acceptable) with distilled water. The water temperature is determined with matched electronic quartz thermometer probes. The scale reading is then taken and recorded. This reading is performed with a meniscus reading device that has a pair of crosshairs which aid in maintaining the eye level with meniscus if properly used. This also magnifies the scale, thereby enhancing estimation of the nearest one-tenth scale division.

The full test measure is then covered with the cover used in the dry weight determination and weighed following the same 5-step procedure described above.

The water is carefully transferred by approximately maximum flow through a glass funnel (2" drain opening, 12" top diameter, and 9" height-volume ≅ 1.75 gal) into a "to contain" "Check Standard". The neck scale reading is determined using the meniscus reading device and the water temperature is determined with the thermometer probes. The values are recorded on the data sheet. The test measure, covered with the cover or cap, is again weighed using the 5-step procedure previously described.

The volume determined by the calibration is calculated by means of a computer program. The actual water density determination, air buoyancy, and temperature correction information (program listing) were not evaluated. If not specified by the customer, the assumed Thermal Coefficient of Expansion for a standard "Terneplate" test measure was reportedly 0.000018 per degree Fahrenheit, however, this number was later changed to 0.0000186 to reflect current technology.

Gravimetric calibrations can be calculated with the use of proper equations and a desk top calculator. Exhibit 1 is a Sample Gravimetric Calibration Data Sheet which reflects the data required

Observer LGC 11/16/72 Test No. 3079814

Sensitivity wt. 0.5 gram Started 1320 Finished 1520

a1

2 Kg. 2 Kg 500g. 200g. 100g. 50g. 20g. 10g. 5g. 2g.		~~13.8~~
	8.8	13.8
	8.8	
5 Gallon S.S. Graduated Neck 188572		~~14.2~~
	10.1	14.1
	10.2	
ditto	~~7.9~~ 8.0	13.9
	8.0	13.8
+Δ 0.5 g.		
Stds		~~11.3~~
	8.4	11.3
+Δ 0.5 g.	8.5	

	Begin	End	Corr Mean
Air Temp	22.4	22.5	22.45
Barometer	749.16	749.01	749.43
R H Scale Reading	47.9	47.1	17.6

Std in grams 4887 Volumes (cm3) 531.8

$O_1 = 11.3$; $O_2 = 12.125$, $O_3 = 10.925$, $O_4 = 9.925$

a2

20 Kg 2 Kg 1 Kg 500 g 200 g 50 g 20 g 20 g 5 g	~~8.1~~	12.3
	8.2	12.2
5 Gallon S.S. with water		~~13.6~~
	8.9	13.5
	8.9	
ditto		~~13.1~~
	7.0	13.1
+Δ 0.5 g	7.0	
Stds		~~11.1~~
	6.7	11.1
+Δ 0.5 g.	6.7	

Scale Reading + 1.2

	Begin	End	Corr Mean
Air Temp	22.5	22.6	22.55
Barometer	748.79	748.99	749.24
R H Scale Reading	45.8	46.7	17.2

Corrected average H_2O Temp. = 20.299

H_2O Temp T_1 20.336 T_2 20.314 20.343

$O_1 = 10.225$, $O_2 = 11.2$, $O_3 = 10.05$, $O_4 = 8.9$

Mix Time 5 min

Stds in grams 23795 Volume (cm3) 2832.7

a3

2 Kg 2 Kg 500 g 300 g 100 g 50 g 20 g 20 g 5 g. 2 g.		~~11.6~~
	8.0	11.5
	8.1	
5 Gallon S.S. Graduated Neck (Wet)		~~14.0~~
	9.3	14.0
	9.4	
ditto		~~12.7~~
	8.3	12.7
+Δ 0.5 g.	8.3	
Stds		~~10.6~~
	6.4	10.6
+Δ 0.5 g.	6.5	

	Begin	End	Corr Mean
Air Temp	22.6	22.6	22.6
Barometer	749.35	748.97	749.57
R H Scale Reading	46.2	45.7	17.0

Drain Time 10 Seconds

Stds in grams 4897 Volume (cm3) 583.0

Check Std 5 Gallon Scale Reading +0.4

T_1 20.416

T_2 20.388 T_1 20.419

$O_1 = 9.775$, $O_2 = 11.675$, $O_3 = 10.5$, $O_4 = 8.525$

Exhibit I. Sample Gravimetric Calibration Data Sheet for the calculation when using an equal-arm balance.

The calculations are performed as follows: (The equations are from publications listed as [2], [3], and [4] in the List of References).

The Sample Data Sheet shows values of O_1, O_2, O_3, and O_4 for each weighing series. These values represent the sum of the average turning points divided by 2. from Reference [4]

$$X\text{-}S = \frac{O_1-O_2 + O_4-O_3}{2} \; \frac{S.W}{O_3-O_2^{*}} = A$$

Solving the 3 weighings shown on the data sheet:

$$A_1 = \frac{11.3-12.125 + 9.925-10.925}{2} \; \frac{0.5}{10.925-12.125}$$

$$A_1 = -0.3802$$

$$A_2 = \frac{10.225-11.2 + 8.9-10.05}{2} \; \frac{0.5}{10.05-11.2}$$

$$A_2 = -0.461957$$

$$A_3 = \frac{9.775-11.675 + 8.525-10.5}{2} \; \frac{0.5}{10.5-11.675}$$

$$A_3 = -0.824466$$

From Reference [3] and [4] the mathematical representation for air density (ρa) and water density (ρw) respectively, are:

$$\rho a \, \frac{mg}{cm^3} = \frac{0.464554 \; \beta - H(0.00252 t_a - 0.020582)}{t_a + 273.16}$$

where β = barometric pressure in mm of mercury,

H = relative humidity, and

t_a = air temperature

*Absolute value

$$\rho w \frac{grams}{cm^3} = 0.001 \cdot \sum_{n=o}^{5} C_n t^n$$

where C_n values are:

n	C_n
0	$999.8395639 \frac{g}{cm^3}$
1	$0.06798299989 \frac{g}{cm^3 °C}$
2	$-0.009106025564 \frac{g}{cm^3 °C^2}$
3	$1.00527299 \cdot 10^{-4} \frac{g}{cm^3 °C^3}$
4	$-1.126713526 \cdot 10^{-5} \frac{g}{cm^3 °C^4}$
5	$6.591795606 \times 10^{-6} \frac{g}{cm^3 °C^5}$

and where

t_w = water temperature in °C

For convenience the equation values for t = 0°C to 39.9°C are presented in Table I.

Solving for the air density of the three data sets gives:

$\rho a1 = 0.000011756$ mg/cm^3 = 0.0011756 grams/cm^3

$\rho a2 = 0.0000117495$ mg/cm^3 = 0.00117495 grams/cm^3

$\rho a3 = 0.0000117516$ mg/cm^3 = 0.00117516 grams/cm^3

and the water density from Table I is:

ρw = 0.9981602 grams/cm^3

It is now possible, using A_1, A_2, A_3, $\rho a1$, $\rho a2$, $\rho a3$, and ρw, to calculate the volumes reflected by the calibration. From Reference [2] the volume contained at test temperature and scale reading is:

T	0.0 C	0.1 C	0.2 C	0.3 C	0.4 C	0.5 C	0.6 C	0.7 C	0.8 C	0.9 C
.0	.999840	.999846	.999853	.999859	.999865	.999871	.999877	.999883	.999888	.999893
1.0	.999899	.999903	.999908	.999913	.999917	.999921	.999925	.999929	.999933	.999937
2.0	.999940	.999943	.999946	.999949	.999952	.999954	.999956	.999959	.999961	.999963
3.0	.999964	.999966	.999967	.999968	.999969	.999970	.999971	.999971	.999972	.999972
4.0	.999972	.999972	.999972	.999971	.999971	.999970	.999969	.999968	.999967	.999965
5.0	.999964	.999962	.999960	.999958	.999956	.999954	.999951	.999949	.999946	.999943
6.0	.999940	.999937	.999933	.999930	.999926	.999922	.999918	.999914	.999910	.999906
7.0	.999901	.999896	.999892	.999887	.999881	.999876	.999871	.999865	.999860	.999854
8.0	.999848	.999842	.999835	.999829	.999822	.999816	.999809	.999802	.999795	.999787
9.0	.999780	.999773	.999765	.999757	.999749	.999741	.999733	.999725	.999716	.999707
10.0	.999699	.999690	.999681	.999672	.999662	.999653	.999643	.999634	.999624	.999614
11.0	.999604	.999594	.999583	.999573	.999562	.999552	.999541	.999530	.999519	.999507
12.0	.999496	.999485	.999473	.999461	.999449	.999437	.999425	.999413	.999401	.999388
13.0	.999376	.999363	.999350	.999337	.999324	.999311	.999297	.999284	.999270	.999256
14.0	.999243	.999229	.999215	.999200	.999186	.999172	.999157	.999142	.999128	.999113
15.0	.999098	.999083	.999067	.999052	.999036	.999021	.999005	.998989	.998973	.998957
16.0	.998941	.998925	.998908	.998892	.998875	.998858	.998841	.998824	.998807	.998790
17.0	.998773	.998755	.998738	.998720	.998702	.998684	.998666	.998648	.998630	.998612
18.0	.998593	.998575	.998556	.998537	.998519	.998500	.998480	.998461	.998442	.998422
19.0	.998403	.998383	.998364	.998344	.998324	.998304	.998284	.998263	.998243	.998222
20.0	.998202	.998181	.998160	.998139	.998118	.998097	.998076	.998055	.998033	.998012
21.0	.997990	.997968	.997947	.997925	.997903	.997881	.997858	.997836	.997814	.997791
22.0	.997768	.997746	.997723	.997700	.997677	.997654	.997630	.997607	.997584	.997560
23.0	.997536	.997513	.997489	.997465	.997441	.997417	.997392	.997368	.997344	.997319
24.0	.997294	.997270	.997245	.997220	.997195	.997170	.997145	.997119	.997094	.997068
25.0	.997043	.997017	.996991	.996966	.996940	.996913	.996887	.996861	.996835	.996808
26.0	.996782	.996755	.996728	.996702	.996675	.996648	.996621	.996593	.996566	.996539
27.0	.996511	.996484	.996456	.996428	.996401	.996373	.996345	.996316	.996288	.996260
28.0	.996232	.996203	.996175	.996146	.996117	.996088	.996060	.996031	.996001	.995972
29.0	.995943	.995914	.995884	.995855	.995825	.995795	.995765	.995736	.995706	.995676
30.0	.995645	.995615	.995585	.995554	.995524	.995493	.995463	.995432	.995401	.995370
31.0	.995339	.995308	.995277	.995246	.995214	.995183	.995151	.995120	.995088	.995056
32.0	.995024	.994992	.994960	.994928	.994896	.994864	.994831	.994799	.994766	.994734
33.0	.994701	.994668	.994635	.994602	.994569	.994536	.994503	.994470	.994436	.994403
34.0	.994369	.994336	.994302	.994268	.994234	.994201	.994167	.994132	.994098	.994064
35.0	.994030	.993995	.993961	.993926	.993891	.993857	.993822	.993787	.993752	.993717
36.0	.993682	.993647	.993611	.993576	.993541	.993505	.993469	.993434	.993398	.993362
37.0	.993326	.993290	.993254	.993218	.993182	.993146	.993109	.993073	.993036	.993000
38.0	.992963	.992926	.992889	.992852	.992815	.992778	.992741	.992704	.992667	.992629
39.0	.992592	.992554	.992517	.992479	.992442	.992404	.992366	.992328	.992290	.992252

Table 1

Density of Air Free Water in g/cm as a Function of the Celsius Temperature Scale
Based on the Work by H. Wagenbreth and W. Blanke,
PTB-Mitteilungen 6-71.

$$V_w = \frac{A_2 - A_1 + M_{s2} - M_{s1} + \rho_{a1} \quad V_{s1} - \rho_{a2} V_{s2}}{\rho w - \rho a2} \text{ cm}^3$$

where M_{s2} = Standards Mass Data Set 2

M_{s1} = Standards Mass Data Set 1

V_{s1} = Standards Volume Data Set 1

V_{s2} = Standards Volume Data Set 2

$$V_w = \frac{-.461957-(-.3802)+23795-4887+.0011756(531.8)-.00117495(2832.7)}{0.9981602-0.00117495}$$

$$V_w = 18960.481 \text{ cm}^3$$

The volume V_w must be corrected to reflect the volume at zero scale reading.

$$V_w = 18960.481 \text{ cm}^3 \times 0.00026417 \frac{\text{gal}}{\text{cm}^3} \frac{-1.2 \text{ in}^3}{231 \text{ in}^3 \text{ gallon}}$$

$$V_w = 5.00879 \text{ gal} - 0.00519$$

$$V_w = 5.00360 \text{ gallons at } 20.299°\text{C}$$

The volume at 60°F (conventional reference temp) may be determined as follows:

$$V_{w60°F} = V_w \left[1 - \beta(t_w - 60)\right]$$

where β = cubic coefficient of thermal expansion

$\beta = 28.8 \times 10^{-6}$ per degree F (changed to 26.5×10^{-6} - 1973)

$t_w = 20.299°\text{C} = 68.54°\text{F}$

$$V_{w60°F} = 5.00360 \left[1 - 28.8 \times 10^{-6}(68.54-60)\right] = 5.00247 \text{ gallons}$$

The volume of the residual water (V_{Rw}) may be determined [2] from the equation

$$V_{Rw} = \frac{A_3 - A_1 + M_{s3} - M_{s1} - \rho_{a3} V_{s3} = \rho_{a1} V_{s1}}{\rho_w - \rho_{a3}} \text{ cm}^3$$

where M_{s3} = Standards Mass in Data Set 3

V_{s3} = Standards Volume in Data Set 3

$$V_{Rw} = \frac{-0.824466-(-0.3802)+4897-4887-0.000117516(583.0)+0.0001756(531.8)}{0.998145-0.000117516}$$

$$V_{Rw} = 9.51456 \text{ cm}^3$$

$$V_{Rw} = 9.51456 \text{ cm}^3 \times 0.00026417 \frac{\text{gal}}{\text{cm}^3} = 0.00251 \text{ gallons}$$

From $V_{w60°F}$ and V_{Rw} the final volume of interest, the delivered volume V_D, can be calculated:

$$V_D = V_{w60°F} - V_{Rw}$$

$$V_D = 5.00247-0.00251 = 4.99996 \text{ gallons}$$

All calibrations witnessed essentially followed the outlined procedure with the exception that the first calibrations witnessed were performed with water drawn from the tap and all later calibrations were with distilled water. This change was considered significant due to the questionable quality of the water supply both from density considerations and air entrainment.

Review of the procedure and repeated calibrations with the same measure indicate that uniform calibration can be realized if the procedure is not varied. No attempt was made to evaluate either the effect or magnitude of deviations in the procedure. The procedure was not judged to be overly restrictive and potential variations in the procedure would only be variable characteristic of the ambient conditions and the personnel performing the calibration.

Testing reflected that a calibration value could be repeated by different individuals if the procedure was conscientiously followed.

Calibration of volumetric test measures is necessarily a manual operation and is somewhat dependent on the mental attitude of the individual performing the calibration. Mental attitude could affect the calibration but the effect cannot be measured or estimated. Care in cleaning, drying, reading, and recording balance readings and scale readings are some of the features that could fluctuate with mental attitude. It is considered, however, that an experienced technician will strive for optimum accuracy.

Since the calculations to establish the NBS calibration values are performed using a computer program, complete examination of the physical data was not attempted beyond the manual calculation which yielded good agreement with computer values. The computer program includes corrections for ambient temperature, humidity, and barometric pressure in the weighing process and is considered highly acceptable. One value used in the computer program that was judged questionable was the cubical thermal expansion coefficient for low-carbon steel measures. Report of tests indicated a value of 0.000018 per °F was assumed. This value reportedly came from the 1945 edition of Metals Handbook and NBS Monograph 62 (issued April 1, 1963). (The computer value was changed to 0.0000186 in 1972.) The National Bureau of Standards, at the request of the American Society for Testing Materials, developed a set of equations to represent the thermal expansion of mild steel from -40 to +400°F. The equations were published in Volume 45, No. 4, April 1961 Technical News Bulletin [5] as well as ASTM D1750-62, API Standard: 2541, Tables for Positive Displacement Meter

Prover Tanks. The Technical News Bulletin article appeared as follows:

Equations Representing Steel Expansion

THE BUREAU has developed a set of equations to represent the thermal expansion of mild steel from −40 to +400 °F, at the request of the American Society for Testing Materials. These equations were derived to assist ASTM Committee D-2 on Petroleum Products and Lubricants in the development of steel standards involving volume. They may also be used in preparing specifications for the steel containers used for storing various types of petroleum products.

To make these equations generally available, they are published here:

$$L_t = L_{60}[1 + 6.2\times10^{-6}(t-60) + 2.0\times10^{-9}(t-60)^2]$$

$$\alpha_m = [6.0\times10^{-6} + 2.0\times10^{-9}(t_1+t_2)]/°F$$

$$V_t = V_{60}[1 + 18.6\times10^{-6}(t-60) + 6.1\times10^{-9}(t-60)^2]$$

$$\beta_m = [17.9\times10^{-6} + 6.1\times10^{-9}(t_1+t_2)]/°F$$

where L_t and L_{60} are the lengths at temperatures t and 60 °F; α_m is the mean or average coefficient of linear expansion per degree Fahrenheit between temperatures t_1 and t_2; V_t and V_{60} are the volumes and β_m is the mean or average coefficient of cubical expansion per degree Fahrenheit.

The values used in these equations are believed to be representative for mild steels to the accuracy of the digits given.

U.S. GOVERNMENT PRINTING OFFICE: 1961 O—587453

Examination of the equations reveals values of 0.000062 for the linear coefficient and 0.0000186 for the cubic coefficient (average).

In an attempt to determine if the typical test measure exhibited an expansion coefficient consistent with the equations, a material sample was obtained from a test measure manufacturer. The sample was submitted to the Crystallography Section of NBS. The following is the pertinent portion of the test report received:

> The following values have been determined for the mean coefficient of linear thermal expansion of a steel plate parallel and perpendicular to the direction of roll.

	Parallel	Perpendicular
68 to -40°F	$6.2 \times 10^{-6}/°F$	$6.3 \times 10^{-6}/°F$
68	6.4	6.5
68 to 212	6.7	6.8

These values were obtained with a vitreous silica dilatometer following the ASTM Method of Test E 228. The specimens were 4 inches in length and the dilatometer was calibrated with two standard reference materials, SRM 736 (Copper) and SRM 739 (Fused Silica).

A mathematical average of the six values yields 6.48×10^{-6} for an average linear coefficient from -40 to 212°F. Multiplying the linear value by three to obtain a close approximation of the cubic expansion coefficient gives 19.4×10^{-6} or 0.0000194. Certainly no definite conclusion can be drawn from a single test other than that 0.000018 is not appropriate for use and further tests may be advisable to determine the best average value for test measure application. It is interesting to note that two manufacturers of test measures requested coefficients from the steel mills from which they obtain their terneplate material. The steel mills furnished values of 0.0000196 and 0.0000195 per degree F. Further study in this area was beyond the scope of the Research Associate Program.

4.1 CONCLUSIONS AND RECOMMENDATIONS. The calibration procedure employed by NBS is judged to be acceptable for use by others. A significant item is, however, neglected. It is generally accepted and has been experimentally verified that a test measure calibration is dependent on the emptying time as well as the alloted drain time following cessation of flow. Historically, only the drain time following cessation of flow is noted, recorded, and reported. This condition should be corrected. For invertable style measures the emptying time would reflect the NBS Calibration Procedure. For bottom-drain measures the device owner would have the responsibility of requesting a specific emptying time when submitting the measure to NBS for calibration. Only the owner knows in what piping configuration the equipment will be used and consequently he should include this time requirement in his request. The actual emptying time during calibration would then become part of the permanent documentation. Devices submitted without an accompanying drain time request would be calibrated with a minimum of hardware attached and the resulting drain time would be reported.

In considering the differences of values for the thermal expansion coefficient it must be pointed out that the differences in total calculated volumes would be slight (1 cubic inch in 500 gallons with a 15°F temperature differential). It does reflect non-uniformity but is considered insignificant if all parties will use consistent coefficients. Until additional research is conducted, the values of 18.6×10^{-6} per °F for low-carbon steel and 26.5×10^{-6} per °F for 18-8 or Type 304 stainless steel should be used by all individuals.

5.0 ACCURACY LIMITS. Accuracy limits are extremely important in every measurement process, especially when dealing with standards calibration and traceability. In dealing with any measurement process, it is essential to determine whether accuracy or precision is the desired quality. The definitions [6] may be simply stated in that precision is the measure of the closeness together of two or more measured quantities and accuracy is a measure of the nearness of a measured value or values to the intended value. Accuracy is the most important characteristic for volume measurement applications. For the purposes of this study, accuracy has been divided into three phases. These phases are: Existing accuracy, required or desired accuracy, and theoretically attainable accuracy.

The existing accuracy is assumed to coincide with and is limited to the estimated uncertainty furnished to a customer on a Report of Calibration. This uncertainty reportedly reflects a standard deviation based on an expected range of two calibrations and assumed negligible systematic error. As the review on this phase progressed, a statement of "Maximum uncertainty" was alluded to by several individuals. Based on information received, an API Task Force assigned to study calibration of Primary Volume Standards prepared a report following a visit to NBS in 1966. The report quoted that the maximum uncertainty which would be reported on Standards of volumes one to fifty gallons would be ±0.02% and for a one-hundred gallon Standard the maximum uncertainty would be ±0.01%. These values were not exactly substantiated by the calibration reports reviewed. (See Table II, page 36.)

The desired accuracy for volumetric test measures is difficult to determine. Referring to the information obtained from the September 1970 meeting at NBS (Page 7), the desired accuracy was ± 0.01%. This statement implies a reduction of the estimated uncertainty by one-half.

From discussions with individuals in various areas of measurement responsibility, one will find that the desired accuracy for volume calibrations of standards is the unattainable absolute accuracy. In actual field applications of volume standards it would appear that absolute accuracy is often assumed since the nominal volume values are employed in checking meter accuracy. Only when such an assumption is questioned is it disclosed that tolerance values for determining equipment acceptability are "interpreted" as including some tolerance contribution from the test equipment. This contribution must necessarily include the 0.02% (if such be the number and it is a first generation calibration) in addition to the allowable tolerance from the nominal value of the Standard. This may reflect a dangerous procedure or philosophy. This very fact is one of the prime justifications for the sponsorship of the Research Associate Program by the American Petroleum Institute. One of the goals of the entire program was to define what portion of a tolerance is contributed by the test equipment and procedure and what portion is actually attributed to the system being tested.

If the mis-measurement contribution can be isolated through the Research Associate Program, meter system evaluation will be much more meaningful. For comparison purposes, Table I! was prepared for values from available Reports of Calibration. This table shows the reported uncertainty, the quoted 0.02% maximum uncertainty, and the 0.01% desired uncertainty.

Review of available Certificates (discontinued during the 1960's) and Reports of Calibration reflect a change in reporting of values. The Certificates stated a quantity at a specific temperature and cited no uncertainty. Statisticians generally emphasize that when no statement of accuracy or precision accompanies a reported number the usual convention is to assume that the last significant figure given is accurate within ±1/2 of that unit. An example in the comparison of two actual reports is as follows:

Certificate	50.00 Gallons at 60°F
Statistical Uncertainty	±.005 Gallons or 1.2 cubic inches
Report of Calibration	49.997 U. S. Gallons, 11549.5 in^3
Estimated Uncertainty	±.02 U. S. Gallons, 4.6 in^3

When the Certificates were discontinued and Report of Calibrations substituted, the uncertainty applied to the volume standards was greater than the uncertainty inferred by the Certificates which leaves a wide variation between similar equipment in the field with different calibration documentation. This will be resolved with time and eventually there will be no operating equipment with Certificates being used.

Attainable accuracy is also a difficult characteristic to evaluate since there must be a starting point. An attempt to determine values for an attainable accuracy would be nothing more than a personal estimate. Uncertainty could be theoretically estimated if any single uncertainty previously listed was selected as a starting point. Such a procedure would necessarily be arbitrary and the resulting values could be meaningless. National Bureau of Standards Report NBSIR 73-287, "Procedures for the Calibration of Volumetric Test Measures", reports on an extensive series of calibrations that were performed in an attempt to evaluate uncertainties. The uncertainties derived from those tests are generally acceptable but not applicable to every calibration process.

To determine if statistically predicted uncertainties would reflect improved values, calculations were performed using the following equation:

$$U_x = 3 \quad n^2 \sigma^2 \quad + nU_s$$

where U_x is the uncertainty of the device being calibrated,

n is the number of times the standard was used,

σ is the standard deviation of the standard, and

U_s is the uncertainty of the standard.

Assuming a 100 gallon standard with a standard deviation of 0.0067 and an uncertainty of 0.02 gal, calculations were performed for build-up calibrations of a 200 and a 500 gallon measure. The resulting values of uncertainty were 0.16 gallons and 0.4 gallons, respectively. The values are not considered to be representative of the actual calibration procedure performed at NBS. Comparison of these calculated values with the values listed for 200 and 500 gallon measures in Table II shows that the calculated values are significantly greater than the reported values.

From a discussion in NBS Report 10396, "Pressure Type Liquid Level Gages", the uncertainty for a "build-up" calibration was taken to be equal to:

$$U_x = NU_s + U_\alpha(\Delta T)NV_s$$

where U_x = Uncertainty of the unknown

N = Number of dumps

U_s = Uncertainty of the Standard

V_s = Volume of Standard

U_α = Uncertainty in the cubic thermal expansion coefficient

ΔT = Temperature difference between calibration temperature and same base temperature.

For the NBS 100-gallon Stainless Steel Standard an uncertainty of 1.38 cubic inches or 0.00574 gallons is stated. For comparison with the previous example, assume $U_\alpha = 4 \times 10^{-6}/°C = 2.22 \times 10^{-6}/°F$, $\Delta T = 60°F-40°F = 20°F$, then

$$U_{x100} = 1 \times 0.00574 + 100 \times 1 \times 2.22 \times 10^{-6} \times 20$$

$$= 0.00574 + 0.00444$$

$$= 0.01018 \text{ gal} = 2.35 \text{ in}^3$$

and for a 200 gallon

$$U_{x200} = 2 \times 0.00574 + 2.22 \times 10^{-6} \times 20 \times 2 \times 100$$

$$= 0.01148 + 0.00888 = 0.02036 \text{ gallons}$$

$$= 4.70 \text{ cubic inches}$$

Comparison of these values with the values in Table II shows much

TABLE II UNCERTAINTY COMPARISONS

MEASURE TYPE & NOMINAL VOLUME	ACTUAL* REPORTED UNCERTAINTY Gallons	ACTUAL* REPORTED UNCERTAINTY Percent	UNCERTAINTY (0.02%) Gallons	UNCERTAINTY (0.01%) Gallons
Graduated Neck 1 Gallon	0.0002	0.02	0.0002	0.0001
Graduated Neck 5 Gallon	0.001	0.02	0.001	0.0005
Slicker Plate 5 Gallon	0.001	0.02	0.001	0.0005
Graduated Neck 10 Gallon	0.001	0.01	0.002	0.001
Graduated Neck 200 Gallon	0.02	0.01	0.04	0.02
Graduated Neck 500 Gallon	0.10	0.02	0.10	0.05
Graduated Neck 30 Gallon	0.01	0.03	0.006	0.003
Graduated Neck 42 Gallon	0.02	0.048	0.0084	0.0042
Graduated Neck 50 Gallon	0.02	0.04	0.01	0.005
Graduated Neck 10 Gallon	0.002	0.02	0.002	0.001
Graduated Neck 100 Gallon	0.02	0.02	0.02	0.01
Graduated Neck 1 Gallon	0.0015	0.15	0.0002	0.0001

* Values represent separate calibration certificates

better agreement. If the relationship used in this example is valid, then by using an accurate, well-known cubic thermal coefficient of expansion that uncertainty contribution would approach zero. That would represent an uncertainty reduction of 40 percent or more.

The ultimate goal for uncertainties associated with volumetric measures, in the eyes of most people involved in measurement, would be for the values to be decreased. It is impossible for any individual to predict that such a reduction could be realized. The actual ability to decrease the estimated uncertainty has been studied with the resulting conclusion that the unknown variance of the cubic thermal coefficient of expansion and the predicted readability of the graduated neck may prevent a reduction of estimated uncertainty.

The calibration data of the "check standard", described in the calibration procedure of Section 4.0, has been collected for 1, 5, and 10-gallon calibrations with good agreement between predicted uncertainty and uncertainty based on a large test population. Similar data for the larger volume is not taken due to the absence of "Check Standards" in the procedure. The resolution of this problem will only come about when an exhaustive study is conducted by persons knowledgeable in statistical evaluation and volumetric calibrations. Such an evaluation is far beyond the scope of the Research Associate Project.

The research project included calibrations to evaluate design and operating characteristics of test measures and included repetitive calibrations of prover standards.

6.0 LIQUID RETENTION OR CLINGAGE TESTS. In order to evaluate test measure characteristics that affect liquid retention, it was necessary to devise a test series that would provide the required information. Preliminary tests were conducted in an attempt to determine which characteristics of a given procedure would measureably affect the amount of liquid remaining in a measure following emptying. It was learned that three variables dominated or controlled this liquid residue. They were:

1. The angle between the vertical axis of the test measure and true vertical during drainage,
2. The time from the beginning of the emptying of a measure to the cessation of flow, and
3. The time from the cessation of flow until the measure is returned to an upright position or the drain valve closed.

The preliminary tests provided an indication that the basic characteristics of test measures could be studied while performing the retention of liquid tests. The most significant feature of test measures concerns the reproducibility of performance and a large contributing factor would be the liquid retention. It was found that this factor could be significantly changed by slight variations of the three variables previously mentioned. Admittedly, there can be other factors that could influence the accuracy of a test measure such as dirt film, corrosion, denting damage, etc. These factors were not considered to be true variables since their effects would be unstable and completely uncontrollable. The tests were limited to clean, reasonable quality volume standards suitable for a commercial measurement process. A test series was planned using carbon steel test measures, both bare and epoxy-coated, stainless steel test measures, and specially designed containers of two square feet surface area. Figure 1, 2, and 3 are photographs of the instruments that were subjected to retention test studies.

6.1 TEST MEASURE TESTS. The testing involved a weighing process to determine the weight of liquid remaining in a measure following a carefully controlled emptying procedure. Weighing of the 5 and 10 gallon test measures was performed with a 2500 pound capacity Russell Equal-Arm Balance. The right arm of the balance was loaded with a 500-pound weight while the left arm was loaded with the test measure and cover, a weigh pan, and sufficient weights to balance the 500-pound weight. The weight of water retained was determined as being equal to the amount of trim weights required on the right arm to balance the left arm which included the wetted test measure. Figure 4 shows the configuration for weighing of the test measures. The weighing of the 1 gallon test measures was done on a 10 kilogram Christian-Becker Equal-Arm Balance. Figure 5 is a photograph of that balance with a test measure on the left side pan and weights on the right pan. For each device tested, the tests were repeated numerous times in order to establish the reproducibility of the results and to properly document that the variables under investigation were indeed contributing factors if subsequently applied to calibration procedures. Since the variable factors seemed to be independent of

Figure 1. Volume standards used for tests - Group 1.

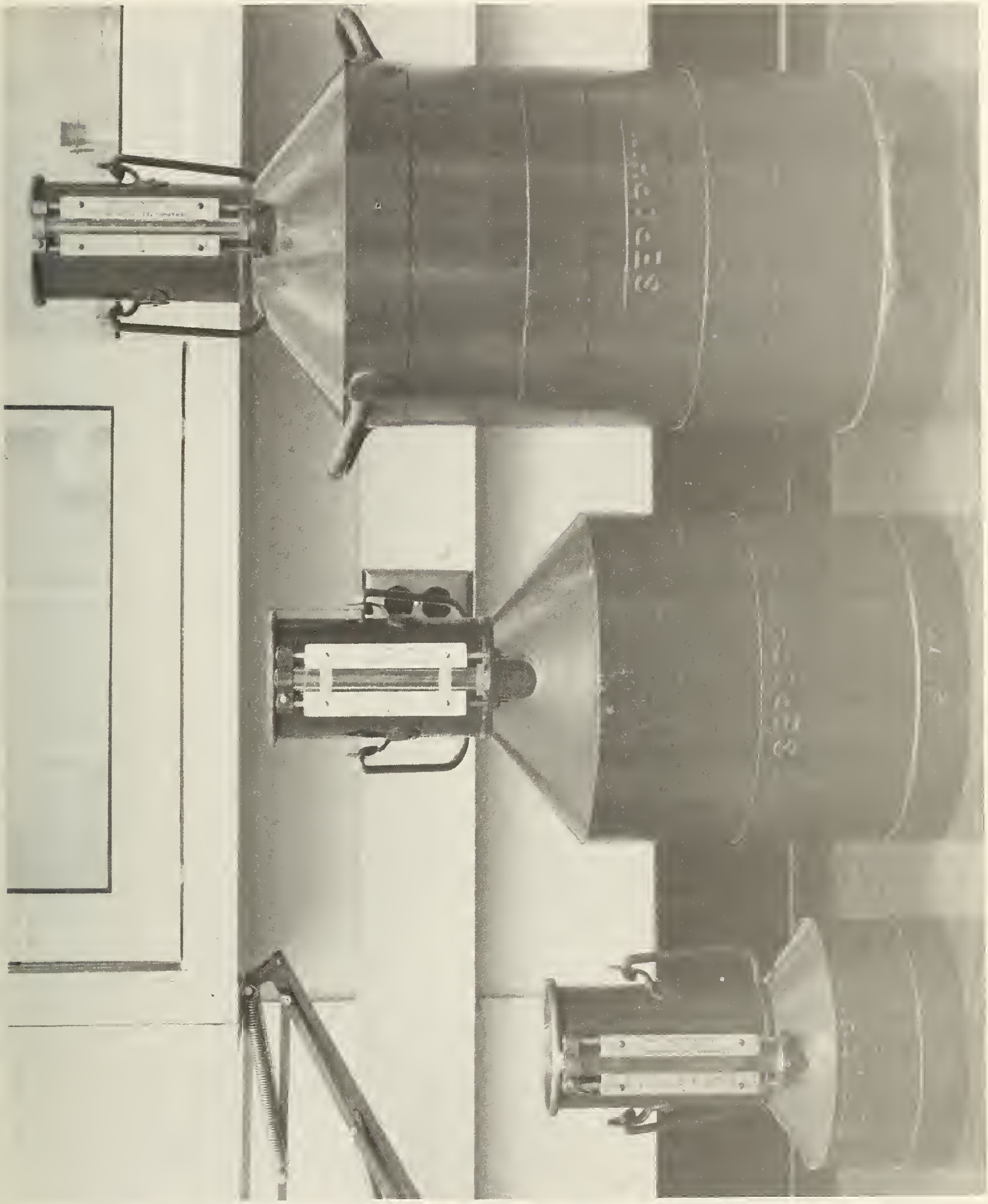


Figure 2. Volume standards used for tests - Group 2.

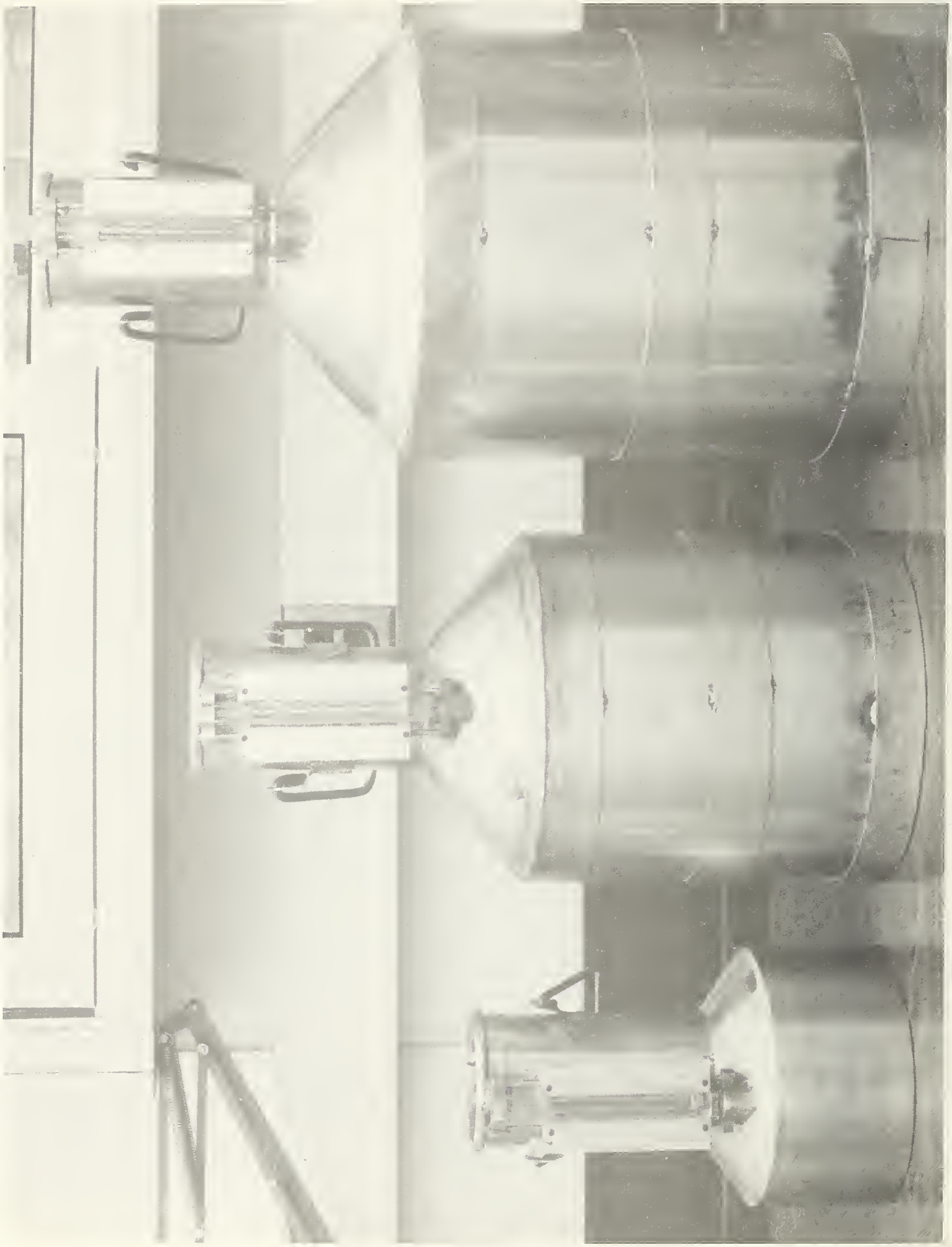


Figure 3. Volume standards used in tests - Group 3.

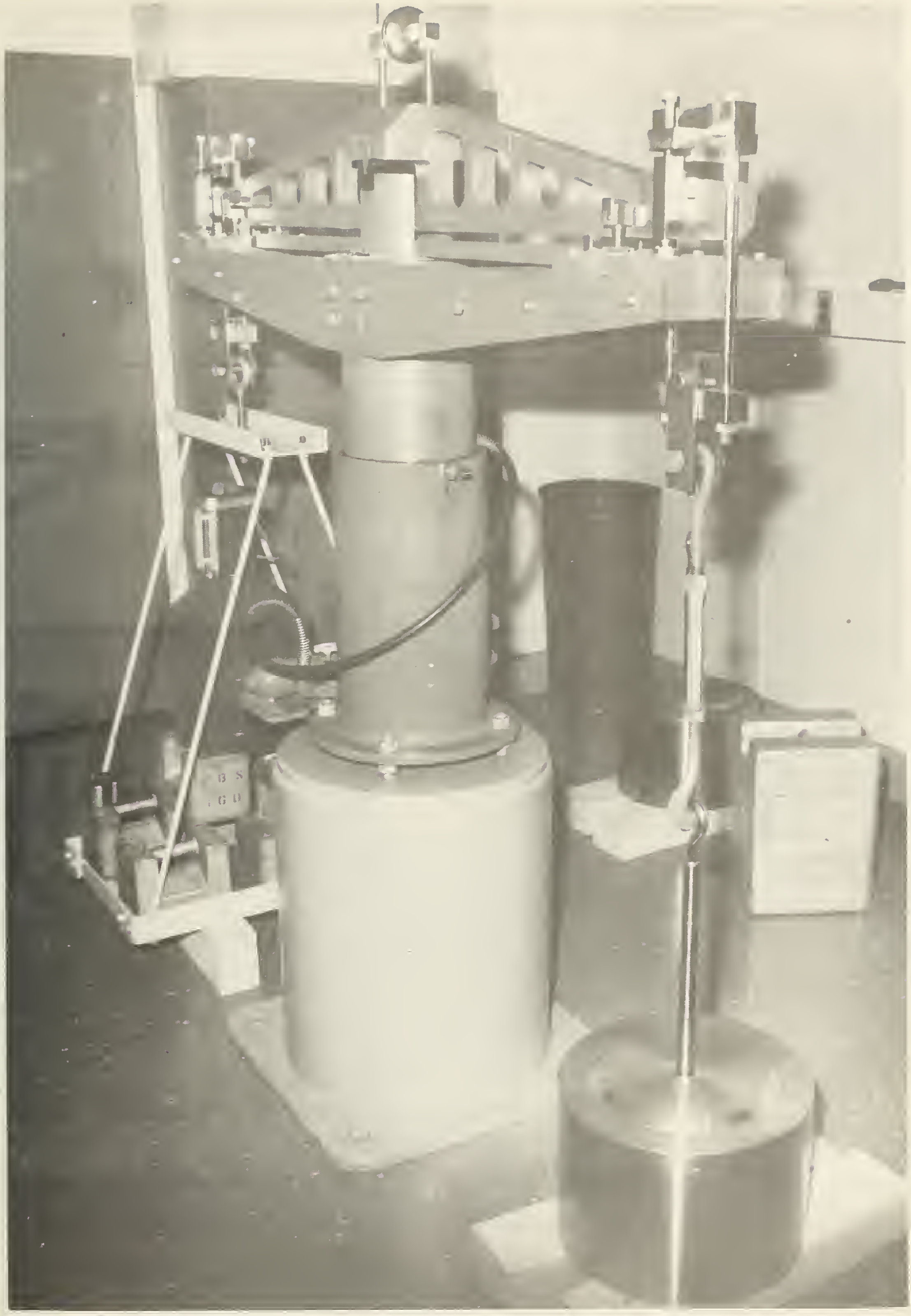


Figure 4. Configuration for weighing on the Russell Balance.

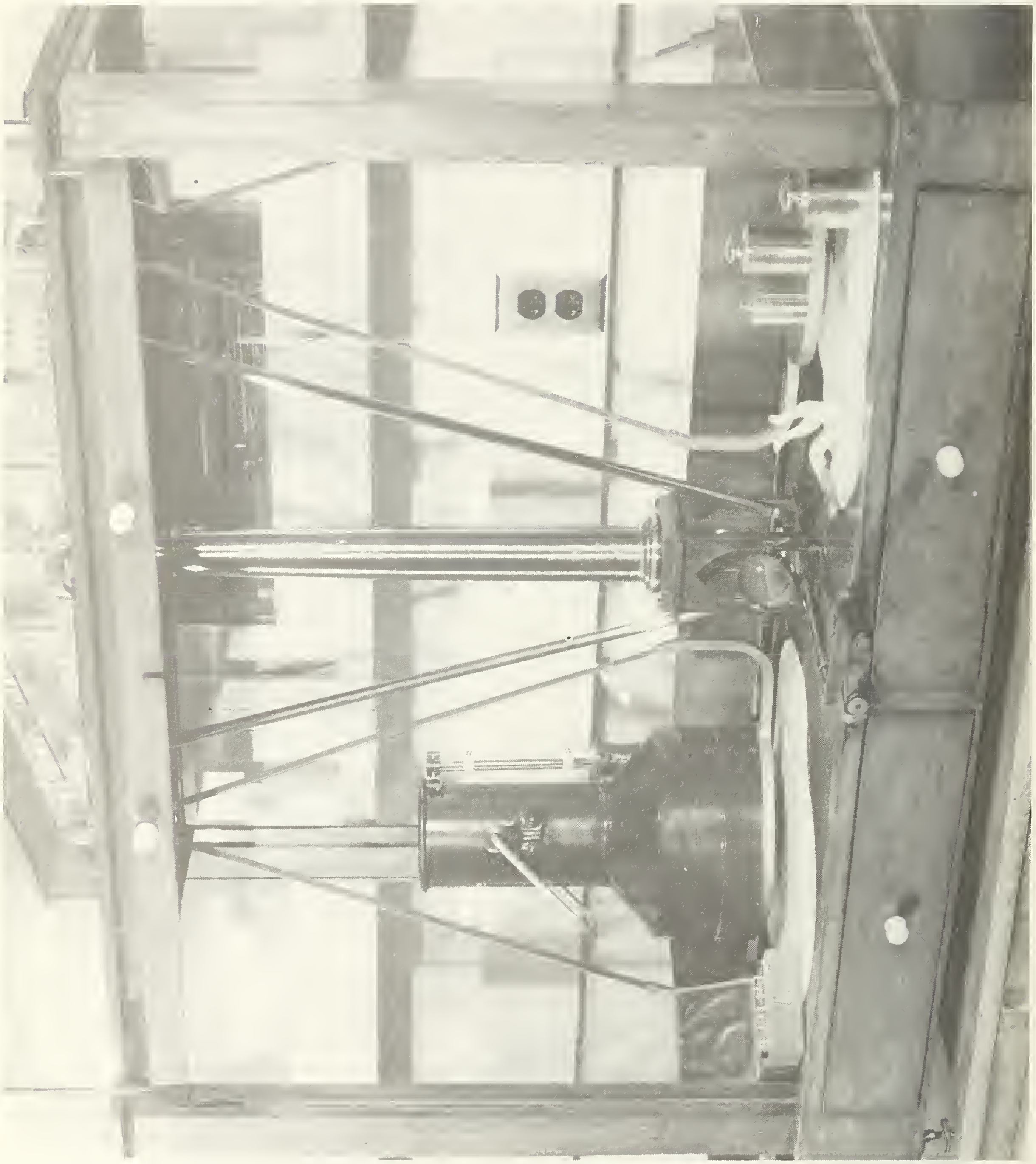


Figure 5. Configuration for weighing a 1-gallon measure.

one another it was necessary to vary only one factor at a time in order to establish what would be considered to be the optimum times and angle. From these tests it was possible to determine at what upper and lower limits the resulting data would exhibit a non-reproducible scatter. The ultimate goal of the test series was to establish the limits within which the variables should be controlled in order to achieve a repeatable calibration and at the same time not be overly restrictive.

6.1.1 EXPERIMENTAL TEST PROCEDURE. All test measures, except the epoxy-coated measures, were cleaned using a degreasing solvent rinse, alcohol rinse, warm water with detergent, clear water rinse, alcohol rinse, and air drying. The cleaning of the epoxy-coated measures was accomplished using only warm water with detergent, clear water rinse, and air drying. The cleaning provided chemically clean dry surfaces for test evaluation.

The test measure with a cover was placed on the balance left arm and weight was added to the appropriate side to achieve a new balance condition. Turning points were observed and recorded on the data sheet. A sensitivity weight (0.005 pound) was added to the right arm load to establish a deflection per unit weight for the test series. The turning points were observed and recorded on the data sheet.

The test measure was removed from the weigh pan and filled with tap water to near zero on the graduated neck. The measure was then emptied in a manner such that the time for emptying, the angle between the vertical axis of the measure and true vertical, and the drain time following cessation of flow could be repeated. Following the completion of the drain, the cover plate was placed on the measure and the wetted container was replaced on the balance. Trim weights were added to the right side of the balance until a near balance condition was achieved. The turning points were observed and recorded on the data sheet.

For each measure the angle of the vertical axis from vertical, the time for emptying, and the drain time following cessation of flow were varied one at a time for the test series.

Exhibit 2 is a completed Data Sheet for one of the series of tests.

6.1.2 CONCLUSIONS AND RECOMMENDATIONS. This test series revealed some interesting information concerning procedures. By varying the time required for emptying a measure the amount of water retained by the measures was significantly changed. This was true as long as the time allotted for drain following cessation of the main flow was held constant. From the data collected, it appears that the procedure for emptying water from a test measure must include a time factor. A procedure that requires 25 to 40 seconds for the emptying of a 5-gallon measure followed by 10 seconds after cessation of the main flow will result in consistent values.

6.2 TWO-SQUARE-FOOT CONTAINERS TESTS. Three test containers were designed and fabricated to evaluate the influence of top and bottom cone angles. The containers were designed such that the cones could be alternately used as top or bottom. (See Figure 6).

Tests similar to those performed with the test measures were

CLINGAGE TEST DATA SHEET

TEST DEVICE 10 GALLON – EPOXY COATED PAGE No. 1

MATERIAL LOW CARBON STEEL MANUFACTURER SERAPHIN

OBSERVER HINE & KEYSAR DATE 12/18/70 IDENTIFICATION NBS #4291

TEST LOAD DESCRIPTION	SCALE READING LEFT	SCALE READING RIGHT	AVERAGE TOTAL	SCALE DIFFERENCE	# CLINGAGE (in^3)
DRY MEASURE WITH COVER (LEFT)	/	~~14.8~~			
	9.1	14.8			
	9.1	.	23.9		
DITTO 0.005# SENSITIVITY WEIGHT ON RIGHT	/	~~12.2~~			
	6.8	12.1			
	6.8	.	18.9	5.0	
WET MEASURE WITH COVER (LEFT) 0.030# ON RIGHT	/	~~14.8~~			
	8.5	14.8			.0294#
	8.5	.	23.3	0.6	0.81 in^3
DITTO 0.040# ON RIGHT	~~7.4~~	~~14.6~~			
	7.2	14.1			.0374#
	7.3	13.9	21.3	2.6	1.04 in^3
DITTO 0.040# ON RIGHT	~~7.3~~	~~13.8~~			
	7.4	13.7			.0372#
	7.4	.	21.1	2.8	1.03 in^3
DITTO 0.040# ON RIGHT	~~7.3~~	13.8			
	7.3	13.2			.0369#
	.	.	20.8	3.1	1.02 in^3
DITTO 0.037# ON RIGHT	~~7.3~~	14.4			
	7.3	14.4			.0348#
	.	.	21.7	2.2	0.96 in^3

ROOM TEMP. 73 °F
WATER TEMP. 10.8 °C

HUMIDITY

WET BULB ________ °C
DRY BULB ________ °C
HUMIDITY 63 %

~ NOTES ~

RUSSELL BALANCE
500# PRELOAD —

20 SEC. POUR TIME
10 SEC. DRAIN "

WATER TEMPERATURE

1 – 10.8 °C
2 – 10.8 °C
3 – 11.0 °C
4 – 10.7 °C
5 – 10.8 °C

54.1 ÷ 5 = 10.8 °C

Exhibit 2
Completed Data Sheet

djhine 12/70

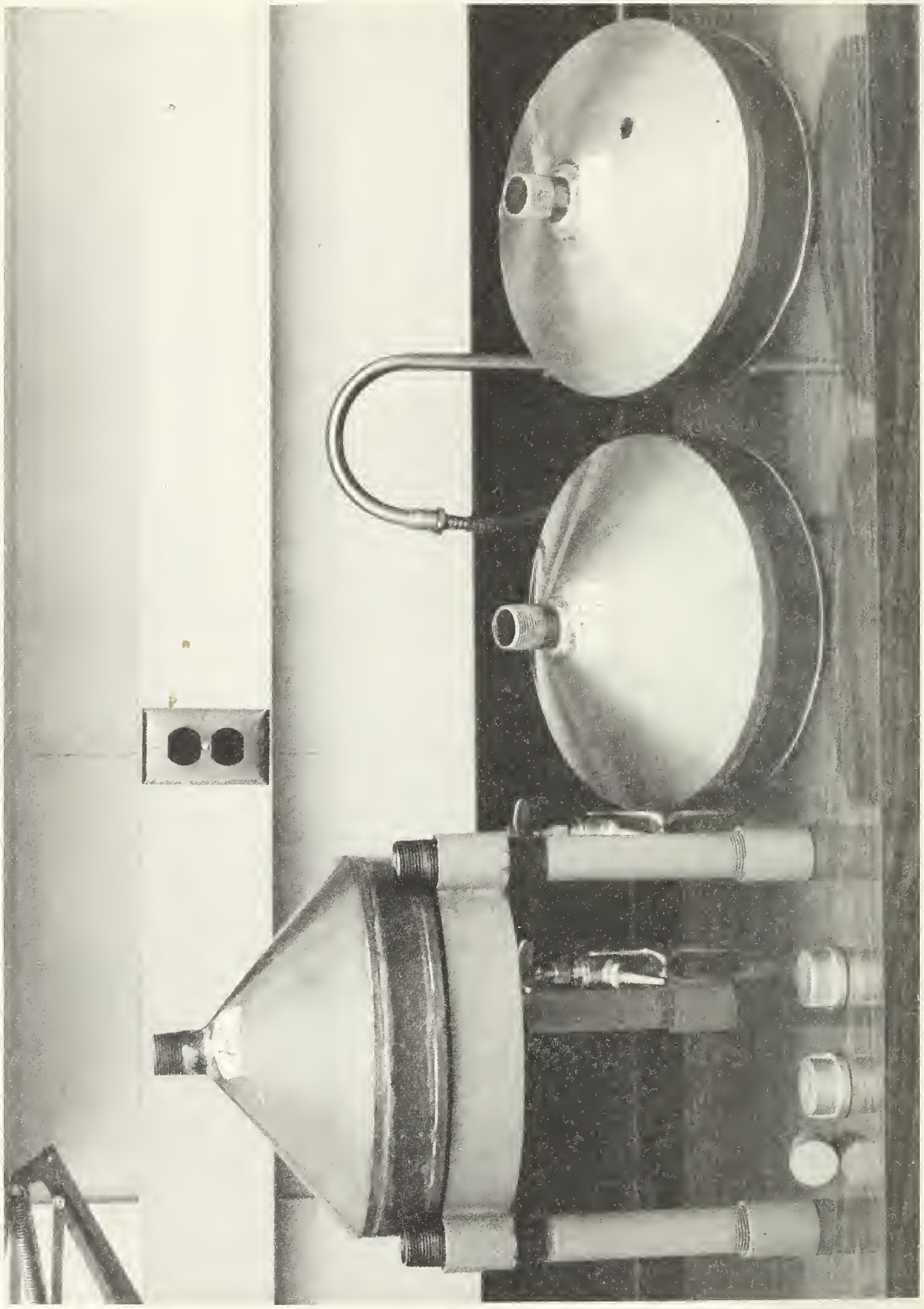


Figure 6. Two-square-foot containers for fluid retention tests.

conducted on the conical test pieces. Weighings were made on a Christian-Becker 10 Kilogram Equal-Arm Balance. The left weigh pan was replaced with a bracket to hold the test section in an upright position while weighings were made. Figure 7 is a photograph of the weighing set-up. The initial weighing was made balancing a bottle with lead shot against the holding fixture and the dry test pieces. In the ensuing tests the weight of water retained by the container was determined as the amount of trim weights necessary to achieve a balance condition.

6.2.1 EXPERIMENTAL TEST PROCEDURE. The test pieces were all cleaned in accordance with the procedure discussed in 6.1.1. The cleaned equipment was weighed on the balance with a pipe cap on one opening and a rubber stopper on the other. Due to weight variation of the cap and stoppers the same cap and stopper were used in all weighings.

The weighed dry container was placed in the ring stand (See Figure 8) and the container was filled with tap water. A cap with a small diameter hole was placed on the container and then the rubber stopper was removed allowing the water to drain. The time for the draining was varied by exchanging caps with different hole diameters.

Following cessation of flow, the container was allowed to drain for 10 additional seconds after which the dried stopper was replaced, the closed cap was substituted for the flow cap and the container was removed to the balance where the weight of water remaining in the container was determined.

Exhibit 3 is a sample data sheet of one test sequence.

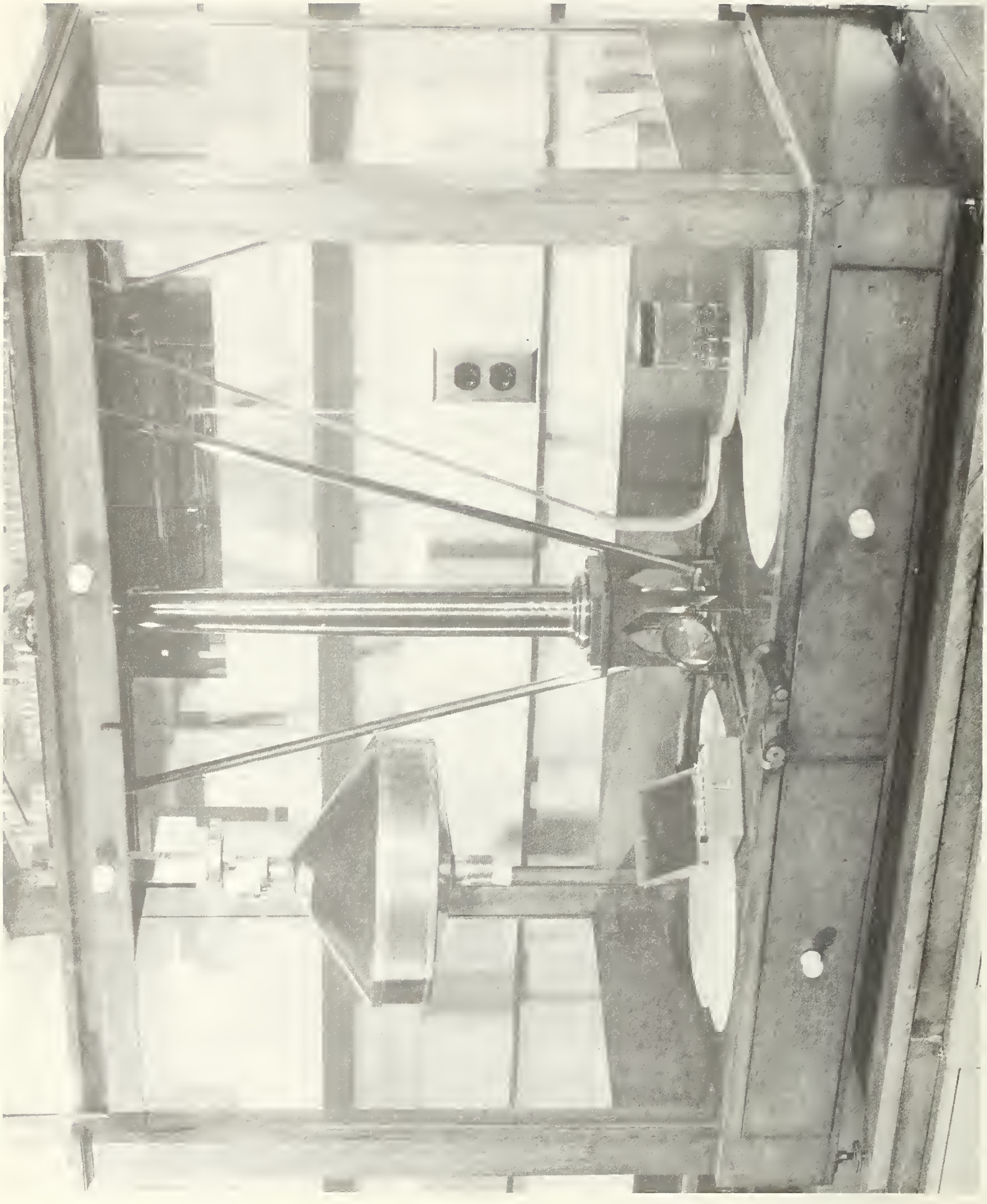


Figure 7. Configuration for weighing two-square-foot containers.

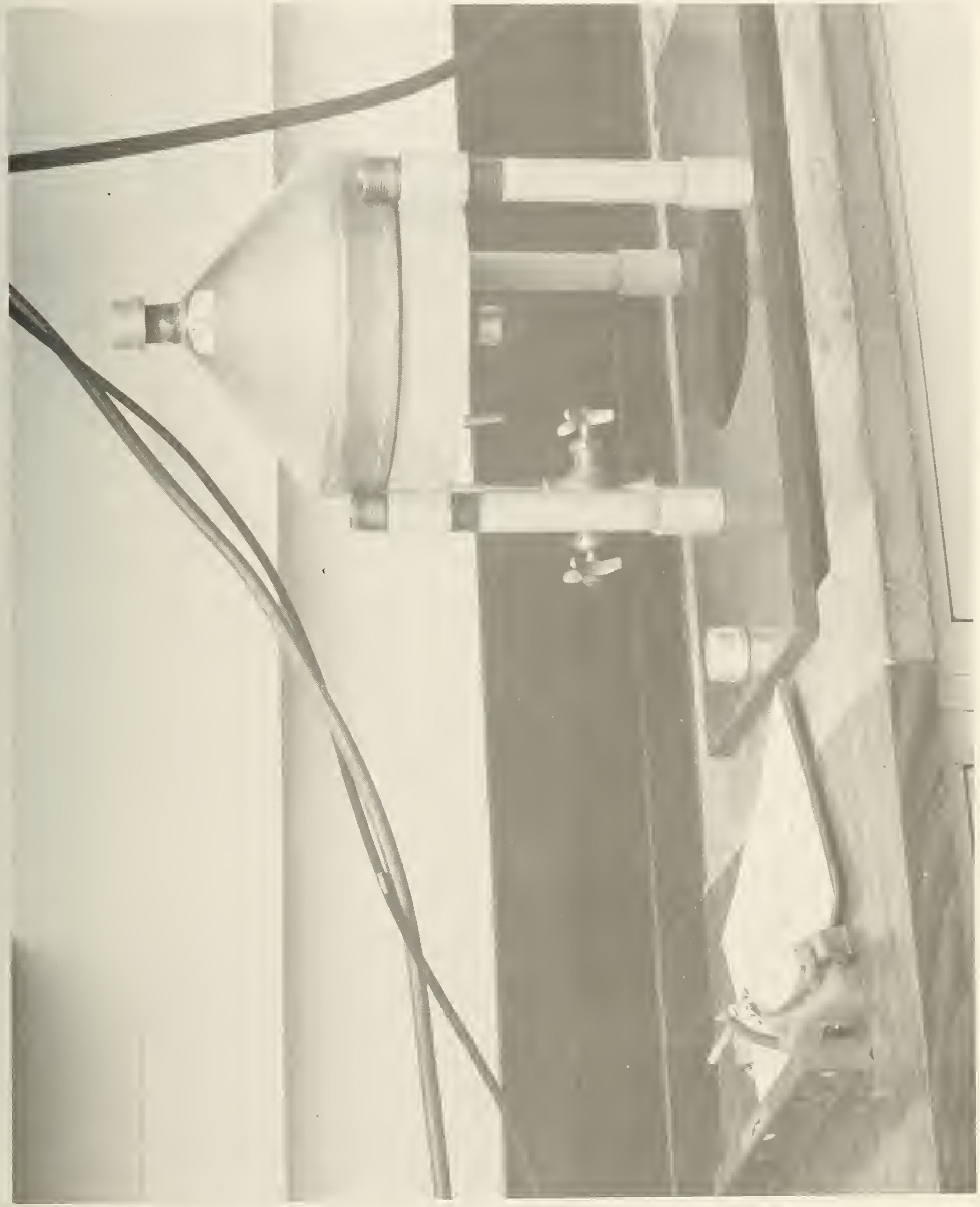


Figure 8. Test set-up for two-square-foot containers.

NBS 506—Analysis paper

GPO 1962 OF—640486

ANGLE EVALUATION EXPERIMENT SERIES

Hine 9

WATER SOURCE Tap Water

WATER TEMPERATURE 68 °F

EXPERIMENT BY Keysar

EXPERIMENT DATE 10/12/71

ROOM TEMPERATURE 72 °F

TEST NUMBER	TOP ANGLE o	BOTTOM ANGLE o	DRAIN TIME	OUTFLO TIME	LEFT-HAND BALANCE PAN LOAD		RIGHT-HAND BALANCE PAN LOAD		CLING WEIGHT Gross/Net	CLING VOLUME in³
								Turning Points		
DRY	40	20	—	—	Test	Piece	Wts.	16.3-22.5		
+ 50 mg Sensitivity weight						"	+50 mg	12.6-21.1		
1			10 Sec	34 Sec.	(#38 Cap Hole)			13.5-27.5	5.53 G	
									5.51	0.34
2				"				13.0-26.0	5.66 G	
									5.65	0.35
3				"				14.3-25.1	5.74 G	
									5.734	0.354
4				"				16.8-23.0	5.65 G	
									5.64	0.348
5				"				17.3-25.4	5.70 G	
									5.66	0.349
6				"				18.3-23.2	5.72 G	
									5.69	0.351
7				"				19.4-22.4	5.72 G	
									5.69	0.351
8				"				16.2-23.4	5.70 G	
									5.692	0.351

Exhibit 3

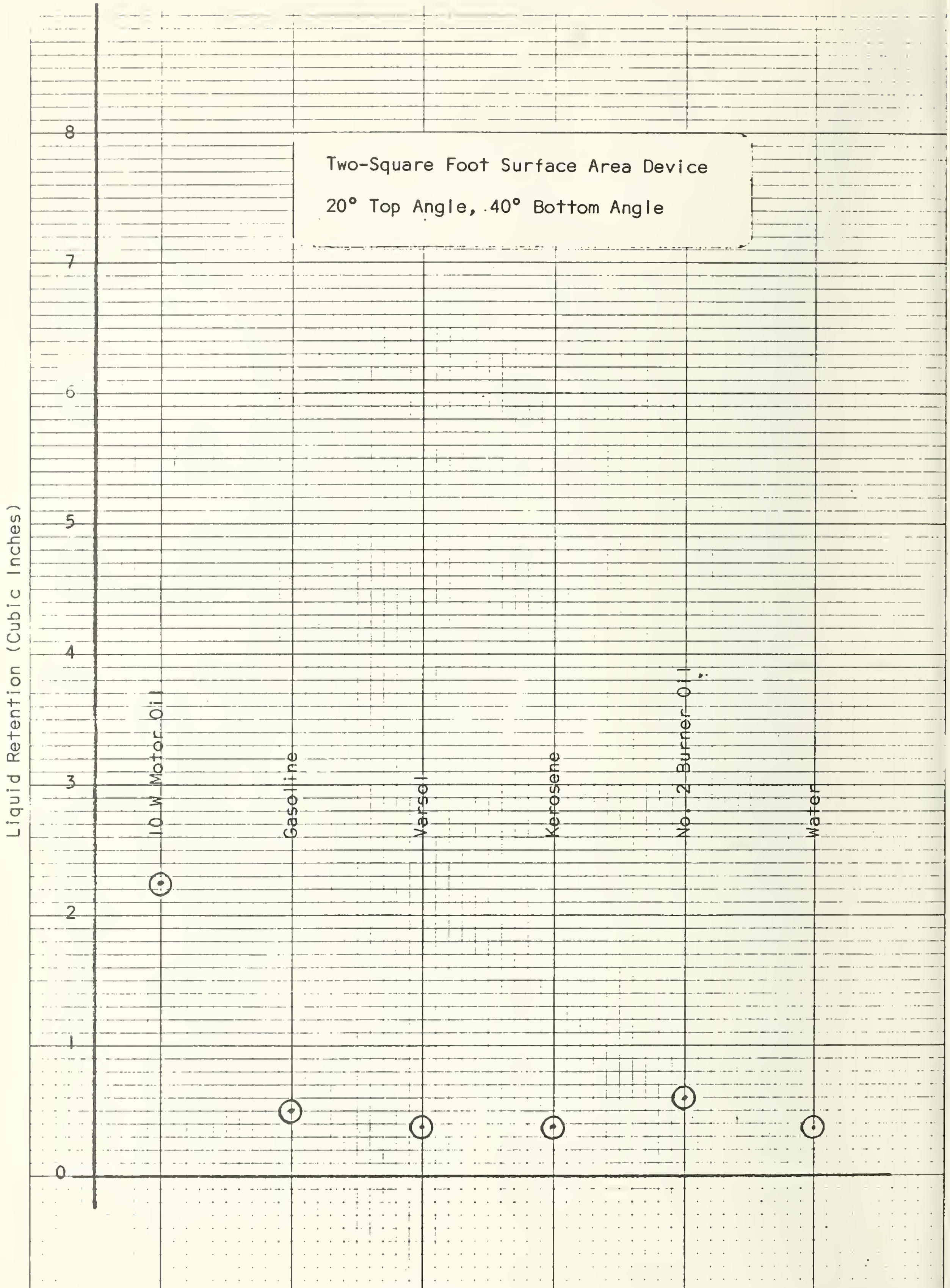
6.2.2 DISCUSSION OF TESTS AND FUTURE TESTS. The test series with the 2-square-foot surface area containers has not resulted in conclusive information concerning optimum angles for measure design. It has shown the marked influence of the time to empty on the amount of liquid retained. It has also provided indication that the smaller bottom angles are quite susceptible to residue buildup.

6.3 TESTING WITH LIQUIDS OTHER THAN WATER. To further extend the evaluation of the test measures as well as the 2-square-foot surface area containers, additional testing was performed with liquids other than tap water. The liquids used and their corresponding viscosity and gravity is as follows:

Liquid	Kinetic Viscosity @25°C	Specific Gravity
No. 2 Burner Oil	0.0332 stokes	0.8626
Gasoline	0.0055 stokes	0.7503
Varsol	0.0120 stokes	0.7892
Kerosene	0.0193 stokes	0.8044
10W Motor Oil	0.6724 stokes	0.8735

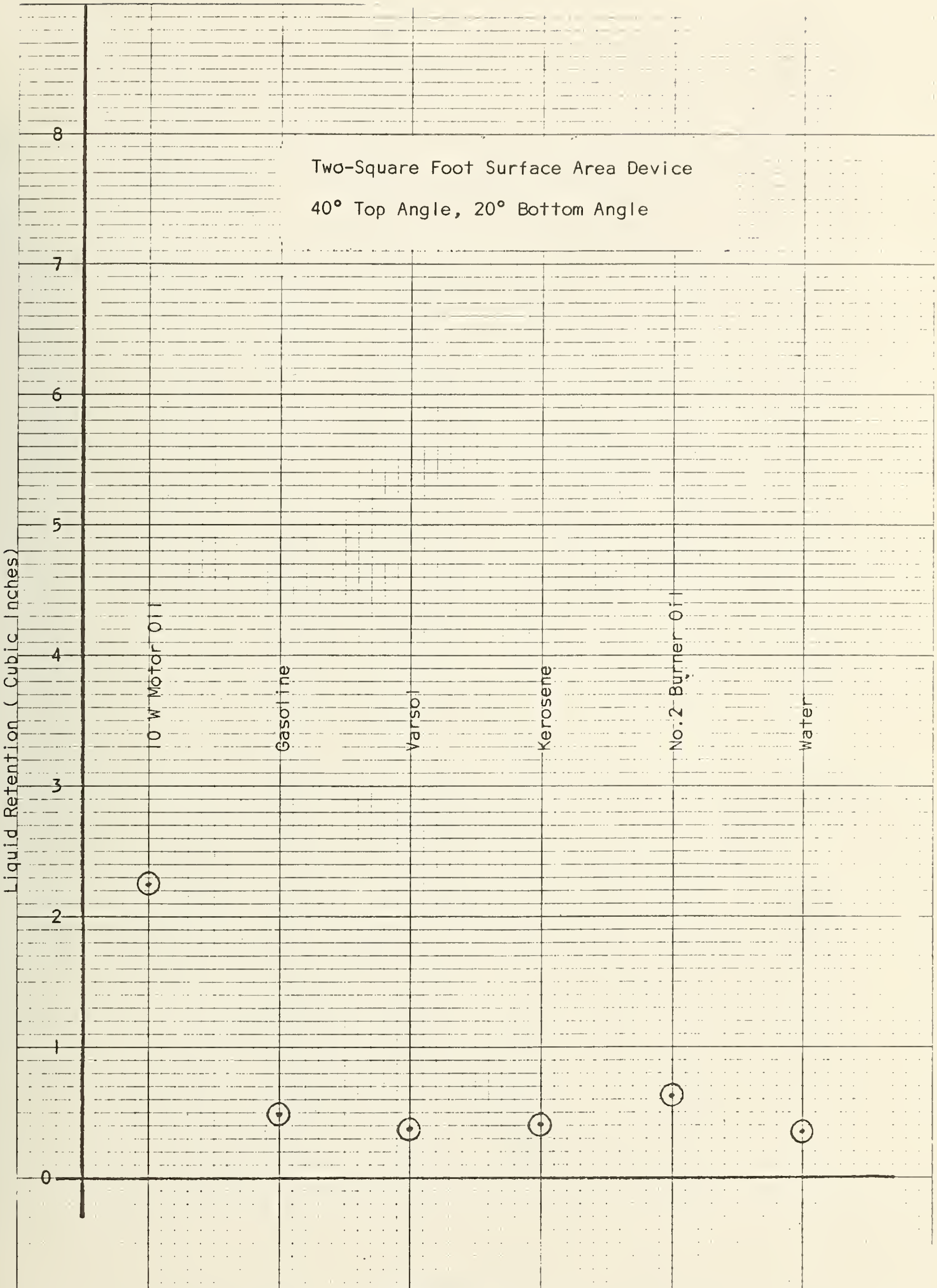
The testing was performed as discussed in Sections 6.1.1 and 6.2.1 of this report in order to have consistent procedures for evaluation of all liquids including tap water. The results of the tests are presented in Figures 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, & 20.

6.4 DISCUSSION OF RESULTS. Review of the data reveals that for small measures or provers the use of water-calibrated equipment with non-viscous liquids is probably acceptable. The water calibrated equipment would not be acceptable for use with more viscous liquids than the No. 2 Burner Oil. For such an application a special



Two-Square Foot Surface Area Device
20° Top Angle, 40° Bottom Angle
Liquid Retention (Cubic Inches)
8
7
6
5
4
3
2
1
0
10 W Motor Oil
Gasoline
Varsol
Kerosene
No. 2 Burner Oil
Water

Figure 9


Two-Square Foot Surface Area Device
40° Top Angle, 20° Bottom Angle
Liquid Retention (Cubic Inches)
0
1
2
3
4
5
6
7
8
10 W Motor Oil
Gasoline
Varsol
Kerosene
No.2 Burner Oil
Water
Figure 10

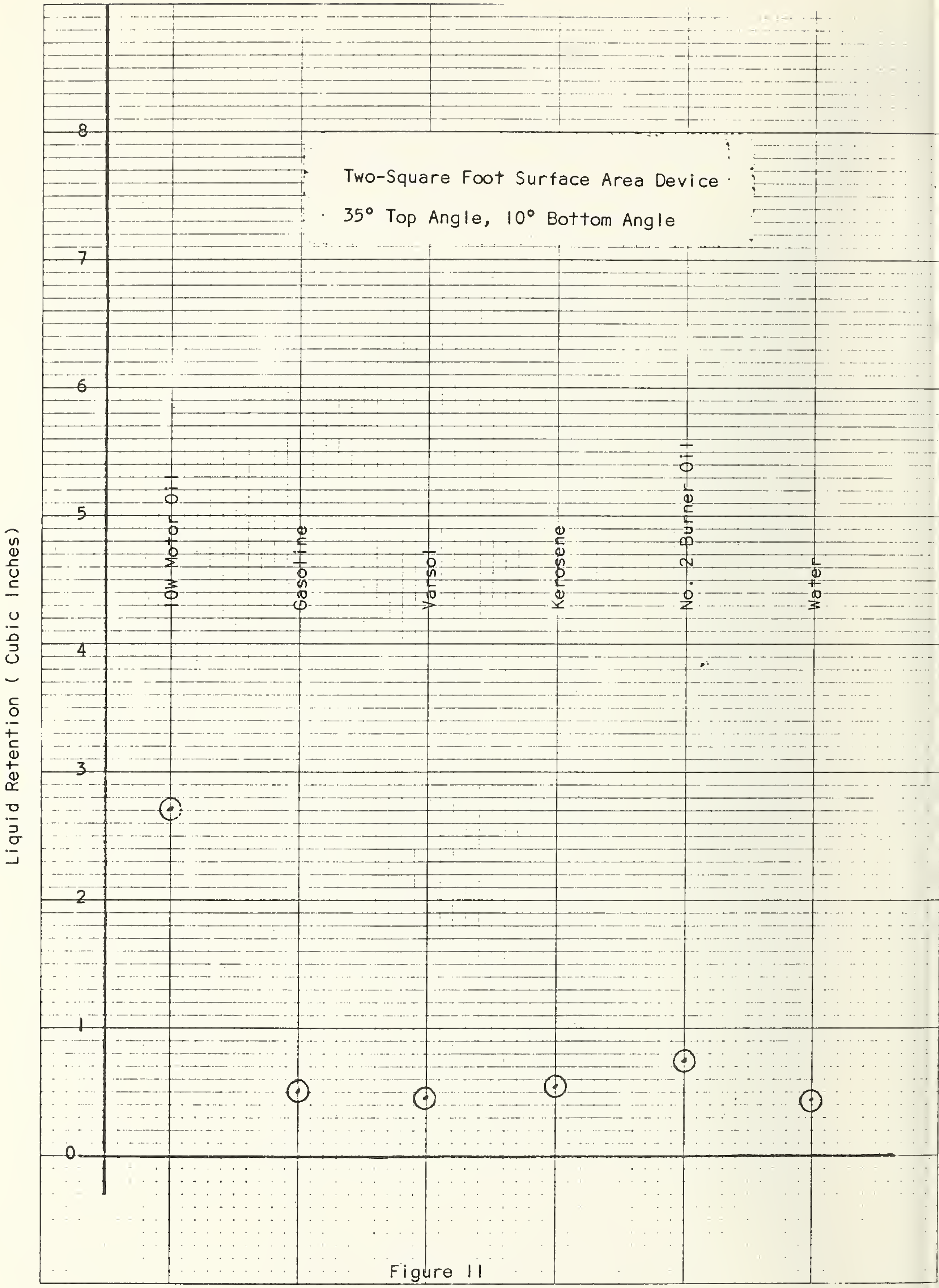

Two-Square Foot Surface Area Device
35° Top Angle, 10° Bottom Angle
Liquid Retention (Cubic Inches)
8
7
6
5
4
3
2
1
0
10W Motor Oil
Gasoline
Varsol
Kerosene
No. 2 Burner Oil
Water

Figure 11

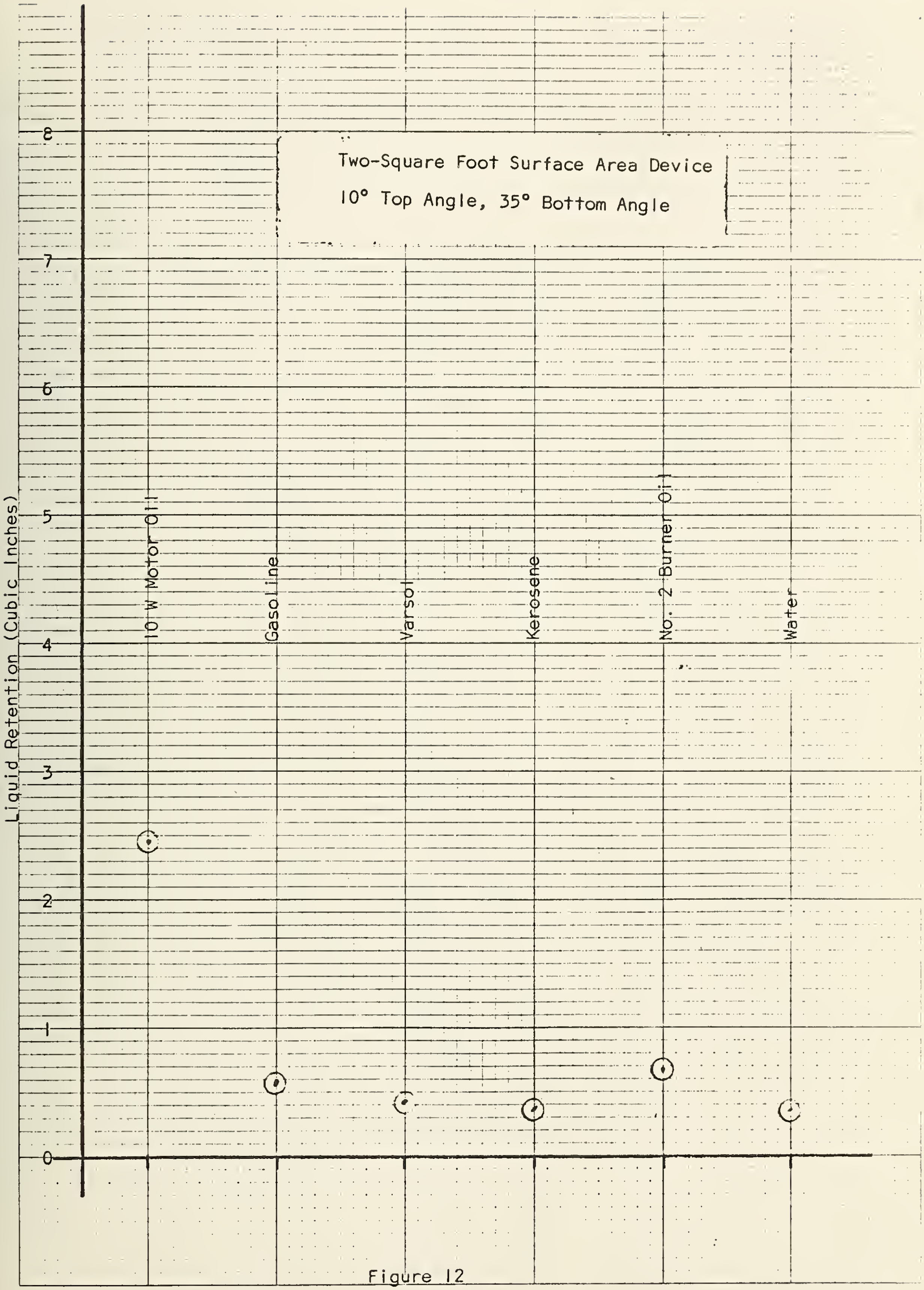

Two-Square Foot Surface Area Device
10° Top Angle, 35° Bottom Angle
Liquid Retention (Cubic Inches)
8
7
6
5
4
3
2
1
0
10 W Motor Oil
Gasoline
Varsol
Kerosene
No. 2 Burner Oil
Water

Figure 12

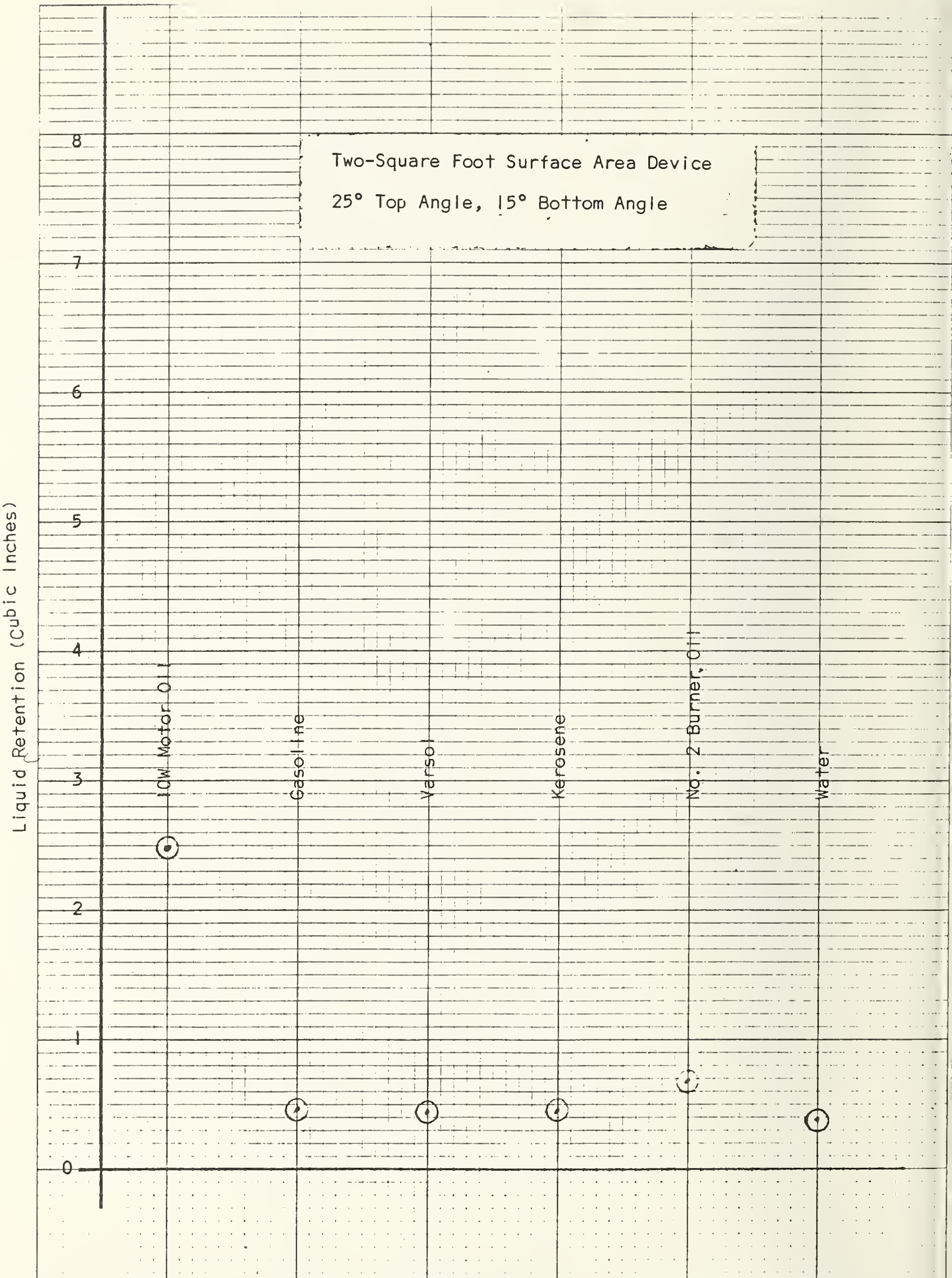
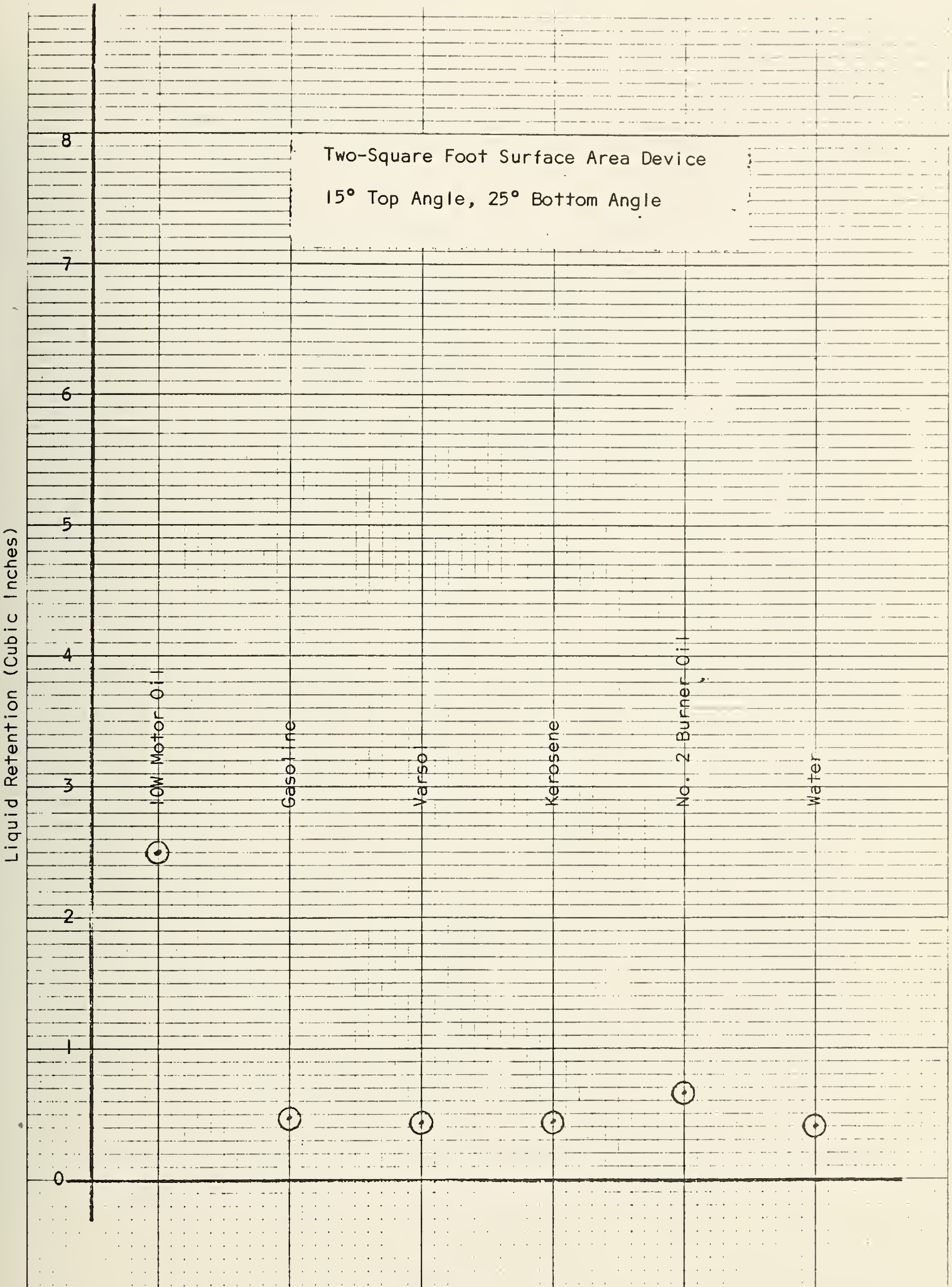
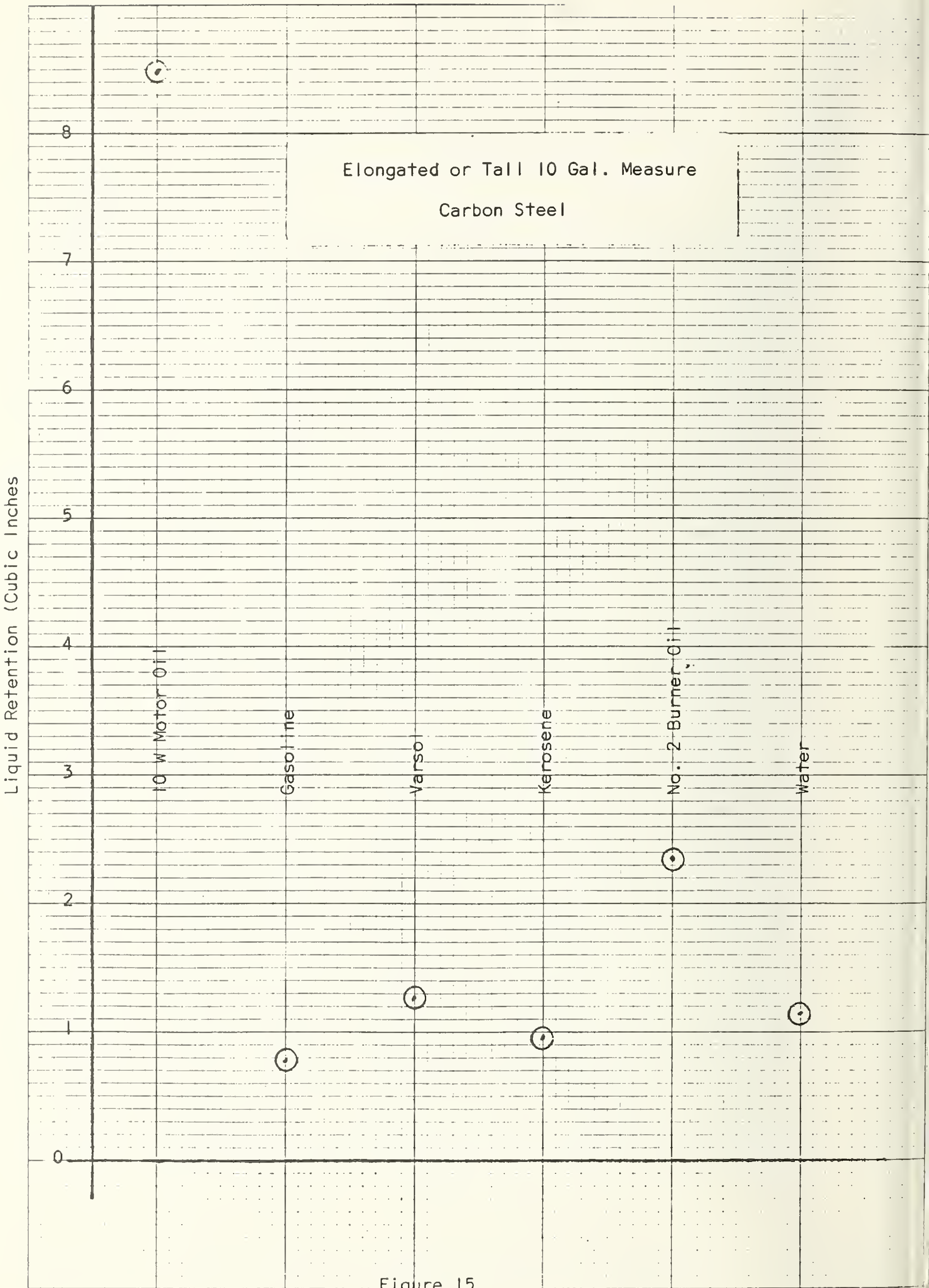

Two-Square Foot Surface Area Device
25° Top Angle, 15° Bottom Angle
Liquid Retention (Cubic Inches)
0
1
2
3
4
5
6
7
8
10W Motor Oil
Gasoline
Varsol
Kerosene
No. 2 Burner Oil
Water

Figure 13



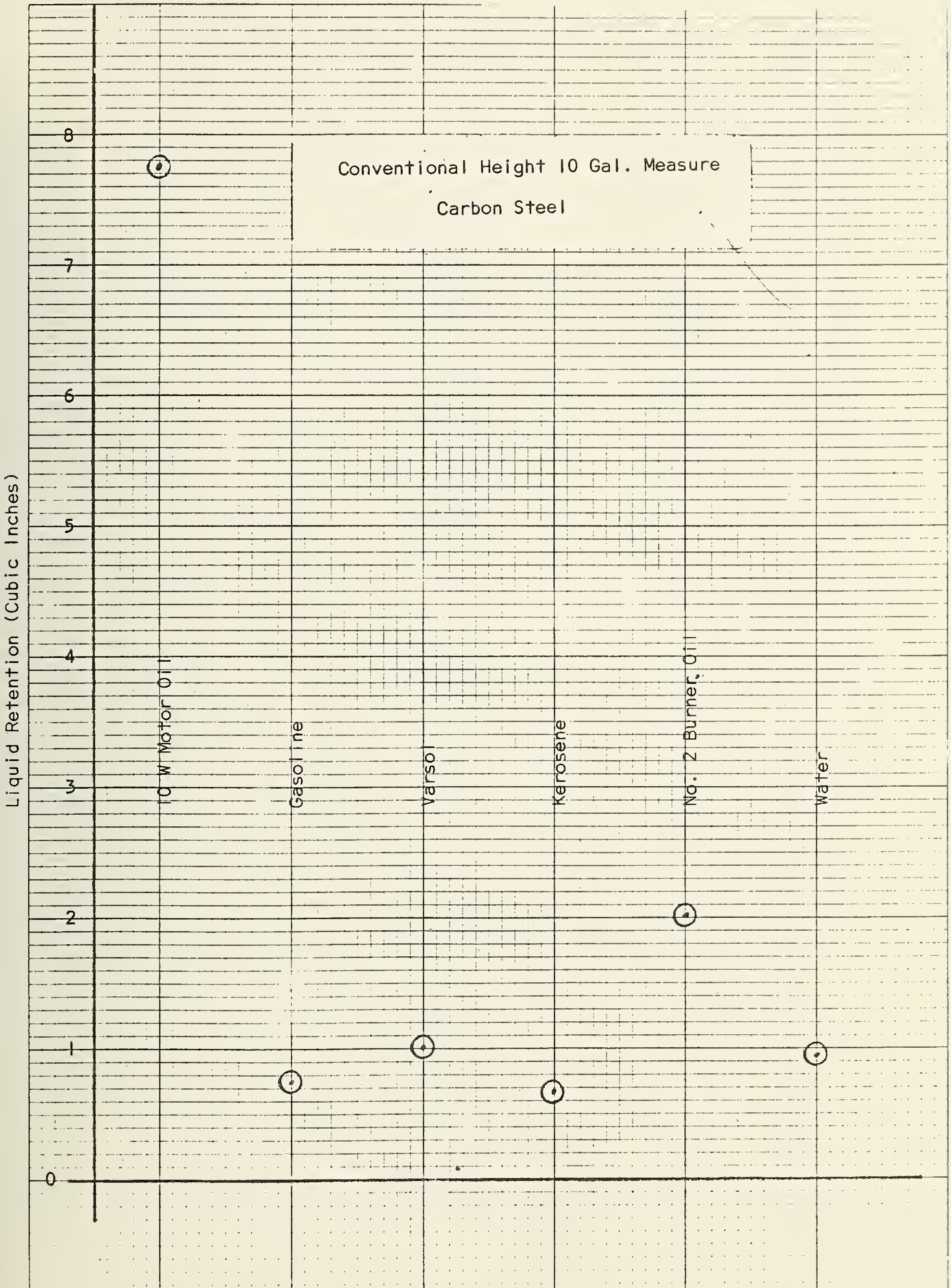
Two-Square Foot Surface Area Device
15° Top Angle, 25° Bottom Angle
Liquid Retention (Cubic Inches)
8
7
6
5
4
3
2
1
0
10W Motor Oil
Gasoline
Varsol
Kerosene
No. 2 Burner Oil
Water

Figure 14



Elongated or Tall 10 Gal. Measure
Carbon Steel
Liquid Retention (Cubic Inches
0
1
2
3
4
5
6
7
8
10 W Motor Oil
Gasoline
Varsol
Kerosene
No. 2 Burner Oil
Water

Figure 15



Conventional Height 10 Gal. Measure
Carbon Steel
Liquid Retention (Cubic Inches)
0
1
2
3
4
5
6
7
8
10 W Motor Oil
Gasoline
Varsol
Kerosene
No. 2 Burner Oil
Water

Figure 16

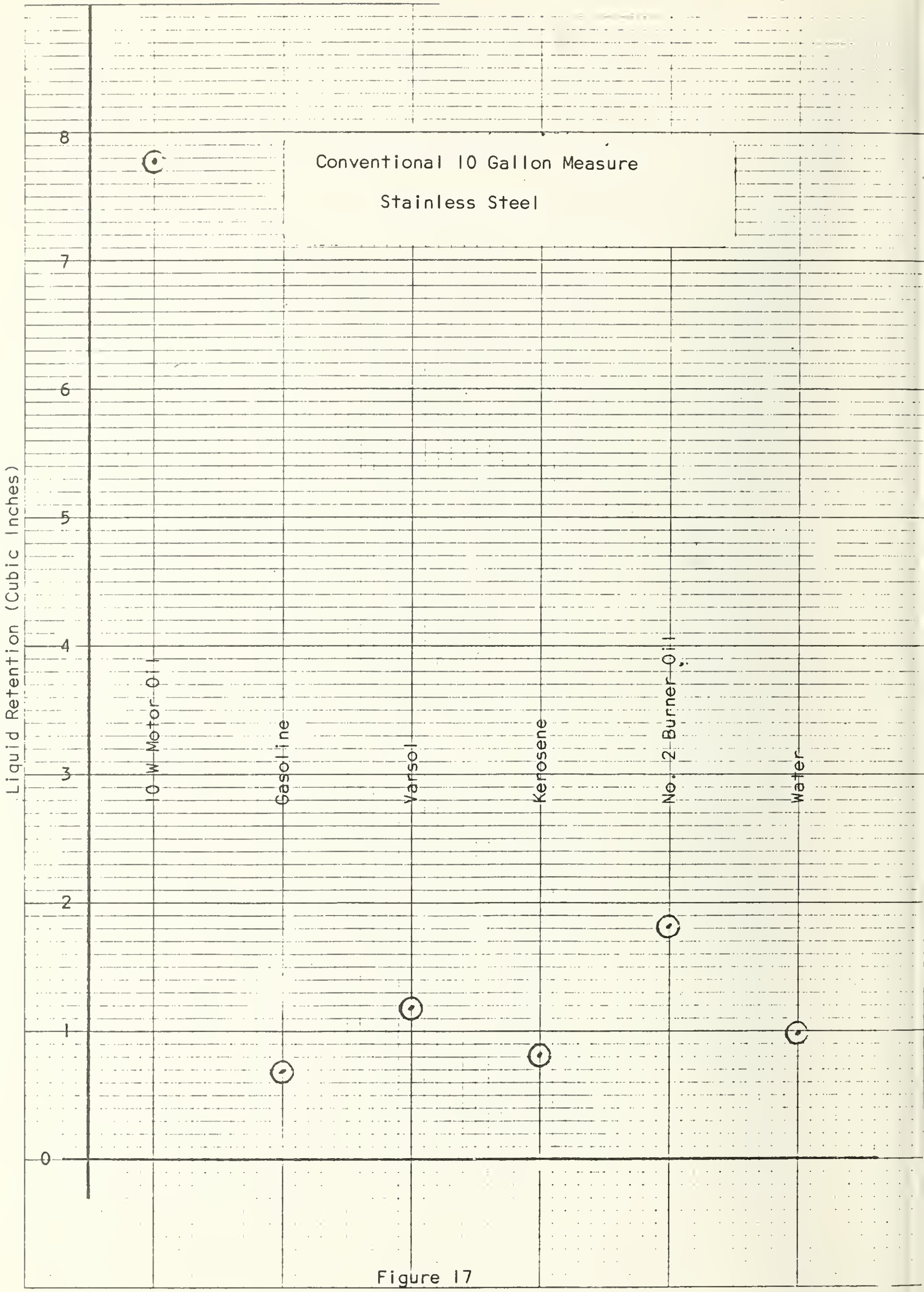

Conventional 10 Gallon Measure
Stainless Steel
Liquid Retention (Cubic Inches)
0
1
2
3
4
5
6
7
8
10 W Motor Oil
Gasoline
Varsol
Kerosene
No. 2 Burner Oil
Water

Figure 17

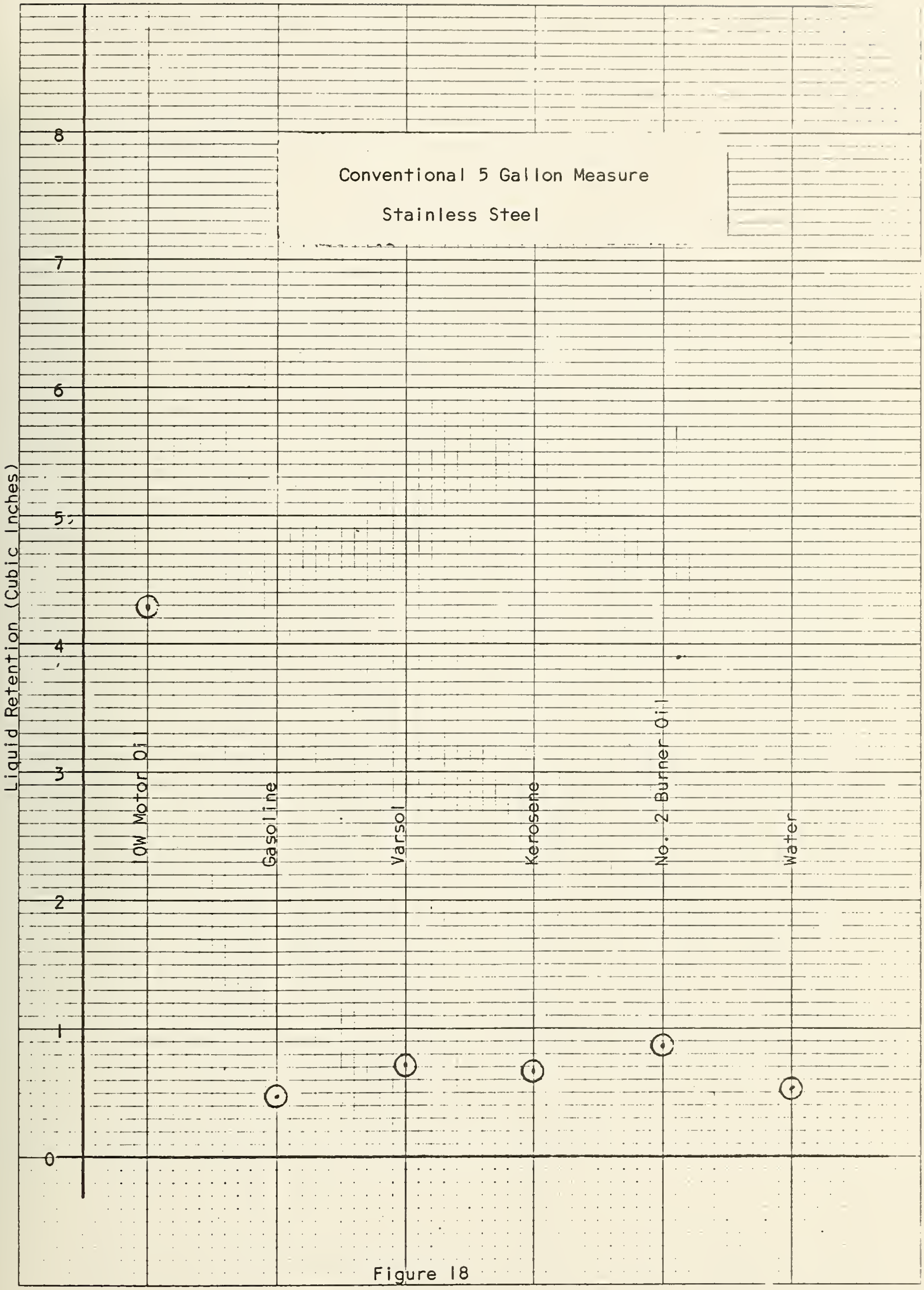

Conventional 5 Gallon Measure
Stainless Steel
Liquid Retention (Cubic Inches)
0
1
2
3
4
5
6
7
8
10W Motor Oil
Gasoline
Varsol
Kerosene
No. 2 Burner Oil
Water

Figure 18

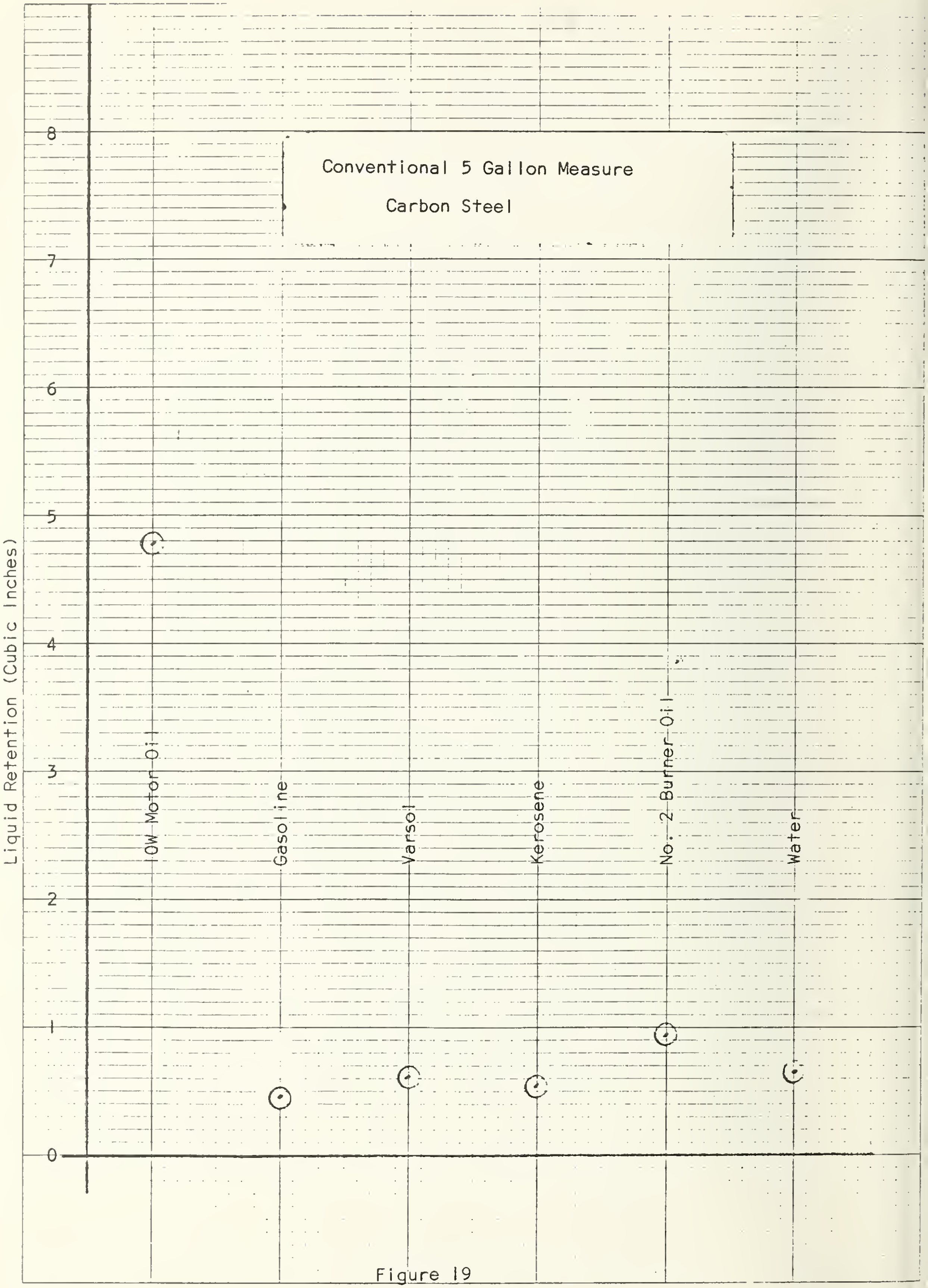

Conventional 5 Gallon Measure
Carbon Steel
Liquid Retention (Cubic Inches)
0
1
2
3
4
5
6
7
8
10W Motor Oil
Gasoline
Varsol
Kerosene
No. 2 Burner Oil
Water

Figure 19

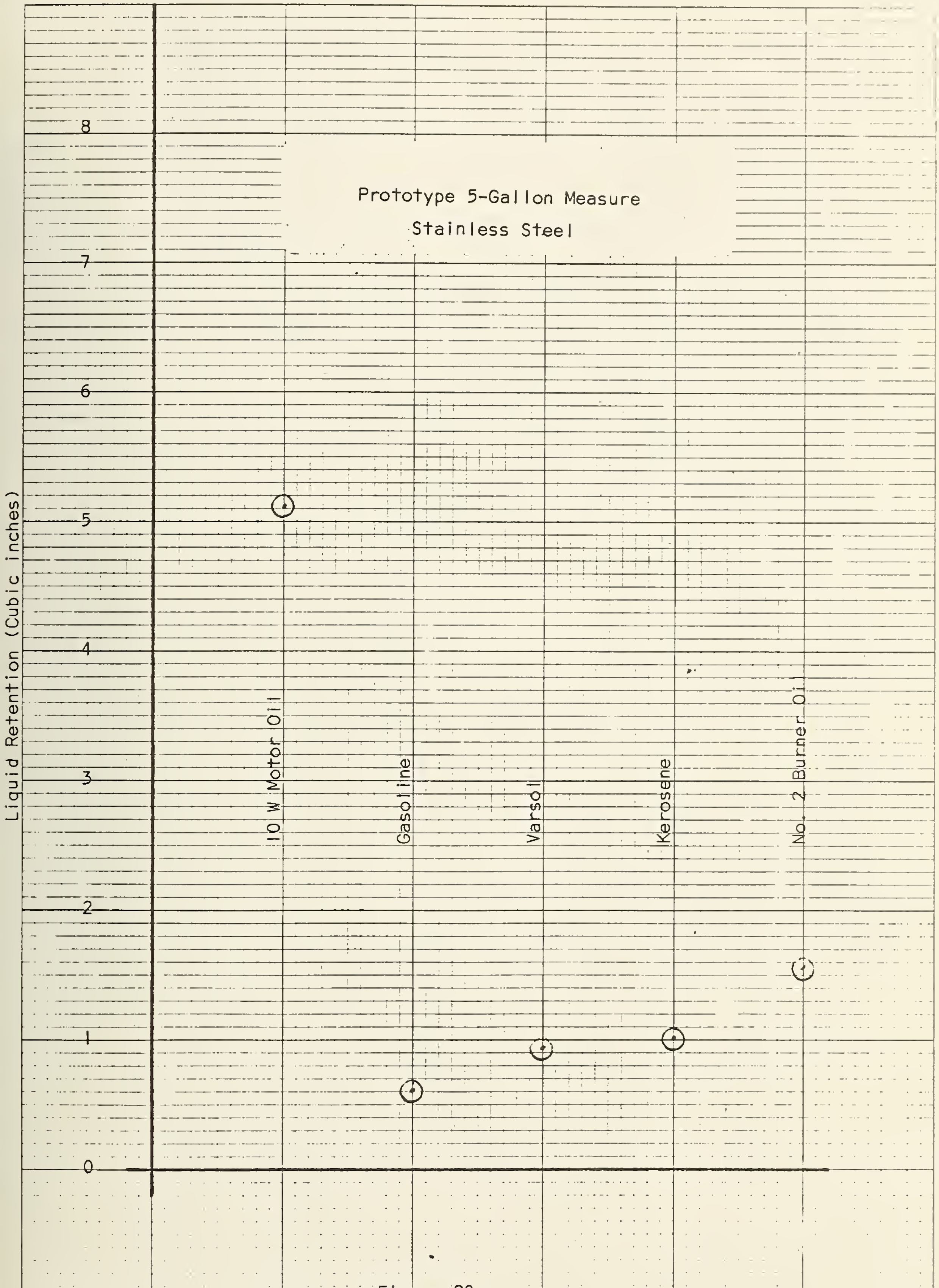

Prototype 5-Gallon Measure
Stainless Steel
Liquid Retention (Cubic inches)
8
7
6
5
4
3
2
1
0
10 W Motor Oil
Gasoline
Varsol
Kerosene
No. 2 Burner Oil

Figure 20

calibration and test method would be required if a "To Contain" measure were not employed.

An attempt was made to correlate surface area with liquid retention. It appeared that for devices of similar geometric configuration an estimate of retention could be made within 10-15 percent. It might be possible to predict the liquid retention of large provers in this manner if a small scale model was tested beforehand with the desired liquid. The need for such a procedure is questionable for most liquids. If the amount of water retained in a 1000 gallon prover was found to be 30 in^3, it is unlikely that the prover would retain ±25 percent different than that amount of gasoline, varsol, or kerosene. Although this 7.5 cubic inches per 1000 gallons is not totally insignificant, it represents less than 2 percent of the current meter system tolerance for a 1000 gallon test draft and would normally be considered beyond the scale readability for a prover of this volume.

The amount of liquid retained by a prover is influenced by the liquid, prover geometry, surface area, surface condition, and the drain procedure. The benefit from an extensive investigation of these factors does not warrant further testing at this time.

7.0 EQUIPMENT SPECIFICATION. One of the primary goals of the research associate program was to collect information that could be used to develop a specification, that if submitted to any fabricator, the result would be an acceptable metal test measure.

As the test measure evaluation program proceeded, it was decided that prior to developing a complete specification it would be necessary to establish the methods and conditions under which equipment would be inspected to judge compliance with a specification.

7.1.0 INSPECTION RECOMMENDATIONS. While conducting the tests associated with the research program and witnessing calibrations by several individuals, it was noted that no consistent examination or inspection procedure was followed. This was considered to be undesirable since it would indicate that the quality of equipment was left entirely up to the judgement of the individual and that acceptance/rejection criteria were non-uniform.

In an attempt to promote uniform practices, an inspection guide was written. After numerous revisions, the draft was sent to over 50 individuals involved in various phases of volume measurement. The individuals who were requested to review the draft represented large segments of the petroleum industry; state, federal, and foreign governments, and equipment manufacturers. The nearly 40 returns of the review request recommended very few changes. Only one negative review was received. That reviewer questioned the usefulness of such a listing until meaningful quantitative limits could be established for the acceptance or rejection of a particular prover. On the other hand, another reviewer requested a copy of the final revised draft in order to implement the inspection process in the company measurement manual. Since the procedure dealt primarily with quality, cleanliness, and potentially ever-changing corrosion and the overwhelming concensus favored publication of the document, a final draft was prepared which incorporated the pertinent recommendations of the reviewers. The following is the text as submitted to the American Petroleum Institute for publication consideration:

INSPECTION OF METAL VOLUMETRIC STANDARDS

Metal Volumetric Standards include all non-pressurized containers employed in determining volume, i.e., test measure standards and meter prover standards. Measurement activities often include inspection or examination of metal volumetric standards. Inspections or examinations are most often required when: 1) a new device is received from the manufacturer; 2) a device is to be used in a transfer transaction or displacement prover calibration; and 3) a device is to be submitted for calibration or recalibration.

The basic design and requirements of metal volumetric standards have been reviewed and evaluated in order to develop an inspection guide that will promote "uniformity and standardization".

I. DESIGN. The basic design must conform to published or recommended specifications of recognized authority.
   - A. National Bureau of Standards (Handbook 105-3).
   - B. American Petroleum Institute.
   - C. Other.

II. SUPPORTING DOCUMENT EXAMINATION. Certain documents must be furnished for examination by the inspector.
   - A. Report or Certificate of Calibration.
   - B. Material Identification (Certified Mill Reports for equipment complying with NBS Handbook 105-3, May 1971).
   - C. Interior Coating Identification (if applicable).
   - D. Drawings.
   - E. Gage glass size and material specification.
   - F. Other documents required by individual company policy.

III. VISUAL INSPECTION OF STANDARD. The device must be subjected to a complete visual inspection of all pertinent features.
   - A. Exterior.
      1. All surfaces affecting volume must be dent-free.
      2. Non-invertable measures must be equipped with a suitable operating drain valve with leak check capability (double block & bleed).
      3. Non-invertable measures must be equipped with two adjustable spirit levels, mounted at right angles to each other on the upper cone. Levels to be of reasonable quality, shielded style or provided with a hinged protective cover.
         - a. must have adjustable legs to allow leveling.
      4. Surface finish must be clean and free of mill scale, grease, etc.
         - a. if exterior surface is painted, the paint coating must be reasonably free of scratches and corrosion damage.

5. Weld quality must conform to an appropriate welding code.
    a. American Petroleum Institute (Guide for Inspection of Refinery Equipment Appendix - Inspection of Welding).
    b. American Society of Mechanical Engineers (ASME Boiler and Pressure Vessel Code).
    c. American Welding Society (Inspection of Welding, Chapter 6 of Welding Handbook, Section I, American Welding Society, New York 1968).
    d. American National Standards Institute, ANSI B-31.3.
    e. Others.
6. Non-invertable measures must have a rigid, sloping (minimum pitch 5°) drain line.
7. (NBS Handbook 105-3, Section 6.2) "Each standard shall bear, in a conspicuous place, the name or trade mark of the manufacturer, the nominal volume (gallons, cubic inches, liters, etc.), and a serial or identification number. The material from which it is constructed shall be identified together with the cubical coefficient of thermal expansion per degree (F or C) for that material."
8. Material identification must be indicated on an inspection plate and must agree with documentation (Section II-B).
    a. Carbon Steel (type)
    b. Stainless Steel (type)
        1. magnetic
        2. non-magnetic
    c. Non-metals.

B. Interior.
1. Joints and seams must be smooth and uniform.
2. Surfaces, including joints and seams, must be clean and free of grease, dirt, or oil film.
3. Surfaces must be smooth and free of rust corrosion.
4. Potential air or water traps either by design or damage are not permissible.
5. Coating material, if used, must be uniformly applied, completely coated, and free of voids or bubbles.
6. Any coating material used, i.e., epoxy, phenolic, etc., must be resistant to the effects of alcohol, benzene, petroleum products, and water.
7. Non-invertable measures must be equipped with a fixed anti-swirl plate (optional API 1101, required NBS Handbook 105-3).

C. Graduated Neck.
  1. The neck must be cylindrical and uniform in diameter.
  2. Scale (non-corrosive metal).
    a. must be firm and secure.
    b. must be easily adjustable.
    c. provision must exist for affixing a lead and wire seal which will detect unauthorized scale adjustment.
    d. scale divisions or graduations must be linear.
    e. scale length must be appropriate to the measure.
    f. applicable volume units must be clearly indicated (i.e., cubic inches, fluid ounces, gallons, etc.).
    g. scale markings must be legible.
  3. Gage Glass.
    a. must be clean and clear after wetting (no droplets).
    b. must be capable of being removed, cleaned, and replaced (see Section II-E).
  4. The top surface must be ground, machined, or formed smooth in order to serve as a level "benchmark".

IV. CASE OR SHIPPING CONTAINER. Any standard normally transported to various locations should be protected with a case, shipping container, or other suitable protective means.
  A. Must provide sufficient protection to instrument during storage or transport (protect against dents and scale damage).
  B. The container design must provide for rigidity.

V. STANDARD INTEGRITY INSPECTION PROCEDURE. Periodically, a measure should be checked to verify integrity (in addition to the initial test when new). A step-by-step procedure is recommended.
  A. Making certain that no thermometers installed will be damaged by exceeding their range, fill with warm to hot water (100 to 140 degrees F). Allow to stand for 30 to 60 minutes.
    1. Check all seams, joints, pipe fittings, gage glass, and overall measure for leaks.
    2. Check drain valve for leaks or air entrapment. Open and close the valve several times to verify positive sealing of the valve. (Optional: Take and record a level reading, then crack drain valve open and draw off approximately 1 gallon into a wetted measure and return the water to the prover. If the level in the

prover standard is lower, either there was air in the piping ahead of the valve, or some part of the valve body cavity previously filled with air is now filled with water.)

B. Drain the standard.
   1. Observe the effectiveness of the anti-swirl plate while the fluid is draining.

C. Fill the standard with the calibrating medium.
   1. Repeat the checks listed in Sections V-A-1 and V-A-2.

D. The thermometers to be used with the standard should routinely be subjected to a calibration or a comparison with a standard thermometer.

7.2.0 SPECIFICATION. As a result of tests conducted with metal volumetric test measures, it was determined that existing 1, 5, and 10 gallon measures are capable of good quality measurement only if the recommended procedure is carefully followed. The uncertainty of their calibration is meaningless if improper emptying procedures are used and insufficient emphasis is made in neck scale reading. These two potential problem areas could be improved by designing a bottom drain measure with a smaller diameter neck. These changes would provide more consistent drains and improve scale resolution. A specification for such a measure was prepared and is presented here for consideration.

EQUIPMENT SPECIFICATION
METAL VOLUMETRIC FIELD STANDARDS
(BOTTOM DRAIN STYLE)
(See Figure 21)

Field Standard Size - This specification covers 1, 5, and 10 gallon capacity field standards.

Type and Design - The standard shall have a barrel of uniform circular cross-section with a smaller diameter neck of uniform circular cross-section connected to the barrel by a conical breast section. The bottom must be deep-dished or conical downward with a drain tube connected to the lowest point and extending outward and downward beyond the circular barrel. A base, which is an integral part of the standard, must be provided and 3 adjusting legs must be attached to the base to enable leveling. The legs must provide a stable footing for the standard. A gage glass and adjustable scale plate assembly must be permanently attached to the upper cone or

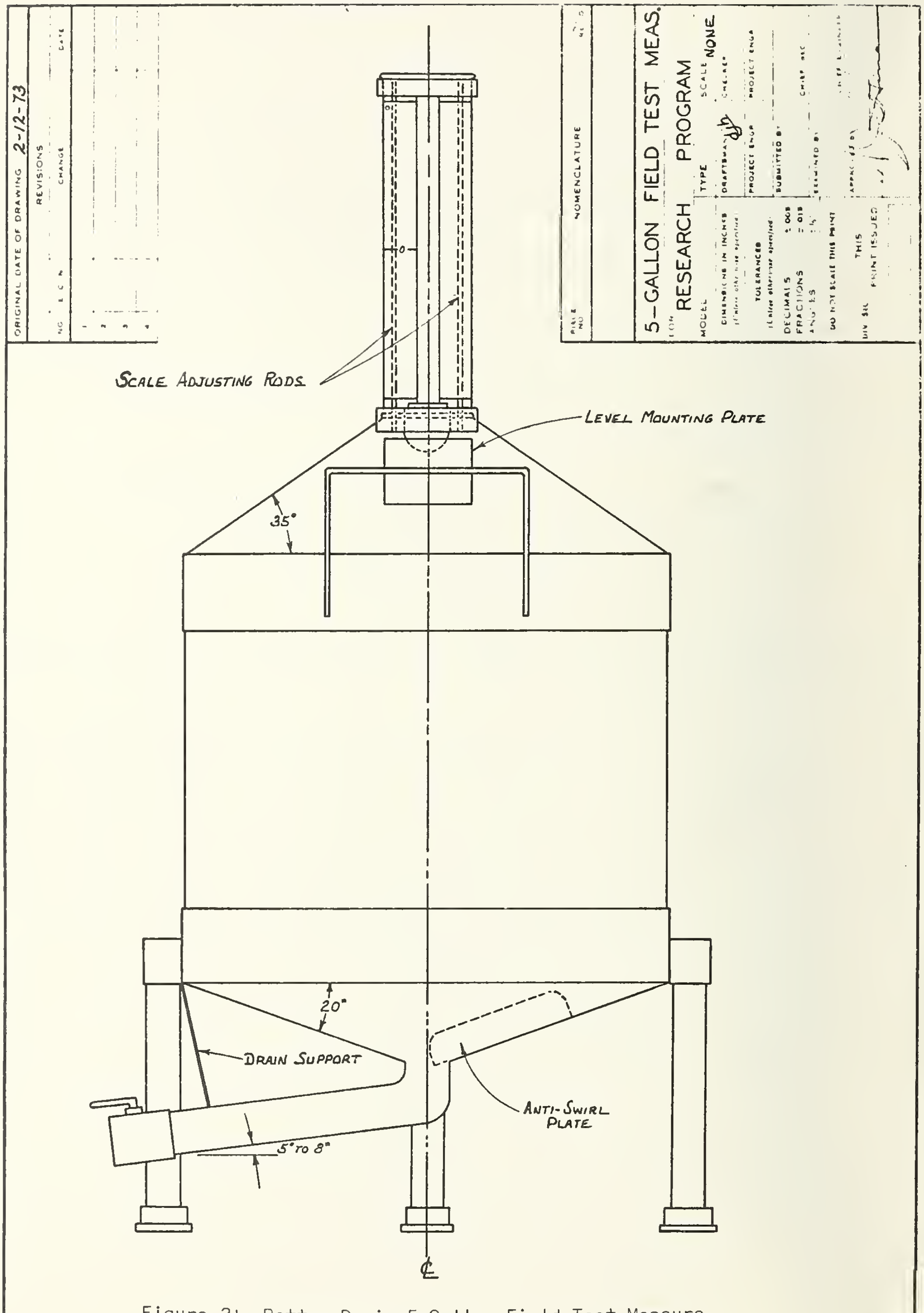


Figure 21. Bottom Drain 5-Gallon Field Test Measure

breast section and the neck. Potential air or contamination entrapments must be avoided.

Material - The minimum low carbon steel or stainless steel material required is 18 gauge (0.0478" nominal), except 16 gauge (0.0598" nominal) material for bottom cone and base. Aluminum, fibre-glass, high impact plastics, or other materials must be of sufficient thickness to equal or exceed the strength characteristics of low carbon steel of specified thickness. Physical properties of any material used must be certified.

The material must be impervious to any hydrocarbon liquid or organic solvents. Dissimilar materials in a measure (i.e., 300 & 400 Series Stainless Steel) are not acceptable.

Fabrication - Field standards must be assembled to withstand reasonable field and transit application.

Joints - All joints must provide strength equal to unjointed material. Joints may be welded, brazed, or soldered. (Order of preference as listed). Joints must be smooth, fully filleted connections. Sharp protrusions or voids are unacceptable. If metal is overheated during fabrication the device must be annealed (heat-treated). NOTE: Soft solder is not permissible for achieving the bottom joint. It can be used to fillet interior seams.

Forming or Shaping - All formed sections (top and bottom cone) must be smooth continuous surfaces. Pockets, dents, or crevices that may entrap air, liquid, or contaminents shall be judged unacceptable.

SPECIAL FABRICATION REQUIREMENTS

Handles - A pair of smooth handles shall be attached to a top reinforcing band. These handles should be located to facilitate lifting the standard.

Reinforcing Bands - External reinforcing bands shall be attached to the cylindrical barrel as judged necessary by the manufacturer for strength and potential damage protection. Minimum 16 gauge (0.0598" nominal).

Surface Preparation - If the standard interior and/or exterior is to be coated or plated, the surface must be peened, sandblasted, pickled, etc., in accordance with the recommendations of the coating or plating manufacturer. Standards that are not coated must be completely free of foreign matter and chemically clean.

Coating, interior - The interior surface must be corrosion resistant and impervious to hydrocarbons and organic solvents. Surface may be coated with galvanized, terne-coated (lead-zinc), baked phenolic, or epoxy resin. Epoxy or phenolic coatings must be 0.005 to 0.007 inches thick. Chemical resistance properties of coatings must be documented to owner.

Coating, exterior - The exterior surface must be corrosive resistant and impervious to hydrocarbons, organic solvents, and normal exposure to atmosphere. Rust resistant materials do not require auxiliary coatings unless specified. Painted measures must be primed with a metal primer (zinc-chromate or equal) prior to painting.

SPECIAL REQUIREMENTS

1. The top surface of the standard must be a rolled edge or fitted with a reinforcing ring. The top surface must represent a level plane when the standard is placed on a level surface.

2. The gage glass must be borosilicate or other material certified to be impervious to extended service in hydrocarbons or organic solvents. The minimum diameter shall be 0.50 inches.

3. The gage assembly must be rigid and shall include a gage glass open at the top for cleaning and positively sealed at the bottom without cement, a scale plate of appropriate divisions above and below zero level, adjusting rods to provide 1/4 scale division adjustments, and have provisions for attaching a "lead and wire" seal such that adjustment or scale removal will destroy the seal. The value of the scale divisions must be clearly indicated on the scale, i.e., cubic inches, cubic centimeters, etc.

4. Each standard shall bear a permanent conspicuous plate upon which the following information appears:

   a. Address, name or trademark of manufacturer.

   b. Material identification (type and thickness).

   c. Cubical coefficient of thermal expansion per degree Fahrenheit or Celsius. (Reference shall be documented).

   d. Manufacturers model number (optional).

   e. Non-repetitive serial or identification number.

   f. Statement of nominal volume and reference temperature.

5. Device must comply with the requirements of Inspection Guide, Section 7.1.0.

6. A positive sealing, fast acting valve shall be attached to the drain line. The valve must be stamped with the same identification number as the standard or provided with means to affix a

lead and wire seal between the valve and drain line. If a ball valve is used it must have both upstream and downstream seals. A short length of metal braided hose or a similar conductor shall be installed on the downstream side of the valve. The end of this hose shall not be threaded.

Anti-Swirl Plate - A baffle or anti-swirl plate must be attached to the bottom to reduce swirl during emptying.

Level Mounting Plate - A two-inch-square flat surface must be provided directly below the scale assembly. This surface may be soldered to the gage assembly bottom nipple and the top cone. A "Bulls-eye" level no greater than 1" diameter is to be mounted on the plate to indicate level when the measure is so adjusted.

Scale Assembly - The scale assembly shall consist of a gage glass, a graduated scale (1 or 2), adjusting rods, fittings to seal the gage glass such that the glass can be replaced without difficulty (cementing is not acceptable), brackets for mounting the assembly on the test measure, and brackets to hold the scale plate rigid. The top bracket, the left-side adjusting rod, and the left-side graduated scale should be drilled to accept a lead-and-wire seal. The assembly must be designed so that the lead-and-wire seal will be broken if the graduated scale is removed or adjusted. NOTE: Right or left side notation refers to the side when viewed from the front.

Scale Plate - The basic scale on all standards shall be cubic inches or cubic centimeters. If dual scales are used to include other units of volume simultaneously, the basic scale must be mounted on the left side and the secondary scale mounted on the right. The scales must be individually adjustable. Only one scale is permitted on a single plate.

Scale Markings - The markings on a scale plate shall be permanent and of contrasting color to the color of the plate. The markings shall include graduation lines and numbers and if only one plate is used for graduations, the second plate can be used for manufacturer identification information.

Scale Graduations - The graduations must provide a minimum indication of fifteen (15) cubic inches above and below the zero line for 1 and 5 gallon and twenty (20) cubic inches for 10 gallon (or metric equivalents). The graduation lines must be of uniform width, not more than 0.025 inch or less than 0.015 inch in width. The minimum distance between scale graduation lines shall be 0.0625 inch (1/16) or minimum 0.070 center to center. The graduation lines shall consist of intermediate lines, major lines, and the zero line. The graduation lines for front mounted scales must extend to the edge of the scale plate nearest the gage glass. The minimum length of these lines is as follows:

	Intermediate Lines	Major Lines	Zero Line
If mounted in front of glass	0.125 inch	0.25 inch	Entire width
If mounted behind the glass	0.50 inch	0.75 inch	Entire width

For the 2" neck measures described in this specification, the intermediate graduations should reflect 1/2 cubic inch and the major divisions should reflect each cubic inch or metric equivalent. Each 5 major divisions should have an adjacent number to indicate the value of that division.

Dimensional Requirements -

Size	Minimum Metal Gage (U. S.)	Neck Diameter (Inside) Inch	Gage Tube Diameter (Inside) Inch	Minimum Top Cone Pitch	Minimum Bottom Cone Pitch	Minimum Drain Size Inch	Approximate Measure Diameter Inch	Approximate Overall Height Inch
1 gal	18* (.0478")	2	1/2	35°	20°	1/2	8	17.5
5 gal	18* (.0478")	2	1/2	35°	20°	1	11	27.
10 gal	18* (.0478")	2	1/2	35°	20°	1	13.5	33.

*Minimum (.0598") U.S. Metal Gage for bottom cone Is 16

<u>Operating Conditions</u> - This specification may be used for Volumetric Standards intended for use with liquids which may include but is not limited to the following:

1. Gasoline
2. Jet fuel
3. Kerosene or stove oil
4. Diesel oil
5. Alcohol
6. Commercial solvents
7. Water
8. Dilute acid

CAUTION: The material of construction must be suitable for the specific liquid application.

8.0 CALIBRATION PROCEDURE. As evaluation tests were being conducted, information was collected concerning procedural requirements to establish repeatable measurements with metal volumetric standards. It developed that a series of recommendations was considered necessary for calibration activity. In evaluating the potential audience for such a listing it was agreed that laboratory metrologists would be the primary interested reader. The problem as to how best to present a calibration procedure recommendation was discussed with a number of State weights and measures laboratory metrologists. The concensus of those contacted was preference of a step-by-step procedure of the entire calibration procedure. A logical benefit of such a presentation is larger acceptance and subsequently greater calibration uniformity.

Two distinct calibrations may be encountered in volume calibration activity. These different values are the amount of liquid a vessel is able to hold or contain and the amount of liquid that may be poured out or delivered from the vessel under specified conditions. The two calibration values are commonly referred to as "To Contain" and "To Deliver". The following descriptions are presented in an attempt to eliminate any misunderstanding of the two types of calibration:

> A "To Deliver" (WET) calibration reflects the volume that the standard will deliver when emptied in a prescribed manner. This calibration requires that the standard be initially filled and emptied in accordance with prescribed procedures (wetted) prior to the filling and emptying process of the calibration.

A "To Contain" (DRY) calibration reflects the volume that a standard will contain when filled to a specified level. This calibration requires that the standard be completely dry prior to each filling.

8.1.0 VOLUMETRIC CALIBRATION PROCEDURE ("To Deliver"). Volumetric Calibration of Field Test Measures should be performed in a stable environment laboratory or calibration facility. The following materials are required prior to beginning this procedure:

1. Clean volume standard (preferably slicker plate).
2. Calibration data for standard.
3. Stop watch.
4. Spirit level of reasonable quality.
5. Thermometers (2) - Immersion Type, 1/2°F divisions or 1/4°F divisions.
6. Powder or liquid detergent.
7. Brush to clean gage glass.
8. Alcohol and degreasing solvent.
9. Compressed air supply.
10. Flashlight or small portable lamp.
11. Inspection mirror.
12. Data sheet for recording observed data. (See Exhibit 4 for sample data sheet)
13. Water stored at ambient temperature.
14. Room thermometer.
15. Extra glass slicker plate or measure cover.

An important preliminary to performing a calibration is to have everything ready and convenient. (See Figure 22). The pertinent

VOLUME CALIBRATION DATA SHEET

Description________________________Manufacturer___________________

Size__________________Material_____________Interior Coating________

Identification Number____________Customer__________________________

Calibration by_____________________Date____________________________

Condition of Measure____

Calibration Fluid_________Time beginning_________Time ending________

Standard used for calibration______________________________________

	No. 1	No. 2
Fluid Temperature in Standard	________	________
Meniscus Level (Memo only)	________	________
Meniscus Level	________	________
Fluid Temperature in Measure	________	________

GRADUATED NECK CALIBRATION

Value of each scale division is:___________________________________

Initial Scale Reading________________

Add_________cubic inches　Actual Scale Reading________________

Add_________cubic inches　Actual Scale Reading________________

Add_________cubic inches　Actual Scale Reading________________

Add_________cubic inches　Actual Scale Reading________________

Add_________cubic inches　Actual Scale Reading________________

Add_________cubic inches　Actual Scale Reading________________

Exhibit 4 Sample Data Sheet

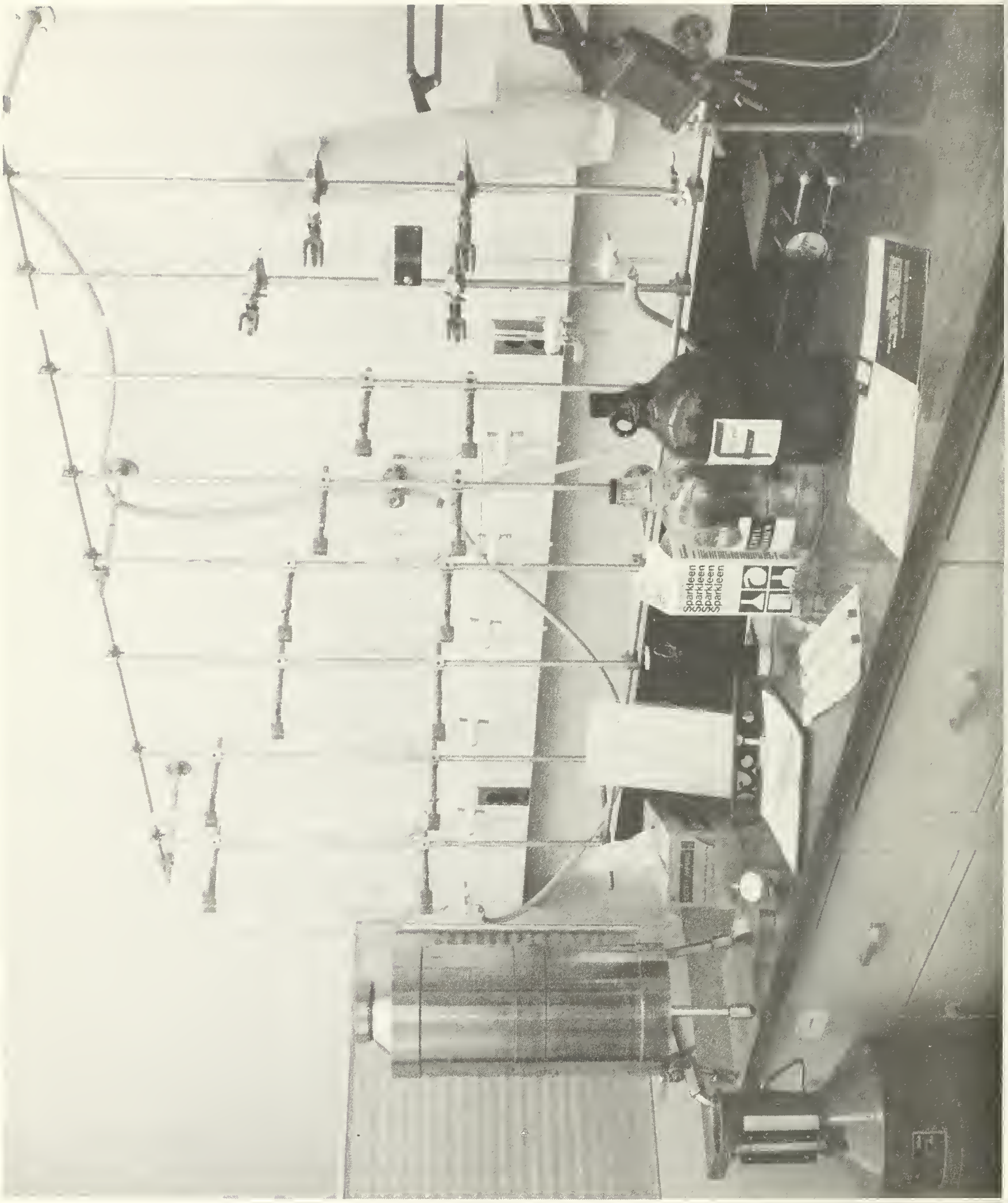


Figure 22: Recommended equipment set-up for volume calibration.

portions of the data sheet should be completed and placed in a position convenient for the metrologist to record his observations.

The first step in the calibration procedure is the visual and physical examination of the device submitted for calibration. The volumetric device should be examined for appropriateness for the intended application. Any discrepancies should be noted in the appropriate section of the data sheet. If acceptance and rejection criteria are not clearly established, discrepancies should be discussed with the proper official before proceeding with the calibration or at least prior to releasing the measure and the calibration report.

A complete physical inspection should encompass a thorough cleaning process. (See Exhibit 5 before proceeding). This can be accomplished as follows:

1. If the test measure is epoxy coated, clean thoroughly with water and detergent; perform steps 5, 6, 7 and 8; inspect as in step 10; then proceed to step 11.
2. Pour approximately 50 mL of degreasing solvent into the dry measure.
3. Rotate and tip the measure to ensure wetting the interior surfaces.
4. Drain solvent from measure, rinse with approximately 50 mL of alcohol as in step 2, and fill about 1/3 full of warm to hot water. Add detergent.
5. With a brush or cloth, wash the interior surface.
6. Clean the gage glass with the detergent and water.

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, D.C. 20234

October 12, 1971

M E M O R A N D U M

To: State Metrologists

From: B. C. Keysar, Engineering Technician
Office of Weights and Measures

Subject: Epoxy-Coated Test Measures

Mr. D. J. Hine, API Research Associate, assigned to the Office of Weights and Measures, has pointed out that there is a high probability that an epoxy-coated test measure submitted for examination and calibration might be subjected to cleaning with an organic solvent in accordance with NBS Monograph 62. Monograph 62 did not include any specific consideration of epoxy-coated equipment and it is likely that the cleaning procedures prior to calibration might easily be construed to include all types of test measures.

Monograph 62 specifies, "After cleaning with an organic solvent,..." and if alcohol is used as the organic solvent, as it is in most cases, a reaction with the epoxy coating will result in permanent damage. There are reportedly some epoxy materials that are not affected by the alcohol or other solvent cleaning but none of these have been evaluated by this office. We recommend that you not clean any epoxy-coated test measures with alcohol unless the manufacturer of the coating specifically states that the material is impervious to alcohol and other organic solvent solutions. The pre-calibration cleaning of epoxy-coated test measures can be accomplished with a bio-degradable detergent and water followed by a clean water rinse until all traces of the detergent are removed and then rinsed with distilled water. This procedure should provide a clean test measure for the subsequest calibration.

Exhibit 5

7. Add warm water until the level is well up in the neck. Let stand for 15 minutes and observe for leaks.
8. Empty the measure and flush with cool water until all suds disappear.
9. Pour 50 to 100 mL of alcohol. Rotate and tip as in step 3.
10. Drain alcohol from measure, fill with water, inspect for leaks and then empty measure.
11. Fill the standard (slicker-plate) with calibration quality water. Use a thermometer to determine the water temperature and record on the data sheet. Transfer this water to the measure to be calibrated using the prescribed 30-second drain following the cessation of flow. Close the drain valve.
12. Using a thermometer, determine the water temperature and record on data sheet. Slowly empty the test measure and when the first drip appears on the lip, time 10 seconds. NOTE: The vertical axis of the measure should never exceed 85° from the horizontal. (See Figure 23). At the end of 10 seconds, return the measure to the upright position and place the extra glass slicker or cover on the top of the neck of the measure to avoid excess evaporation. The measure and standard are now prepared to receive calibration water.
13. Fill the standard with calibration water. Determine the water temperature and record. Add water to the standard and slide the slicker plate into position. Verify that no

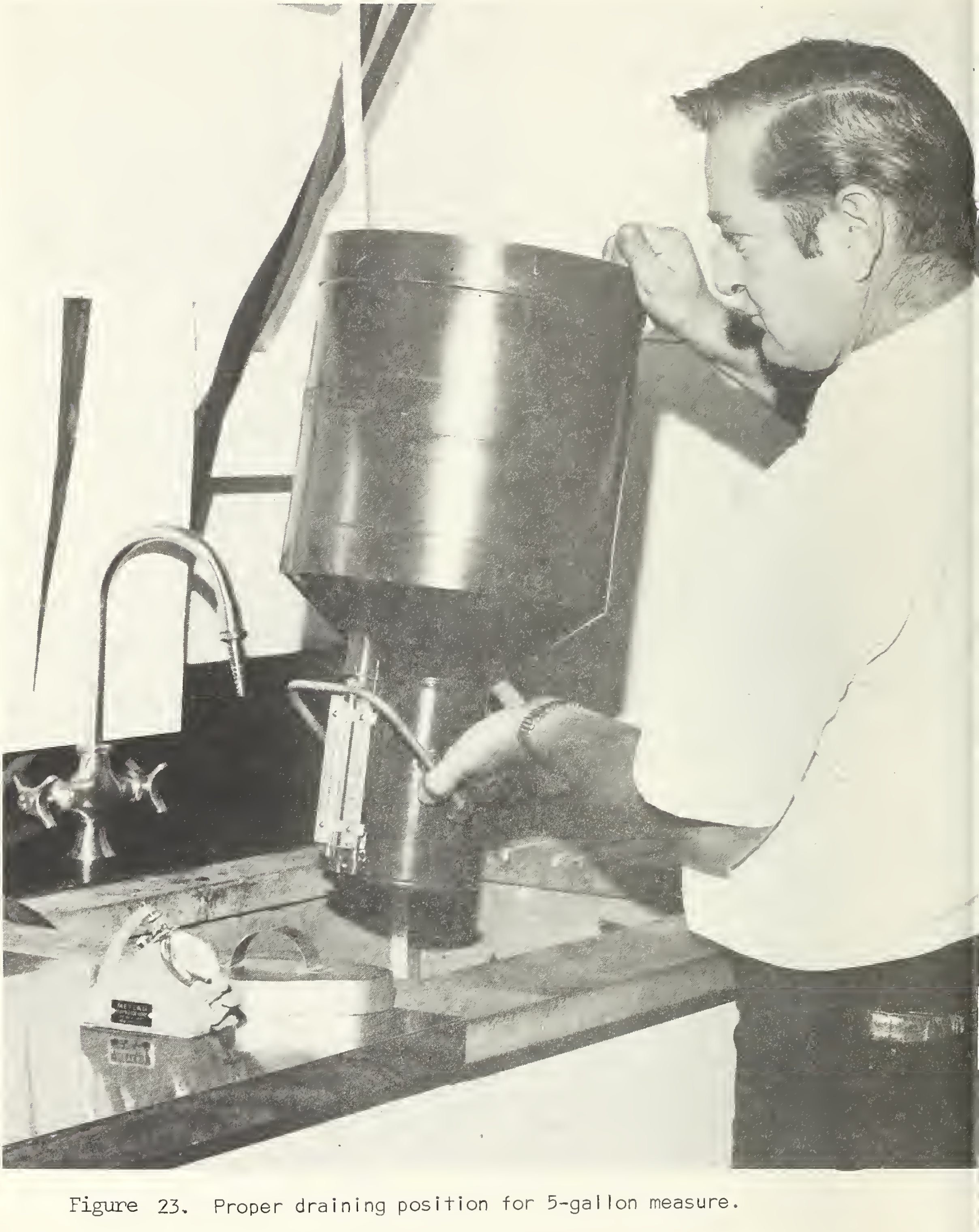


Figure 23. Proper draining position for 5-gallon measure.

air bubbles appear under the plate.

14. Place the test measure, with cover removed, in position such that the top of the neck is slightly above and not quite touching the open drain pipe of the standard. Open the drain valve and immediately slide (don't lift) the slicker plate off the top of the standard. Allow standard to drain 30 seconds after cessation of flow as in step 11. Close the drain valve.

15. Carefully transfer the test measure full of water to a level bench such that the meniscus in the gage glass is approximately at eye level.

16. Tilt the measure to raise the meniscus about 1 inch, then return to level condition. This will insure that the level in the neck is the same as the gage glass. NOTE: This can also be accomplished by either blowing gently into the top of the glass or by inserting a finger into the top of the glass and removing quickly, causing the water in the glass to rise.

17. When the meniscus has come to rest, estimate and record (Memo only the scale reading corresponding to the meniscus level when viewed at a distance of several feet. (ALWAYS READ AND RECORD THE BOTTOM OF THE MENISCUS LEVEL).

18. Placing the eye close to the scale and gage glass (approximately 5 inches), read and record the scale value corresponding to the level of the meniscus bottom. (Levels between scale divisions should be estimated to the nearest 0.1

division.) A convenient aid to scale reading is a rectangular piece of white paper with a line drawn through the center. (See 5-Gallon measure - Figure 1). The paper is inserted between the scale plate and the adjusting rods and in back of the gage glass. Starting with the line on the paper below the meniscus, slowly raise the paper until the line exactly coincides with the bottom level of the meniscus. Record the observed level and compare with data from item 17. This will eliminate gross reading errors.

19. Insert a thermometer on a string into the gage glass and slowly raise and lower the thermometer for approximately 20 seconds. Slowly raise the thermometer until the indicated temperature is just visible in the gage glass and can be read. This reading will be the water temperature. Remove the thermometer and record the observed water temperature.

20. Empty the test measure as described in step 12.

21. Repeat steps 13 through 20 recording data as indicated.

22. Compare the data from Run #1 with Run #2. If the temperature has remained virtually constant and the scale readings do not differ by more than 1/2 of a scale division, the calibration is finished. If the temperature is different, the temperature corrected volumes must be calculated to judge agreement between the two determinations.

23. Calibration of the graduated neck is accomplished by removing water until the scale reading is significantly

(15 in^3 if possible) below zero. Add liquid from a flask calibrated in increments of 5 scale divisions, reading and recording each incremental level, until the fluid level is well above zero. This should be performed twice to establish proper accuracy.

24. If a test measure is to be stored for an extended period in an environment that could promote rusting, the measure should be adequately protected. It can be thoroughly dried and stored in a sealed box containing a desiccant or it could be thoroughly wetted with kerosene prior to storage.

25. Perform calculations as follows:

CHANGE IN CAPACITY CAUSED BY CHANGE OF TEMPERATURE

If the capacity of a measure at any temperature, for example 60°F, is known, the capacity at another temperature may be determined by the use of the following formula:

$$V_t = V_{60} [1 + \alpha(t-60)]$$

where V_t = Capacity at t°F,

V_{60} = Capacity at 60°F,

α = Coefficient of cubical expansion of the material of which the measure is made, per degree F and

t = Water temperature °F

Average coefficients (per °F) for the metals most widely used in capacity standards are:

Brass	0.000030	(7)
Copper	.000028	(7)

Low carbon steel	.0000186	(5)
18-8 stainless steel	.0000265	(8)

(Numbers in parentheses indicate reference numbers.)

CORRECTION FOR DIFFERENCE IN TEMPERATURE

If the temperature of the water in the standard differs from that of the water in the measure being calibrated, a correction must be applied to bring the volumes of water to the same temperature basis.

A table for this purpose has been incorporated (Table I) in API Standard 1101 [9]. Lacking such a table, factors for the adjustment of water volumes to a common temperature may be derived from the density values. Water density tables are available from various handbooks as well as Table I, page 24 of this report.

Any correction to the water volume is partly offset by the volume change in the metal measures. (The temperature of a measure is assumed to be the same as that of the water contained.) To adjust the capacity of one measure to the capacity it would have at the temperature of the other, a modification of formula (1) may be used.

$$\text{Correction} = V\alpha(t-t_1) \qquad (2)$$

where V = measured volume

α = coefficient of cubical expansion of the measure whose volume is being adjusted.

$t-t_1$ = temperature difference between measures.

As an example of the correction for a difference in temperature, let us assume that the average temperature of the water in a standard calibrated to deliver 5 gallons at 60°F was 74°F, but after being emptied into the test measure it was measured at 76°F. Both measures are of mild (low carbon) steel.

The change in the volume of water from 74 to 76°F may be computed from the formula

$$V_{76} = V_{74} \times \frac{\text{density of water at } 74°F}{\text{density of water at } 76°F} \quad (3)$$

$$= 5 \text{ gal} \times \frac{0.99747}{0.99721}$$

$$= 5.001304 \text{ gal}$$

The change is 5.001304 - 5.000, or 0.001304 gal.

While the volume of water was increasing, the capacity of the prover also increased by an amount represented by formula (2), or

$$5 \times 0.0000186 \times 2 = 0.000186 \text{ gal}$$

The net correction for the temperature difference, therefore, is 0.001304 - 0.00186 or 0.001118 gal (0.2583 in^3). Because the water in the measure is warmer than when in the standard, the level in the gage will be higher than it would be if the temperature had remained the same, and must be lowered by 0.0011168* galbefore adjusting the scale to the water level.

If the two measures are made of materials having the same thermal

*When performing correction calculations all significant digits should be used, however; prior to any adjustments the resulting value should be rounded to two decimal places due to the scale readability limitations.

expansion coefficient, no further correction is necessary since the standard is correct at 60°F.

CORRECTION FOR DIFFERENCE IN THERMAL EXPANSION OF MEASURES

If a standard is being used to calibrate a measure made of material having a different thermal expansion coefficient, and the temperature is other than the standard temperature (usually 60°F), a correction must be applied to account for the difference in volume change of the two instruments. The correction may be represented by the following equation:

$$C = V\,(t-60)\,(\alpha_1-\alpha_2) \qquad (4)$$

where C = correction,

V = measured volume,

t = temperature of observations (°F),

α_1 = cubical coefficient of thermal expansion of metal in standard per degree Fahrenheit, and

α_2 = cubical coefficient of thermal expansion of metal in measure being calibrated per degree Fahrenheit.

For example, suppose that a 5-gallon measure made of low-carbon steel is being calibrated with a 5-gallon standard made of 18-8 stainless steel. The average temperature (measured in the water when the instruments are full) is 75°F. The correction would be:

$$C = 5\,(75-60)(0.0000265-0.0000186)$$

$$= 0.00059 \text{ gal.} = .1369 \text{ in}^3$$

The standard, having a larger expansion coefficient, will, when filled and emptied into the measure, fill the prover to a higher level by 0.1369 in^3 than it would if both measures were at the standard temperature of 60°F. If the water level in the measure was lowered by 0.1369 in^3 and the zero line on the scale adjusted to that level, the measure would be correct at 60°F.

When working at a temperature below 60°F, the scale should be adjusted upward when other conditions are as in the preceding example. At 50°F the correction would be 5 X 10 X 0.000079 or 0.0004395 gal (0.0912 in^3). If 0.0912 in^3* of water were added to the prover and the zero line on the scale adjusted to that level, the prover would be correct at 60°F.

26. If the calculated equivalent scale reading does not reflect need for scale adjustment the test measure should be sealed with a lead-and-wire seal and returned to the owner along with a report of calibration.

27. If the scale requires adjustment, the measure should be retested using steps 11 through 20, inclusive, to verify that proper adjustment had been performed.

8.2.0 <u>VOLUMETRIC CALIBRATION PROCEDURE ("To Contain")</u>. "To Contain" calibrations are best accomplished using a gravimetric technique. If a gravimetric calibration is to be performed, it is recommended that the procedure outlined in Section 4.0 be used. If a volumetric "To Contain" calibration is to be performed, the procedure outlined in Section 8.1.0 should be modified such that the standard is thoroughly dried prior to performing step 14 of the calibration procedure.

9.0 TEST MEASURE PROTOTYPE. The specification of Section 7.2.0 was used to purchase a device to be used in a field test program.

The "as built" measure was thoroughly inspected to determine compliance with the specification. The measure was found to conform to all specification requirements with the exception of having an approximate neck inside diameter of 2.125" instead of the specified 2". The overall height of the measure is approximately 32 inches. The prototype measure was judged to be acceptable. The general description of the measure as indicated on the identification plates includes:

Delivers 5 Gallons to zero

Model M Special, Serial Number 18994

Stainless Steel type 304

Cubical coefficient of thermal expansion 26.5 X 10^{-6} per °F

Figure 24 is a photograph of the measure.

The measure was subjected to a gravimetric calibration employing the NBS procedure discussed in section 4.0.

9.1 FIELD TEST PROGRAM. A test program was devised to check operating gasoline dispensers with both a conventional 5-gallon field standard and the prototype. The tests consisted of routine dispenser checks with each dispenser being checked independently with both measures. The tests were conducted by B. C. Keysar and D. J. Hine. The procedures used for the tests, following inspection and pretest determinations in accordance with NBS Handbook 112, were as follows:

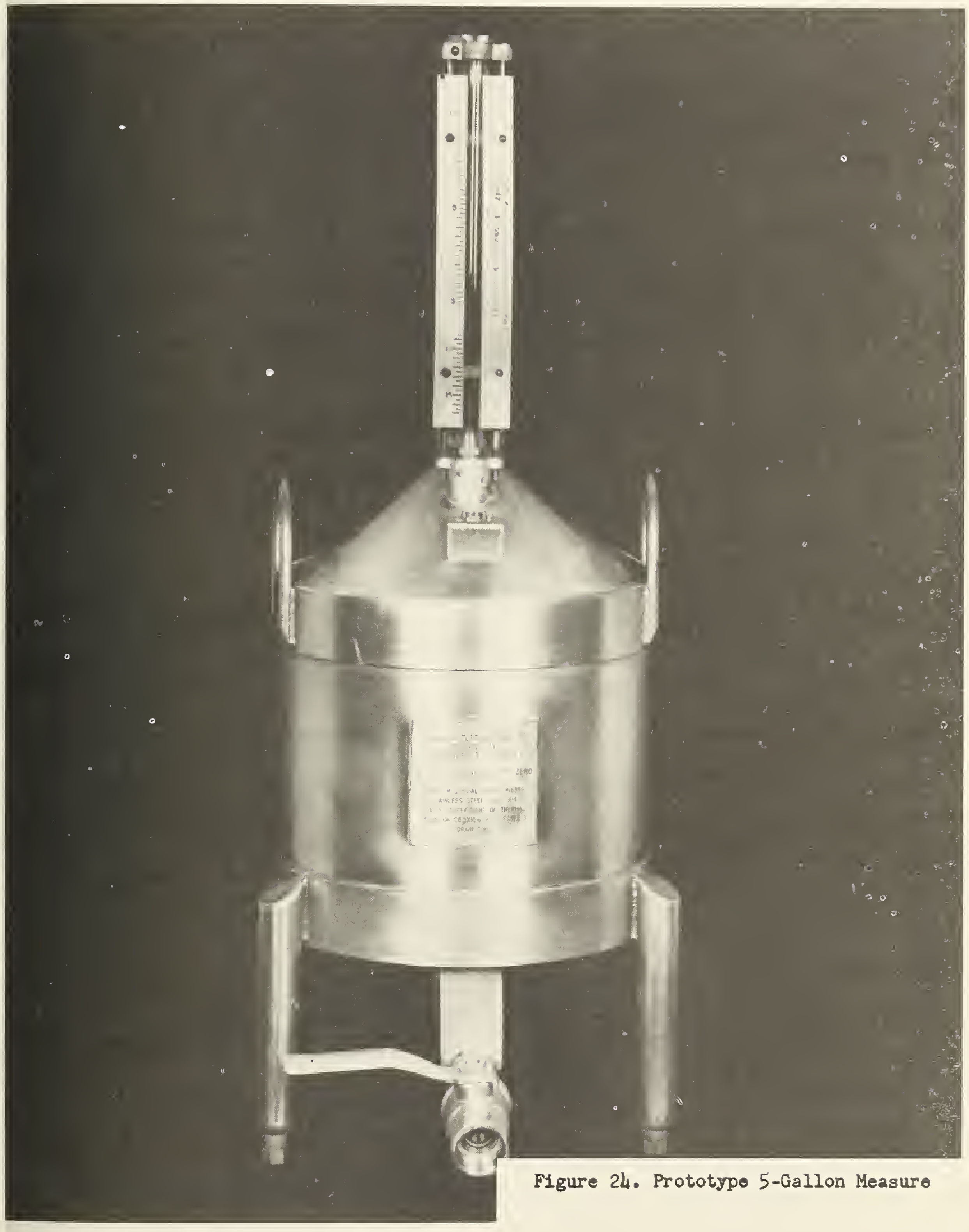


Figure 24. Prototype 5-Gallon Measure

Prototype Measure

1. The measure was placed adjacent to the dispenser to be tested and adjusted to level condition. The position of the 3 legs of the measure was marked for convenience in returning after each draft.
2. The dispenser register was returned to zero and the indicator position noted if not zero.
3. The totalizer readings were noted and recorded.
4. The electrical switch was activated to energize the dispenser pump.
5. A 5-gallon draft was made to wet the measure with test product.
6. The wet-down draft was returned to appropriate storage as directed by the service station operator. A 10-second drain following cessation of main flow was used.
7. A 5-gallon draft was made to the measure. If the dispenser was equipped with an automatic nozzle, the fast-flow setting was used. The draft was terminated with the register indication as close as possible to 5.0 gallons.
8. The test measure neck scale indication was observed and recorded.
9. Dollar amount verified by manual price/gallon computation.
10. The product was returned to appropriate storage as in Step 6.
11. Repeat Steps 2, 4, 7, 8, and 6.
12. Repeat Steps 2 and 4 followed by a slow-flow 5-gallon draft

made into the standard. If the dispenser was equipped with an automatic nozzle, the slow-flow setting was used; otherwise slow flow was obtained manually. The draft was terminated as close to 5.0 gallon registration as possible.

13. Repeat Steps 8, 6, and 3.

Conventional Measure. The test procedure employed with the conventional measure was exactly the same as that with the prototype with the following exceptions:

Step 1. The measure was not leveled since it has no adjustment.

Step 8. To obtain the measure liquid level indication, the measure was held by the bail several feet off the ground by one of the testers while the reading was observed and recorded by the other tester.

Step 6. Emptying of the measure was accomplished by slowly inverting the measure to allow the liquid to drain into a funnel and subsequently to storage. The time to drain the measure was maintained at 25 to 30 seconds followed by a 10 second drain after cessation of the main flow.

9.1.1 ADDITIONAL FIELD TESTS. To further evaluate the prototype measure, the two measures were transported to a weights and measures office and with the assistance of three inspectors additional testing was performed. This testing was limited to a relatively small sample since the goal was to determine how the two measures would compare when used by persons normally responsible for testing gasoline dispensers.

9.2 FIELD TEST DATA. When conducting the tests described in 9.1 and 9.1.1 the data was recorded on the form shown as Exhibit 6. A summary of the data collected during the routine phase of the field test program is shown in Exhibit 7. The results of the additional field tests conducted on six dispensers is not included, however; the results of those tests differed only in that the magnitude of the difference between the two standards was greater. Comparison of the data presented in Exhibit 7 reveals that in most tests the results obtained with the conventional field standard were slightly more positive (less negative) than indicated with the prototype standard.

9.3 CONCLUSIONS FROM FIELD TESTS. The field test program for testing gasoline dispensers was very limited and was performed primarily to verify the capability of the prototype measure. The tests did provide evidence that the concept of the measure was extremely good. Scale reading was greatly simplified for the width of 1/2 cubic inch division was greater on the prototype than 1 cubic inch division on a conventional measure. Additionally, the emptying procedure was much easier since the prototype measure was drained through its own hose and no funnel was required. Also, the drain time was not influenced by any human factor. It was recognized that the process of moving the standard from the dispenser to the storage tank fill pipe was awkward for only one individual. This could easily be

Data Sheet

Date of Test ____________________ Observer ____________________

API/NBS RESEARCH ASSOCIATE PROGRAM - RETAIL FUEL DISPENSER INVESTIGATION

Location ____________________

DIspenser manufactured by: ____________________

Manufacturer Model and/or Serial No. ____________________

Product Delivered: Premium ______ Regular ______ 3rd Grade ______

Last OFFICIAL inspection by: ____________________ Date ____________

Weather ____________________

Field Standard Identification ____________________

Scale Reading

Draft No. 1 (normal) ____________

Draft No. 2 (normal) ____________

Draft No. 3 (slow) ____________

Draft No. 4 ( ) ____________

Remarks ____________________

____

____

____

Total Number of dispensers tested at this location ____________

Exhibit 6. Field Test Data Sheet

SUMMARY OF DATA - SERVICE STATION FIELD TESTS

Location	Date	Standard Used	#1 Normal	#2 Normal	Average	Slow Flow Test
1	7/9/73	API Special	-0.5	-0.7	-0.6	-1.4
1	7/9/73	FS-282-5	+3.0	+2.0	+2.5	-1.0
1	7/9/73	API Special	-6.9	-6.25	-6.5+	-5.0
1	7/9/73	FS-282-5	-3.0	-3.0	-3.0	-4.0
1	7/9/73	API Special	+0.6	-0.7	-0-	-0-
1	7/9/73	FS-282-5	+1.5	+3.0	+2.25	+0.5
1	7/9/73	API Special	-4.3	-3.0	-3.65	-3.5
1	7/9/73	FS-282-5	OUT OF PRODUCT			
1	7/9/73	API Special	-2.5	-3.1	-2.8	-4.1
1	7/9/73	FS-282-5	OUT OF PRODUCT			
2	7/10/73	API Special	-5.5	-4.25	-4.8	-3.25
2	7/11/73	API Special	-7.0	-6.25	-6.6	-5.5
2	7/10/73	FS-282-5	-4.5	-3.5	-4.0	-2.5
2	7/11/73	FS-282-5	-5.0	-5.5	-5.75	-4.5
2	7/10/73	API Special	-5.5	-5.2	-5.35	-4.2
2	7/11/73	API Special	-7.7	-7.7	-7.7	-5.5
2	7/10/73	FS-282-5	-4.5	-5.0	-4.75	-3.5
2	7/11/73	FS-282-5	-6.5	-6.0	-6.25	-5.5
3	7/11/73	API Special	-1.25	-0.75	-1.0	+2.0
3	7/11/73	FS-282-5	-3.5	-2.0	-2.75	+2.5
3	7/11/73	API Special	-5.1	-4.7	-4.9	-4.3
3	7/11/73	FS-282-5	-4.5	-4.5	-4.5	-3.0

Exhibit 7

SUMMARY OF DATA - SERVICE STATION FIELD TESTS

Location	Date	Standard Used	#1 Normal	#2 Normal	Average	Slow Flow Test
3	7/11/73	API Special	+1.25	-1.25	-0-	+3.0
3	7/11/73	FS-282-5	-0.5	-0.5	-0.5	+1.5
3	7/11/73	API Special	-3.2	-5.25	-4.2	-4.0
3	7/11/73	FS-282-5	-4.5	-5.0	-4.75	-6.0
3	7/11/73	API Special	+3.5	+2.75	+3.1	+7.3
3	7/11/73	FS-282-5	+2.5	+2.5	+2.5	+8.5
3	7/11/73	API Special	+0.75	-1.25	-0.25	-1.0
3	7/11/73	FS-282-5	-1.0	-0.5	-0.75	-0-
4	7/12/73	API Special	-0.5	-2.75	-1.6+	-1.5
4	7/12/73	FS-282-5	-2.5	-2.5	-2.5	-1.5
4	7/12/73	API Special	-1.5	-3.75	-2.6+	-1.75
4	7/12/73	FS-282-5	-1.5	-1.0	-1.25	-0-
4	7/12/73	API Special	-2.25	-1.0	-1.6+	+10.25
4	7/12/73	FS-282-5	-1.5	-0.5	-1.0	+11.0
4	7/12/73	API Special	-1.75	-2.0	-1.8+	-4.5
4	7/12/73	FS-282-5	-1.0	-0.5	-0.75	-3.0
5	7/13/73	API Special	+6.0	+3.0	+4.5	+5.5
5	7/13/73	FS-282-5	+2.5	+2.0	+2.25	+5.0
*5	7/13/73	API Special	-17.5	-17.5+	-17.5+	-18.0
*5	7/13/73	FS-282-5	-20.0	-20.0	-20.0	-15.5

Exhibit 7 Continued

SUMMARY OF DATA - SERVICE STATION FIELD TESTS

Location	Date	Standard Used	#1 Normal	#2 Normal	Average	Slow Flow Test
5	7/13/73	API Special	+2.0	-0.5	+0.75	+2.2
5	7/13/73	FS-282-5	-0-	+0.5	+0.25	+4.5
5	7/13/73	API Special	+4.2	+3.5	+3.8+	+3.5
5	7/13/73	FS-282-5	+5.0	+4.5	+4.75	+4.0
5	7/13/73	API Special	+3.5	+2.25	+2.8+	+4.5
5	7/13/73	FS-282-5	+0.5	+1.5	+1.0	+5.5
*5	7/13/73	API Special	+23 in^3 @ 4.85 Gallons on register			
*5	7/13/73	FS-282-5	+30 in^3 @ less than 5 Gallons on register			
*5	7/13/73	API Special	+8.5	+6.7	+7.6	+9.9
*5	7/13/73	FS-282-5	+8.5	+8.5	+8.5	+13.0
5	7/13/73	API Special	-1.5	-2.5	-2.0	-0.5
5	7/13/73	FS-282-5	-2.5	-1.0+	-1.75+	+3.5-
*5	7/13/73	API Special	In excess of +30 in^3			
*5	7/13/73	FS-282-5	In excess of +30 in^3			

*These meters were either replaced or adjusted by Official Company Repairman and were verified as being left delivering just slightly (1 to 2 in^3) on the plus side.

corrected by attaching a carrying handle to the measure or mounting the measure on a wheeled cart.

From the limited tests it appears that it would be impossible to predict within several cubic inches the result of a second normal flow test based on the result of the first. The major problem here would seem to be that under most conditions the history of the dispenser just prior to the first test is generally unknown to the person performing the inspections. It might well be a questionable philosophy to accept a single normal-flow test as an indication of the operating capability of the dispenser.

It is felt that the tests conducted by B. C. Keysar and D. J. Hine represent a much more controlled and exact application of a conventional metal field standard than might be encountered in observing a routine weights and measures inspector's procedure. The facilities where dispensers are tested seldom include a means to allow the measure to be suspended several feet off the ground to facilitate leveling and reading of the graduated neck scale. The operation is therefore dependent upon the island being relatively level so that the measure can be placed on the island to allow the neck scale to be more easily viewed. Conceding that the island is level, the proper method to read the graduated neck scale will require the inspector to be on his hands and knees!

9.4 RECOMMENDED FIELD TEST PROCEDURE. For either a conventional field test measure or a measure fabricated from the specification of 7.2.0, a well-defined procedure is necessary.

In June 1973 the Office of Weights and Measures published NBS Handbook 112, Examination Procedure Outlines for Commercial Weighing and Measuring Devices. Exhibit 8 is a modified reprint of EPO No. 21 of that Handbook which covers single product motor fuel dispensers. EPO No. 22 covers blended product motor fuel dispensers. The Examination Procedure Outline provides an excellent summary of appropriate reference numbers to NBS Handbook 44. To supplement the EPO, an Examination Checklist was prepared and is shown in Exhibit 9. This checklist is intended to simplify the Device Inspection and Pre-Test Determinations and should be completed prior to actual performance testing.

To properly inspect a motor-fuel dispenser, a step-by-step procedure must be followed. The procedure includes both visual and manual inspection and should proceed as follows:

1. The dispenser panel covers are removed by authorized personnel.
2. With a checklist similar to Exhibit 9, complete all items except 11 and 16.
3. Record the totalizer reading on the test report form.
4. Place the measure to be used adjacent to the dispenser being tested and establish level condition for the measure.
5. Activate the switch to energize the dispenser pump.
6. Make a normal draft into the measure. During the draft

Reprinted from
U.S. Department
of Commerce NBS
Handbook 112
(Modified)

EPO NO. 2

Examination Procedure Outline for RETAIL MOTOR-FUEL DISPENSERS—SINGLE PRODUCT

It is recommended that this outline be followed for conventional, single-product, power-operated retail dispensers—"gasoline pumps."

	H-44 General and Liquid Measuring Device Code References
INSPECTION:	
1. Indicating and recording elements.	
Design	S.1.1.
Readability	G-S.5., G-S.6., G-UR.3.2.
Unit Price and Product Identity	S.1.4.3., S.1.4.4., UR.3.2.
Advancement and Return to Zero	S.1.1.4., S.1.4.2., UR.3.1.
2. Measuring elements.	
Air eliminator vent (if self-contained pump)	S.2.1.
Security seal on adjusting mechanism	G-UR.4.4., S.2.2.
3. Discharge hose	S.3.4.,UR.1.1.,S.3.1.
4. Marking requirements	G-S.1., S.4.1., G-UR.3.3.
5. General considerations.	
Selection	G-UR.1.1.
Maintenance	G-UR.3.1.,G-UR.4.1.
Installation	G-UR.2.1., UR.2.1., UR.2.4.
Accessibility	G-UR.2.3.
Assistance	G-UR.4.3.
PRE-TEST DETERMINATIONS:	
1. Tolerances.	
Applicable requirements	G-T., T.1.
Basic values	T.2.1., T.2.4.

TEST:

Allow 10-second drain period each time test measure is emptied.

To determine proper operation of totalizers, observe and record the totalizer indications before and after all test drafts.

1. Normal test—full flow—basic tolerance	N.1., N.2., N.3.4., N.4.1.
If first test is well within tolerance, proceed to 2; otherwise, repeat this test.	
2. Check computed price on both sides of dispenser (See Price Computation Table.)	G-S.5.5.
3. Special test—slow flow basic tolerance	N.4.2., N.4.2.2.
4. Check effectiveness of zero-set-back interlock. On equipment with remote pumping systems, activate one dispenser and check all others operated by the same pump to make certain they will not operate without activating the individual starting levers.	S.2.5.1., UR.3.4.
5. Check effectiveness of anti-drain valve	S.3.6.
6. Elapsed time-test (if necessary)	N.4.3., T.2.4.

Security seal—Apply lead-and-wire seal to secure adjusting mechanism.

Note on the official report the number of gallons of product dispensed during test.

RETAIL MOTOR FUEL DISPENSER EXAMINATION CHECKLIST
(Reference: NBS Handbook 44 & NBS Handbook 112, EPO 21 & 22)

LOCATION ______________________________

DISPENSER: Make & Model ______________ Serial No. __________

PRODUCT DISPENSED: ______________________________

	Yes	No
1. Equipment suitable for application and properly installed (G-UR.1.1, G-UR.2.1, & UR.2.1)	____	____
2. Primary indicating and/or recording element (S.1.1)	____	____
3. Acceptable units and sub-division units (S.1.1.2)	____	____
4. Convenient indicator scale graduations (S.1.2.1, G-S.5 & G-S.6)	____	____
Clear interval between graduations 0.04" or more (S.1.2.3)	____	____
Graduation width 0.008" or more (S.1.2.2)	____	____
5. Indicator index symmetrical with graduations and no more than 0.06" clearance between the index and the graduations (S.1.3)	____	____
6. Functional Zero-Set-Back Interlock (S.2.5.1)	____	____
7. Proper return to zero function or operation (S.1.1.4)	____	____
8. Meter equipped with a vented vapor eliminator (S.2.1)	____	____
9. Meter adjustment element properly sealed (G-UR.4.4 & S.2.2)	____	____
10. Automatic directional flow valves (G-UR.2.1 & S.2.3)	____	____
11. Piping prevents discharge of metered liquid to other than the delivery point (include leak check) (G-UR.4.1 & S.3.2)	____	____
12. Equipment does not facilitate perpetration of fraud (G-S.2)	____	____
13. Meter used for dispensing single product (S.4)	____	____
14. Meter used for dispensing blended product (S.4 & S.1.4.3)	____	____

15. Tolerance for Tests (G-UR.4.1, G-T, T.1, & T.2):

____ in^3	____ in^3	____ in^3
Maintenance	Acceptance	Special

	Yes	No
16. Antidrain Valve test performed and accepted	____	____

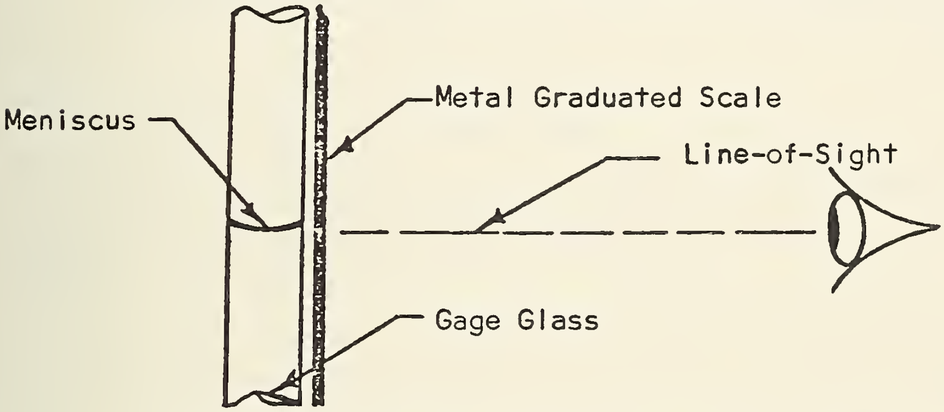
Date ______________ Inspector ______________

Exhibit 9

observe the hose, nozzle, and visible piping for leaks. If an automatic shut-off nozzle is used, use the fast setting. Stop the indicator as close as possible to an even incremental gallon. Deactivate the dispenser pump and place the nozzle in its proper location. If the measure is not wetted from a previous test proceed to Step 9.

7. Read the scale of the measure and record on the report. Complete Item II of checklist.

NOTE: The reading of the scale is an important function of inspection. The eyes must be level with the liquid meniscus as shown below to obtain an accurate scale reading.



It might be necessary for the inspector to be on his hands and knees to properly read the scale. An alternative would be to have a means to suspend the measure from its bail or handle.

8. Compare the recorded scale reading with the appropriate tolerance. If the scale reading is well within the tolerance, the test is considered acceptable. If not, the test must be repeated. Verify the accuracy of the Amount of Sale display.

9. Return the liquid in the measure to the appropriate storage tank as directed by the service station operator. Care must be exercised in the emptying process. The drain hose or funnel must be grounded to the fill tube and contact with the measure maintained during emptying. If the measure is not equipped with a drain valve, slowly tilt the measure and pour the liquid into a funnel inserted into the tank fill tube. The elapsed time for emptying should be between 25 to 30 seconds followed by a 10-second drain following cessation of the main flow.

NOTE: During emptying, the axis of the measure should be between 75 to 85 degrees from the horizontal.

10. If the normal test is to be repeated, repeat Steps 4, return the indicators to zero, 5, 6, 7, 8, & 9. If not, go to Step 11. (A complete test should consist of 2 normal flow tests and 1 slow flow test.)

11. Repeat Step 4, return the indicator to zero, and repeat Step 5.

12. Make a slow draft into the measure. If an automatic nozzle is used, use the slow setting. Fill rate should be about 20 percent of normal rate. Stop the indicator as close as possible to an even incremental gallon. Deactivate the dispenser pump and place the nozzle in its proper position.

13. Repeat Steps 7 & 8.

14. With the dispenser pump off, place the nozzle in the measure and open the nozzle to check the antidrain valve. Only a small quantity of liquid will drain and then stop if the valve is functioning.

NOTE: Do not shake, elevate, or otherwise attempt to force leaking. This will VOID the test.

15. Repeat Step 9. Caution: If this is the last dispenser to be tested at this location, additional care must be taken to completely drain the measure of flamable liquid before placing it in a vehicle.

16. Read and record the totalizer reading. Verify the gallons dispensed during the test with the difference between begin and end totalizer readings.

17. Complete the test report, affix a seal if appropriate, and have the dispenser panels replaced by an authorized person.

10.0 TEST MEASURE EVALUATION SUMMARY. The examination of test measure design and performance provided evidence to substantiate the need for changes in the design of the features that contributed most to non-uniform measurement. The two major sources of potential error were found to be scale reading errors and emptying in a manner other than that used when the measure was calibrated. The tentative specification addresses itself to features that would greatly reduce these error sources. One feature of the specification that could require attention is the difficulty of cleaning and inspecting through the 2" neck opening. It would require that care be taken to protect the measure from an atmosphere that would promote rusting. This requirement is no different than for existing measures. Additionally, the small diameter neck may increase the foaming problems found with some petroleum products. This condition, as with conventional measures, requires the inspector to maintain continual surveillance during testing to avoid overflow which voids the test.

In addition to design change needs, it was also established that there was a need for uniform acceptance/rejection criteria for use by all volume calibration agencies. With existing practices, the only uniform criteria that might be exercised would be rejection if the measure leaked or was completely erroded with rust. To establish a rust level that would control the acceptance or rejection of a given measure would be extremely difficult and would be perhaps even more difficult to uniformly promote with all potential users. However, it should be realized that rust corrosion and severe dirt films are forms of equipment abuse. A measure that conforms to the design specifications included in this report will not exhibit a severe rust condition unless it has been improperly maintained.

A calibration report specifies a volume that is based upon the measure being clean and reasonably free of corrosion damage. If the measure does not meet these qualifications when inspected, the calibration is nearly meaningless.

Damage to a test measure in the form of dents is a very sensitive problem. If the calibration is performed on a dented or otherwise damaged measure, it is impossible to establish, to everyone's satisfaction, that the damage existed prior to calibration. Some calibrating agencies attempt to include a damage description on the report of calibration but the success of this is questionable. Any dent or damage to a test measure should be repaired so that it isn't externally visible and doesn't allow air or foreign material entrapment. This must be done prior to submitting for calibration or recalibration.

Since the procedure used in the calibration of a test measure has been found to be important to achieving reproducible calibration values, the importance of adapting the scale reading and emptying portions of the laboratory calibration procedure to field applications of the test measures cannot be overemphasized. This philosophy must be promoted by all users if uniformity is to be realized.

Every person who performs calibration work with metal volume standards should realize that they are working with a precision instrument. The reference to this equipment as buckets or cans promotes a crude image and oftentimes results in crude treatment. These devices are instruments which deserve and require careful treatment both in handling applications and storage.

A clean, properly maintained and used test measure will promote improved measurement.

11.0 INTRODUCTION TO LARGE VOLUME PROVER DESIGN & EVALUATION. During the first two years of the API/NBS Research Associate Program, it became evident that the program must be expanded beyond the study of 1, 5, and 10 gallon field standards. Representatives of the petroleum industry and weights and measures jurisdictions were actively suggesting that the research program be expanded to include larger volume provers for application in truck-loading facility meter inspection and truck-mounted meter inspections. Approvals were obtained from API and NBS and the expansion was begun.

12.0 PROVER DESIGN STUDIES. The study of prover design had primarily been completed when an attempt was made to locate existing field standards design criteria in the very early stages of the Research Associate Project. Further studies supported the earlier conclusion that standard prover specifications were virtually non-existent.

A review of the angle evaluation liquid retention studies and the reports on the engineering survey conducted by American Petroleum Institute in the mid-1960's resulted in certain design criteria that would be considered.

Since the API survey had selected API Standard 1101, "Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter", this document was used as the base starting point in developing a "Tentative Large Volume Prover Specification". The Specification covered 4 Volumetric Provers (50, 100, 750 & 1500 gallon) mounted on a single trailer.

The specification was completed, reviewed by API Weights and Measures Task Force Members and representatives of NBS Office of Weights and Measures, revised to reflect comments received during review, and submitted to four known prover manufacturers for bid.

Following receipt of the bids from the manufacturers, the bids were evaluated and a contract was awarded to the lowest bidder.

13.0 VOLUMETRIC PROVER FABRICATION. The manufacture of the provers was initiated immediately following award of contract. Several changes were made to the specifications at the request of the manufacturers. These changes included fabricating the 50 and 100 gallon provers of stainless steel and epoxy coating the 750 and 1500 gallon provers in lieu of terne-plate or galvanized coating. These changes were approved and reflected no additional cost.

During fabrication, several visits were made to the manufacturers' facility. These included a visit prior to final assembly and a visit for a final checkout and calibration by water-meter method. Several modifications were requested to the provers before final approval for shipment could be given. The provers were approved for shipment prior to receipt of the scale plates to avoid unnecessary delay in shipping to NBS.

13.1 EXAMINATION AND CALIBRATION. When the prover system was received at National Bureau of Standards it was immediately subjected to a thorough inspection. Several defects were noted in the provers that required correction before the equipment could be calibrated. The major problem was a weld seam on the bottom cone discovered by interior inspection, that would deter proper draining of the large prover. The seam was ground smooth and the epoxy coating was subsequently patched. An excessive amount of welding slag, sand-blasting sand, and fabrication debris resulting from the modifications required at final checkout necessitated an extensive cleaning which included complete disassembly of the main valve.

Following the repairs and thorough cleanup of the interior of the provers and exterior of the trailer and provers, the provers were subjected to a series of calibrations. The provers were received without the scales installed and it was therefore necessary to conduct an initial calibration to position the scales. After the scales had been installed the provers were subjected to a check calibration. An unacceptable difference was noted between the water-meter calibration and the calibration against NBS standards. Due to lack of facilities and time, the water meter was not verified for accuracy at the manufacturers' facility. A water-meter "check" calibration should only be accepted if previously checked against an approved standard. Due to the unusual height of the two large provers mounted on the trailer, a procedure was developed and modifications to the calibration facility were made to permit calibration of the provers.

The provers were then subjected to a routine official calibration by the Mass and Volume Section of the National Bureau of Standards.

14.0 PLANNED FIELD TEST PROGRAM. The field test program was devised to verify the applicability of the large volume provers that had been designed, fabricated, and calibrated under the auspices of the API/NBS Research Associate Program. To accomplish this goal, it was considered necessary to conduct a large number of tests on as many meters as possible in an allotted period of time. Additionally, the concensus was that tests should be conducted within as wide a range of products and ambient temperatures as possible. For this reason, tests were scheduled at two loading terminals in Milwaukee, Wisconsin and two loading terminals in the Washington, D. C. area. Two series of tests were scheduled for each terminal location so that tests could be performed in both the cold winter months and the moderate to hot summer months.

A document was prepared describing the guidelines under which the tests would be performed and was supplied to the terminal manager prior to initiating the test series. A copy of the document is included as Exhibit 10.

THE AMERICAN PETROLEUM INSTITUTE IS CONDUCTING A SERIES OF TESTS AT VARIOUS TANK TRUCK LOADING FACILITIES. THESE TESTS ARE PART OF THE RESEARCH ASSOCIATE PROGRAM SPONSORED BY THE DIVISION OF MARKETING IN COOPERATION WITH THE NATIONAL BUREAU OF STANDARDS. THE RESEARCH ASSOCIATE PROGRAM INVOLVES THE DEVELOPMENT OF VOLUMETRIC STANDARDS DESIGN AND CORRECT USE OR APPLICATION PROCEDURES.

FIELD PROVERS OF 50, 100, 750, AND 1500 GALLONS HAVE BEEN DESIGNED, FABRICATED AND CALIBRATED IN PREPARATION FOR FIELD TEST INVESTIGATIONS. THE MAJOR GOALS OF THE FIELD TESTING WILL BE TO ACHIEVE A UNIFORM EQUIPMENT DESIGN SPECIFICATION AND UNIFORM METER TEST PROCEDURE REQUIREMENTS FOR USE WITHIN THE PETROLEUM INDUSTRY AND WEIGHTS AND MEASURES JURISDICTIONS.

ALL TESTS WILL BE CONDUCTED IN STRICT COMPLIANCE WITH INDIVIDUAL LOADING TERMINAL OWNER SAFETY AND OPERATIONAL REQUIREMENTS AND NORMAL OPERATION WILL HAVE PRECEDENCE OVER THE FIELD TEST REQUIREMENTS WHEN NECESSARY.

THROUGHOUT THE TESTS, NO METER WILL BE ADJUSTED OR OTHERWISE ALTERED BY THE TEST PERSONNEL. THE OFFICIAL TEST PERSONNEL WILL CONSIST OF THE API RESEARCH ASSOCIATE, D. J. HINE; API SPECIAL REPRESENTATIVE, W. A. KERLIN; AND NBS REPRESENTATIVE, B. C. KEYSAR. THESE MEN WILL COORDINATE ALL TEST WORK WITH THE PLANT MANAGER OR A REPRESENTATIVE DESIGNATED BY HIM.

THE TEST DATA WILL BE EVALUATED IN ACCORDANCE WITH METHODS USED BY THE WEIGHTS AND MEASURES JURISDICTION HAVING AUTHORITY OVER THE INSTALLATION AND/OR BY PLANT METHODS. A COPY OF ALL TEST DATA WILL BE SUPPLIED TO THE PLANT MANAGER WHEN TESTING IS COMPLETED.

THE FOLLOWING "FIELD TEST PROCEDURE OUTLINE" WILL BE USED THROUGHOUT THE TESTS UNLESS MODIFIED BY MUTUAL AGREEMENT:

FIELD TEST PROCEDURE OUTLINE

1. INVESTIGATE EXISTING PLANT METER CALIBRATION PROCEDURES AND/OR GUIDELINES.

2. INVESTIGATE EXISTING PLANT SAFETY PROCEDURES THAT MUST BE ADHERED TO DURING METER CALIBRATION OR TRUCK LOADING OPERATIONS.

3. STUDY THE SYSTEM TO BE TESTED CONCERNING METER SIZE, LIQUID TEMPERATURE AND PRESSURE MEASUREMENT AT OR NEAR THE METER, NORMAL AND MAXIMUM AVAILABLE FLOW RATES, TEMPERATURE COMPENSATION, FLUID GRAVITY, PROPER METER INSTALLATION, ETC.

4. CHECK METER ADJUSTING ELEMENT FOR APPROPRIATE SEAL AND RECORD ON DATA SHEET. CHECK FOR COMPLIANCE WITH HANDBOOK 44 REQUIREMENTS.

5. POSITION THE TRAILER-MOUNTED SYSTEM AT THE LOADING RACK DESIGNATED BY THE PLANT PERSONNEL AND ESTABLISH LEVEL CONDITION WITH LEVELING JACKS.

6. PLACE FIRE EXTINGUISHERS AND BARRICADE SIGNS IN APPROPRIATE POSITIONS.

7. CONNECT GROUND WIRE TO APPROPRIATE PROVER GROUNDING LUG AND AVAILABLE POSITION GROUND.

8. IF FACILITY HAS SET-STOP FEATURE, SET APPROPRIATE VOLUME FOR PROVER BEING USED.

9. POSITION DRAIN LINE TO PROVER. DO NOT CONNECT.

10. IF THE METER BEING TESTED IS EQUIPPED WITH A TEMPERATURE COMPENSATOR (ATC) OR TEMPERATURE-GRAVITY COMPENSATOR (ATG), IT SHOULD BE DE-ACTIVATED UNLESS THE METER IS EQUIPPED WITH BOTH NET AND GROSS INDICATION.

11. PERFORM PROVER "WET-DOWN" AT NORMAL LOADING RATE OF THE INSTALLATION.

12. MAKE NOTATIONS ON DATA SHEET OF FLUID TEMPERATURES AT METER AND PROVER, PRESSURE AT METER, AMBIENT TEMPERATURE AND WEATHER DESCRIPTION, NECK SCALE READING, AND METER READING. IF METER SYSTEM IS EQUIPPED WITH A RECORDING ELEMENT, PRINT A TICKET AFTER EACH TEST RUN. CHECK PROVER DRAIN VALVE FOR LEAK.

13. CONNECT DRAIN LINE TO PROVER AND DRAIN PROVER, AS DIRECTED BY PLANT PERSONNEL, ALLOWING 30 SECOND DRAIN AFTER CESSATION OF FLOW.

14. CONDUCT A "NORMAL FLOW TEST" AT FULL FLOW AND PROMPTLY RECORD ALL TEMPERATURES, PRESSURE, NECK SCALE READING, AND METER READING OR PRINTOUT.

15. CONDUCT A "SLOW FLOW TEST" AT A MINIMUM DISCHARGE RATE OF 20 PERCENT OF THE MAXIMUM RATED FLOW OR AT THE MINIMUM DISCHARGE RATE MARKED ON THE DEVICE, WHICHEVER IS LESS. RECORD ALL DATA AS IN STEP 14.

16. CONDUCT A METER TEST AT AN INTERMEDIATE FLOW RATE AND RECORD ALL DATA AS IN STEP 14.

17. REPEAT STEPS 7 THROUGH 16 USING THE LARGER OR SMALLER PROVER NOT PREVIOUSLY USED.

15.0 INITIAL FIELD TESTS. Prior to beginning the first series of field tests, the prover system was subjected to "shake-down" to establish operating procedures and allow the personnel that would be conducting the tests to become familiar with the equipment.

Prior to loading any petroleum product in either of the provers, it was discovered that the inlet nozzle to which the bottom-load-adapter was flanged was 3 inch size rather than 4 inch. This defect was discovered when the adapter was removed and had not been obvious during the initial examination. The 3 inch nozzles were cut out and replaced with a 4 inch nozzle. A calculation based on the theoretical dimensions of the two nozzles was performed to determine the prover volume change created by the modification. The epoxy coating was repaired following the welding modification.

Following the modification to the nozzles, the provers were subjected to a series of runs and were judged to be performing to expectations. The system was considered to be ready to begin the scheduled field test intinerary. The prover system was towed to Milwaukee, Wisconsin for the first series of testing.

The metering systems to be tested were subjected to a visual examination in accordance with pre-test determinations presented in NBS Handbook 112. To simplify the visual examination, a Check-List was prepared utilizing NBS Handbook 112. The Check-List is shown in Exhibit 11.

Following the pre-test examination, the tests were initiated. It was immediately evident that the pump-back facility of the loading terminal would prove to be a serious deterrent to the conduct of the

TRUCK LOADING FACILITY PRE-TEST METER EXAMINATION CHECK-LIST
(Reference: NBS Handbook 44 & NBS Handbook 112, EPO 25)

LOCATION ______________________ PRODUCT METERED ______________________

METER: Size ________, Make & Model No. ________________, Serial No. ______________

	Yes	No
Equipment & installation suitable for application (G-UR.1.1 & G-UR.2.1)	____	____
Primary indicating and/or recording element (S.1.1)	____	____
Acceptable units and sub-division units (S.1.1)	____	____
One (1) gallon or equivalent unit (S.1.1)	____	____
Convenient indicator scale graduations (G-S.5 & S.1.2)	____	____
0.008" or more graduation width _____ 0.04" or more clear interval _____		
Indicator index symetrical with graduations, no more than 0.04" between index and graduation, 0.06" or less clearance between graduation and index. (S.1.3)	____	____
Proper return to zero function or operation. (S.1.1.4)	____	____
Meter equipped with a vapor eliminator. (S.2.1)	____	____
Meter adjustment mechanism properly sealed. (S.2.2 & G-UR.4.4)	____	____
Meter equipped with ATC and properly sealed (S.2.6 & S.2.6.3)	____	____
Can ATC be properly deactivated. (S.2.6.2)	____	____
Is adequate thermowell provided for meter temperature (Special)	____	____
Automatic directional flow valves. (S.2.3)	____	____
Meter equipped with automatic set-stop mechanism. (S.2.4)	____	____
Piping prevents discharge of metered liquid to other than the delivery point (include leak check) (S.3 & G-UR.4.1)	____	____
System does not facilitate the perpetration of fraud. (G-S.2)	____	____
Is meter used for single product. (S.4 & G-S.1)	____	____
Legible markings and instructions. (G-S.6 & G-UR.3)	____	____

Maintenance tolerance of 25 in^3 plus 1/2 in^3 per indicated gallon on Normal Tests, 1 in^3 per indicated gallon on Special Tests, and Acceptance tolerance of 12.5 plus 1/4 in^3 per indicated gallon. (G-UR.4.1, G-T, T.1, & T.2.)

______________________ __________
Inspector signature Date

Exhibit II

tests. It oftentimes took several hours to prime the pump in order to pump-off the test liquid. It was also noted that it was difficult to determine when the prover was empty. A crewman had to stand on top of the prover to watch the product level during unloading.

Representatives from the API Division of Marketing Weights and Measures Task Force visited the test site to view the testing. In addition to the pump-off problem and visual emptying determination, concern was indicated over a small pool of liquid retained in the bottom drain line of the provers at the junction of the screwed elbow on the bottom of the prover to the sloped drain line leading to the drain valve. The decision was made that the prover drain lines be modified to correct the pool condition and provide visual indication when the prover was empty. Also, a decision was made that a portable pump and motor system be obtained to include with the test system to eliminate the need to depend on plant facilities.

With these decisions, the drain lines of the two large provers were removed and transported back to the National Bureau of Standards for modifications. A pumping system was ordered as well as two 4 inch sight flow indicators to incorporate in the modified drain lines.

The drain lines were subjected to several tests to determine the amount of liquid retained in the pool and it was discovered that the pool in either drain line consisted of less than one-half cubic inch. The decision to modify the drain lines was for aesthetic value as well as visual acceptability by outside observers. The drain lines were modified by welding a half screwed coupling to a weld elbow which was in turn welded to a pipe nipple that was threaded on the end to accept the drain valve. The sight-flow-indicator was installed downstream of the drain valve in order to eliminate having this fixture within the calibrated volume of the provers.

The volumes of the as-built drain lines and the modified drain lines were determined by repeated water fillings and the calibrated volumes of the provers were adjusted accordingly.

16.0 FIELD TEST PROGRAM. The field test program was intended to provide a large number of meter tests in order to test the capability of the provers. In addition to the planned large quantity of testing, it was also necessary to observe and record a large number of test parameters. These parameters included meter register indication, flow rate, prover neck scale reading, meter pressure, nine or ten temperature readings depending upon the system, prover pump-off time, and drain-down times.

In order to help eliminate errors by omission of required data, three sets of tasks were developed for the three persons usually in attendance during the tests. The assignments were as follows:

Crewman #1: Responsible for the operation of the meter. This assignment included having an appropriate ticket in the register; determining by checking with the other members of the crew when the test was ready to begin; obtaining the flow rate during the run; making the meter register reading; assist in reading the liquid-in-glass thermometers; and timing the pump-off and drain-down periods.

Crewman #2: Responsible for the operation of the prover. This assignment included all valve manipulations, assisting with temperature determinations during the run, determining the liquid level on the neck scale, and assist in reading liquid-in-glass thermometers.

Crewman #3: Responsible for the general conduct of the test. This assignment included recording all data on the data sheet, assisting with temperature determinations during the run, obtaining temperature determinations from the electronic thermometer, making periodic gravity determinations of the metered product, and assisting other members of the test crew as required.

With this distribution of assignments it was found that each member of the test group was well occupied and only during pump-back of the product from the prover to storage was there any unused time.

During the conduct of these tests it was agreed that a sequence for the tests must be formulated so that each meter would be examined within the same guidelines. The test sequence decided upon was as follows:

Preliminary Run - Meter system stability check to include: flow rate check, set-stop function, and generally inspect the meter operation. This run could be eliminated if the prover was wet-down from a previous run on a different meter and the inspection could be performed while a tank-truck was loading through the meter to be tested.

First Run - Normal Flow Rate - one meter operating - record all data.

Second Run - Normal Flow Rate - one meter operating - record all data.

Third Run - Slow Flow Rate - one meter operating - record all data.

Additional Runs - Additional runs were made to determine the repeatability of the meter, influence on the flow rate and repeatability of the meter when two or more meters were operating with the same test liquid, and an additional slow-flow run.

16.1 TESTING PROBLEMS. During the conduct of the field tests there were a number of problems encountered that are worthy of discussion.

16.1.1 Product Pump-Off. As discussed in Section 15.0, problems were encountered with terminal facilities for returning metered product to storage. In addition to the pump-back facilities being either non-existent or inoperable, it was found that in some cases product could not be returned to storage if that same product was being loaded through another meter. This was caused by the return line being connected to the supply line from storage which had a higher pressure than could be obtained with the pump-back pump.

During slow periods in the terminal, testing would proceed quite well; but during normal loading it resulted in test delay. This same piping configuration presented another potential problem in that during the slow loading periods the same product would be recycled through the meter into the prover and through the pump into the supply line. Recycling would continue until a truck arrived to load the same product being tested.

A further problem in the product pump-off area is that at some locations no means is provided at the loading position to return the product to storage. During the field tests, one such location was encountered and the problem was resolved by the terminal operator furnishing a tank truck for pumping the metered product into. Even this resulted in delays since the truck had to move to the pump-back facility after each 7,000 to 8,000 gallons of testing. It is also expensive to tie up a truck and driver for the test period. Every truck loading facility should be equipped with convenient product pump-back facilities. The design should promote meter inspection and/or calibration without inconvenience to either terminal operation or testing personnel.

16.1.2 Product Temperature and Pressure Measurement. It was often difficult or impossible to find a means to measure the metered product temperature and pressure at or near the meter. To make these measurements it was necessary to find a pressure tap or other opening that could accept a short nipple that was screwed to a pipe tee so that both temperature and pressure could be measured. Since pressure and temperature at the meter are important in evaluating terminal operating equipment, the capability for making these measurements should be included in every loading terminal design.

16.1.3 Flow-Control Valves. At several test locations the control valves that are used to regulate meter flow-rate, starting stage, stopping stage and meter shut-down were found to be overly sensitive to adjustments or could not be adjusted due to faulty O-Rings or ruptured diaphragms. Several meters had to be bypassed during the testing due to such difficulties. The flow rate has a decided effect on meter performance and any auxiliary equipment that controls or effects flow rate should be capable of proper adjustment with a minimum of maintenance. It is also desirable that flow rate adjustment be provided with a security seal to prevent unauthorized adjustments.

16.1.4 Flow Strainers. Most piping systems in loading terminals include a flow strainer upstream of the meter to protect the metering element against foreign debris. Although not every strainer basket was inspected during the field tests, of those that were inspected an alarmingly high percentage had extensive damage. The experience of the field tests indicates that an established routine inspection of the strainer is needed.

16.1.5 Slow-Flow Control. A problem was encountered during the field tests in establishing a slow-flow rate. To obtain slow-flow through a meter, a valve must be throttled that is normally open. In many cases, the only available control is through the main shut-off valve upstream of the meter. It was found that when gasolines are throttled through a valve upstream of the meter, the disturbance may create a vapor-liquid mixture that subsequently passes through the meter. The difference in meter error between upstream and downstream throttling is significant.

The best uniform solution to this problem would be the installation of a control valve between the prover and the bottom-load adapter so that flow could be throttled into the prover rather than into the meter. This solution should improve the meter accuracy and promote a uniform method for meter testing.

16.2 VAPOR RECOVERY SYSTEM TESTING. A logical extension to the Field Test Program developed during the testing. Though more and more loading terminals are installing vapor recovery or disposal systems, few are being provided with appropriate proving standards. It is generally agreed that every measuring device should be calibrated under *normal operating conditions*.

16.2.1 TEST OBJECTIVE. The objective of the tests was to examine meter performance when operating with a closed proving system as compared to operating with an open proving system.

16.2.2 METHOD OF TESTS. The tests were conducted with the 1545.55 gallon volumetric prover designed specifically for bottom-loading, vapor recovery meter proving. The vapor recovery on this prover was accomplished through a 4" elbow welded on the flanged top cover. Removal of the top cover provided an open-to-atmosphere prover similar to those used by both weight and measures jurisdictions and the petroleum industry.

During the tests with the closed prover system, the pressure inside the prover was periodically monitored. The pressure at beginning of loading was approximately 0.5 psig but would drop to about 0.3 psig and remain constant during the majority of the loading. It is considered that this slight pressure deters evaporation. No discernible change in flow rate between the open and closed system tests could be detected.

16.2.3 TEST RESULTS. Approximately 150 tests were performed on nine meters. Each meter was tested for about one-half day in both the open and closed configurations. Results of the tests on each meter were averaged and are shown in Figure 25.

The meter number versus the meter error is illustrated on the graph of Figure 26. This graph indicates the definite offset between the data points obtained by the two test methods. Going still further, Figure 27 is a plot of meter number versus the difference in meter error. The arithmetic average of these error differences is represented by the solid line through the 1.11 gallon per 1000 value.

16.2.4 DISCUSSION AND SUMMARY OF RESULTS. The data reflects a serious error or bias in a measurement program. More importantly, referring to NBS Handbook 44, Fourth Edition reveals that the "allowable maintenance tolerance", listed in the Liquid Measuring Device Code Table 3, is 525 cubic inches for a 1000 gallon draft. The 1.11 gallons or 256.4 cubic inch per 1000 gallons (average error of Figure 27) is using 48.84 percent of the maximum allowable maintenance tolerance.

Another serious problem worthy of discussion is the fact that the comparison tests may well reflect conservative differences due to the ideal physical characteristics ot the prover used for the tests. This prover was designed for bottom loading and the penetration through the prover wall was made with a weld elbow extending inside the prover. The elbow diverts the flow and promotes a very gentle stirring action during the entire loading process. All of the provers witnessed during the field tests have not had this

METER 1 AIR TEMPERATURE - 56°F PRODUCT TEMPERATURE - 72°F <u>METER ERROR/M GALS.</u> WITH RETURN = -1.47 GAL. WITHOUT RETURN = -2.18 GAL. DIFFERENCE = 0.75 GAL.	METER 2 AIR TEMPERATURE - 53°F PRODUCT TEMPERATURE - 69.5°F <u>METER ERROR/M GALS.</u> WITH RETURN = +0.58 GAL. WITHOUT RETURN = -0.74 GAL. DIFFERENCE = 1.32 GAL.	METER 3 AIR TEMPERATURE - 64°F PRODUCT TEMPERATURE - 67.5°F <u>METER ERROR/M GALS.</u> WITH RETURN = +0.19 GAL. WITHOUT RETURN = -1.15 GAL. DIFFERENCE = 1.34 GAL.
METER 4 AIR TEMPERATURE - 72°F PRODUCT TEMPERATURE - 69.5°F <u>METER ERROR/M GALS.</u> WITH RETURN = -0.14 GAL. WITHOUT RETURN = -1.38 GAL. DIFFERENCE 1.24 GAL.	METER 5 AIR TEMPERATURE - 59°F PRODUCT TEMPERATURE - 66.3°F <u>METER ERROR/M GALS.</u> WITH RETURN = +0.76 GAL. WITHOUT RETURN = -0.27 GAL. DIFFERENCE = 1.03 GAL.	METER 6 AIR TEMPERATURE - 53°F PRODUCT TEMPERATURE - 64.5°F <u>METER ERROR/M GALS.</u> WITH RETURN = +0.26 GAL. WITHOUT RETURN = -0.73 GAL. DIFFERENCE = 0.99 GAL.
METER 7 AIR TEMPERATURE - 47°F PRODUCT TEMPERATURE - 61.5°F <u>METER ERROR/M GALS.</u> WITH RETURN = +0.44 GAL. WITHOUT RETURN = -0.54 GAL. DIFFERENCE = 0.98 GAL.	METER 8 AIR TEMPERATURE - 50°F PRODUCT TEMPERATURE - 60.3°F <u>METER ERROR/M GALS.</u> WITH RETURN = +1.04 GAL. WITHOUT RETURN = -0.30 GAL. DIFFERENCE = 1.34 GAL.	METER 9 AIR TEMPERATURE - 70°F PRODUCT TEMPERATURE - 61.9°F <u>METER ERROR/M GALS.</u> WITH RETURN = +1.71 GAL. WITHOUT RETURN = +0.61 GAL. DIFFERENCE = 1.10 GAL.

Figure 25: METER TEST RESULTS

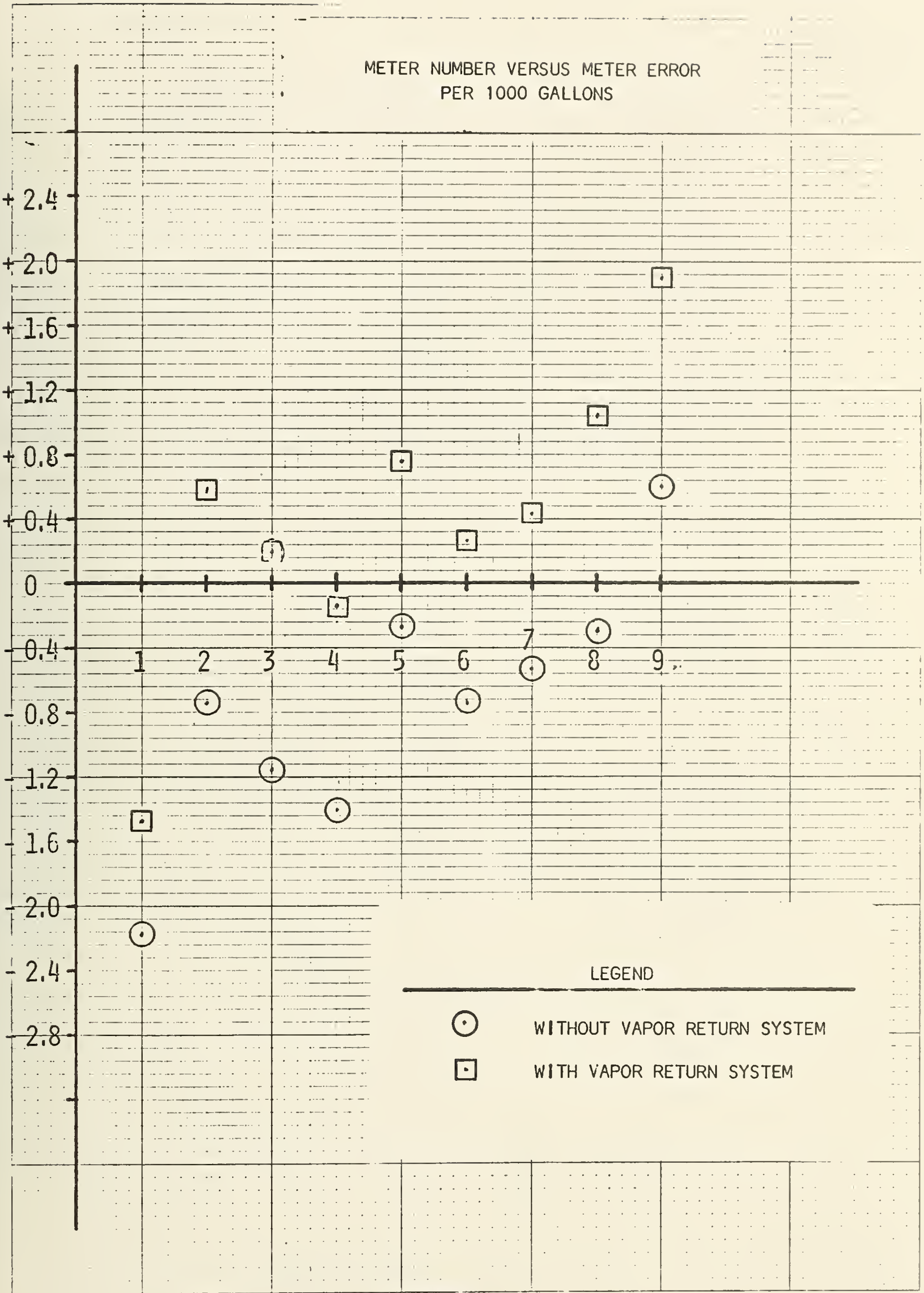

METER NUMBER VERSUS METER ERROR
PER 1000 GALLONS
+ 2.4
+ 2.0
+ 1.6
+ 1.2
+ 0.8
+ 0.4
0
- 0.4
- 0.8
- 1.2
- 1.6
- 2.0
- 2.4
- 2.8
1
2
3
4
5
6
7
8
9
LEGEND
WITHOUT VAPOR RETURN SYSTEM
WITH VAPOR RETURN SYSTEM

Figure 26

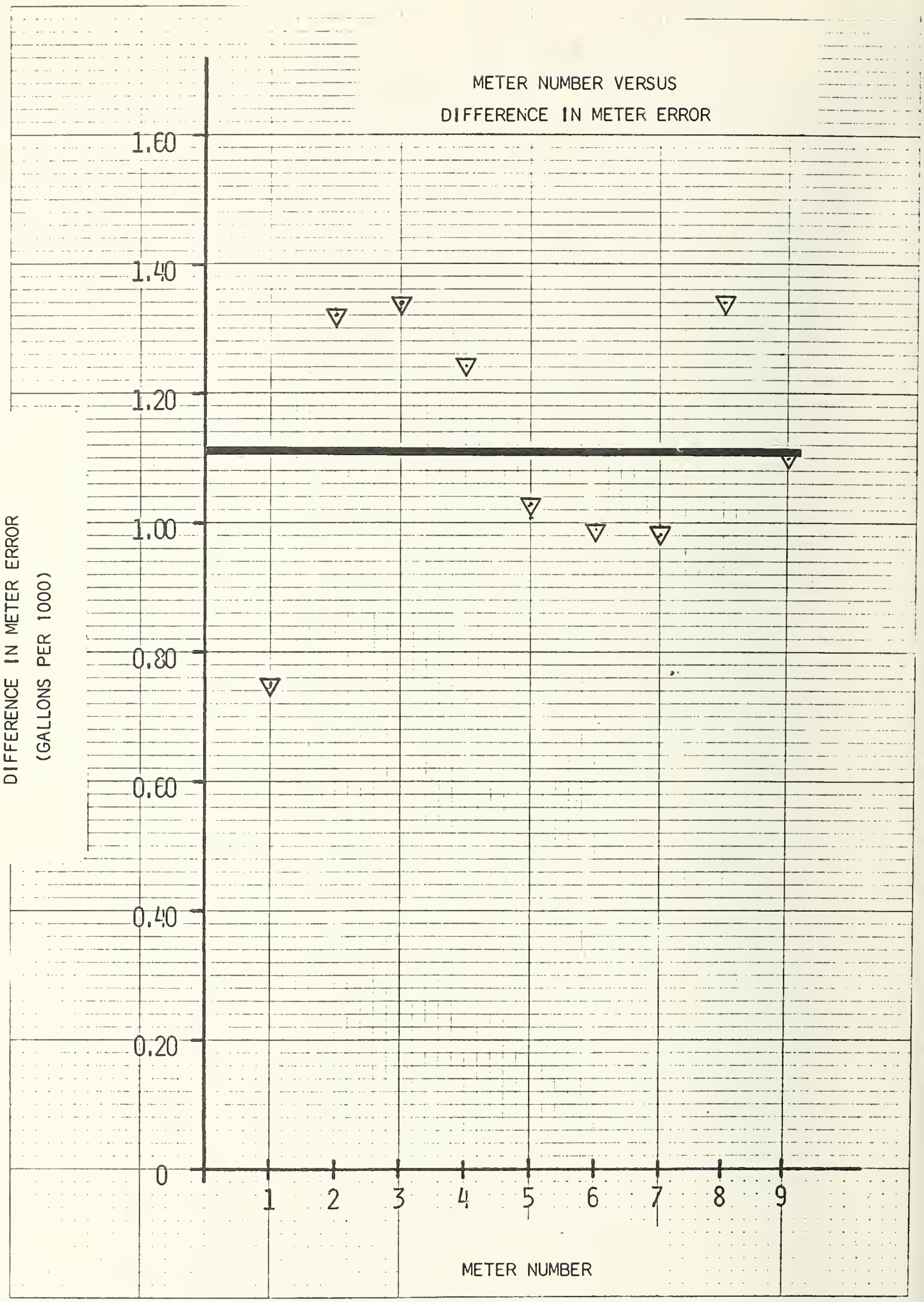

METER NUMBER VERSUS
DIFFERENCE IN METER ERROR
DIFFERENCE IN METER ERROR
(GALLONS PER 1000)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0
1
2
3
4
5
6
7
8
9
METER NUMBER

Figure 27

feature. The incoming stream on those provers would create a violent boiling action during loading that assuredly would promote greater vapor release and higher density vapor than experienced with the prover used for the vapor recovery test series.

Still another important feature that has been indicated by the field test program deals with the proving procedure. It was noted that the first test on a meter should be discarded even though the prover may be "wet-down" from a previous meter test. It is impossible to predict the history of the meter system during the prior loading and it is, therefore, necessary to make an initial run in order to appropriately stabilize the system in preparing to perform the proving operation.

From the comparison tests of vapor recovery, a cost analysis was prepared to examine the "mismeasurement" value. The analysis includes several values that may not reflect any specific operation as to monthly terminal gasoline throughput nor does it particularly reflect a known "street value" for the product. The analysis does reflect that the value of the measurement error is potentially very large.

COST ANALYSIS

HYPOTHETICAL TRUCK-LOADING TERMINAL WITH A MONTHLY GASOLINE THROUGHPUT OF 215,000 BARRELS OR 9,030,000 GALLONS

IF AN INAPPROPRIATE PROVER IS USED TO CALIBRATE THE TERMINAL METERS:

MISMEASUREMENT $= 9{,}030{,}000 \times \frac{1.11 \text{ GALLONS}}{1000 \text{ GALLONS}}$

$= 10{,}023$ GALLONS

IF THESE MISMEASURED GALLONS HAVE AN AVERAGE STREET VALUE OF \$0.50:

MISMEASUREMENT VALUE $= 0.50 \times 10{,}023$ GALLONS PER MONTH

$= \$5{,}011.50$ PER MONTH

OR

ANNUAL MISMEASUREMENT VALUE $= \$5{,}011.50 \times 12$ MONTHS

$= \$60{,}138.00$ PER YEAR

The results of the test series and the above analysis reflect a very serious potential measurement error. The value is always against the meter owner as the meter would be adjusted to deliver more product than registered or "under-register". Such will be the case if open volumetric provers are used in the calibration of meters that normally operate as closed-fill systems.

16.3 FIELD TEST DATA ANALYSIS. The analysis of the data collected during the field test program was done in two ways. First, following completion of meter tests in a particular loading terminal, the recorded data was reported to the terminal manager or superintendent on a special form developed for that purpose. Exhibit 12 is a copy of the report form. A report was prepared for each meter tested with each prover and the information was furnished only to individuals designated by the terminal superintendent. The information was intended for use in comparing test data when the meters were subjected to routine calibration check by terminal personnel. Second, upon completion of the field tests, the completed data sheets were subjected to a comprehensive evaluation and data analysis process.

16.3.1 PROVER VOLUME VERIFICATION. Guarantee was needed that the volumes of the provers, as previously determined by water calibration, was valid. The provers were subjected to a routine volumetric calibration. The 60°F Volumes were determined to be 1545.55 gallons and 758.181 gallons as shown on the Report of Calibrations in Exhibit 13 and Exhibit 14. The values compare favorably with the previously determined 1545.51 gallons and 758.257 gallons with the smaller prover having the largest difference and that being only 0.01 percent of the total volume. The values used for statistical data analysis were 1545.51 and 758.2 gallons respectively.

16.3.2 PRODUCT TEMPERATURE MEASUREMENTS. The temperature of the product in the prover was determined at three depths in the prover through liquid-filled thermowells installed in the prover shell.

REPORT OF METER TEST
(FOR UNOFFICIAL USE ONLY)

METER MANUFACTURER ____________________

MODEL NO. __________ SERIAL NO. __________

OTHER IDENTIFICATION ____________________

DATE TESTED ____________________

METERED PRODUCT ____________________

PROVER CAPACITY ____________________

NUMBER OF TESTS: ______ @ NORMAL FLOW RATE (______ GPM)

______ @ SLOW FLOW RATE (______ GPM)

AVERAGE ERROR PER 1000 GALLONS (NORMAL) __________

AVERAGE ERROR PER 1000 GALLONS (SLOW) __________

POSTED PRODUCT TEMPERATURE ______ °F

PRODUCT TEMPERATURE AT METER OR IN PROVER ______ °F

REMARKS ____________________

____

____

REPORT PREPARED BY ____________________

Exhibit 12

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234

REPORT OF CALIBRATION

Submitted by: American Petroleum Institute
Washington, D. C.

Test No. 232.09/332
Seal No. 4448

Item: 760 Gallon Vessel (Graduated Neck Type)

Maker: Kirkwood Tank Company (Maker #4090-1)
Material: Low Carbon Steel
Assumed Cubical Coefficient of Expansion:
0.0000186 per degree Fahrenheit

With the vessel described above in a standing position and a reference attitude established by leveling the attached levels, and when drained for 30 seconds after cessation of the main flow, the volume of water delivered is as follows:

Scale Reading*	Volume Delivered at 60°F (U.S. Gal)**	Volume Delivered at 60°F (in^3)	Estimated Uncertainty (in^3)
0	758.181	175140	± 36.8

A scale division, between -160 and +180 as established by separate test, is equivalent to 24.3 in^3.

Position of the graduated scale was not changed as part of the calibration procedure.

*The scale reading is determined by the intersection of the horizontal plane, tangent to the bottom of the gage meniscus, with the graduated scale.

**The volume established is based on the density of water (reference available on request). A U.S. gallon is equivalent to .003 785 412 m^3 or 231 in^3.

For the Director,

Paul E. Pontius

Paul E. Pontius, Chief
Mass and Volume Section
Optical Physics Division

Date: 13 June 1975

Exhibit 13

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234

REPORT OF CALIBRATION

Submitted by: American Petroleum Institute
Washington, D. C.

Test No. 232.09/332
Seal No. 4447

Item: 1500 Gallon Vessel (Graduated Neck Type)

Maker: Kirkwood Tank Company (Maker #4090-2)
Material: Low Carbon Steel
Assumed Cubical Coefficient of Expansion:
0.0000186 per degree Fahrenheit

With the vessel described above in a standing position and a reference attitude established by leveling the attached levels, and when drained for 30 seconds after cessation of the main flow, the volume of water delivered is as follows:

Scale Reading*	Volume Delivered at 60°F (U.S. Gal)**	Volume Delivered at 60°F (in^3)	Estimated Uncertainty (in^3)
0	1545.55	357021	± 71.3

A scale division, between -235 and +235 as established by separate test, is equivalent to 25 in^3.

The position of the graduated scale was not changed as part of the calibration procedure.

*The scale reading is determined by the intersection of the horizontal plane, tangent to the bottom of the gage meniscus, with the graduated scale.

**The volume established is based on the density of water (reference available on request). A U.S. gallon is equivalent to .003 785 412 m^3 or 231 in^3.

For the Director,

Paul E. Pontius

Paul E. Pontius, Chief
Mass and Volume Section
Optical Physics Division

Date: 13 June 1975

Exhibit 14

Additionally, both commercial quality liquid-in-glass thermometers and quartz-crystal temperature probes with electronic digital read-out were used at each of the three measurement points.

The results of data examination for the liquid temperature measurements indicate two conclusions. First, liquid-in-glass thermometers, read to the nearest one-tenth degree and periodically compared with a standard thermometer for accuracy, will provide temperature measurements of sufficient accuracy and the accuracy associated with the electronic device is not necessary for this application. Second, the temperature of the product can be accurately determined by a single thermowell located at the approximate center-height of the prover. At no time for the tests conducted during clear, cloudy, rain, sleet, or snow in both summer and winter was a temperature gradient of significant proportions noted and recorded. The only possible advantage to installing more than one thermowell in a volumetric prover would be redundancy to reveal gross reading error or to identify an erroneous indication created by a defective thermometer or a thermowell with insufficient liquid fill.

16.3.3 STATISTICAL ANALYSIS OF FIELD TEST DATA. The data sheets completed during the field tests were screened to eliminate any meter tests where an insufficient amount of data was taken or tests terminated because of equipment malfunction. The balance of the data sheets were used in the analysis to evaluate the meter and prover performance. Due to the extensive number of tests performed on each meter, it was expedient to reduce the number of tests analyzed to three normal-flow tests and one slow-flow test. The tests were selected on the basis of being the first values appearing on the data sheet rather than selecting what appeared to be the best or more accurate tests. This was done to eliminate biased data selection.

16.3.3.1 ANALYSIS OF GROSS TEST DATA. The initial analysis was performed by comparing the meter register indication against the prover volume adjusted to include the neck scale reading. The results of this analysis must be considered from the standpoint of statistical significance. To simplify the statistical language, an approximate assumption can be made that a "standard deviation" represents one-third of the "maximum uncertainty" of the normally distributed data set being examined. With this definition, the percent of acceptable data points at which the meter-prover system operated can be examined. For a normal (Gaussian) probability distribution plus or minus one standard deviation will include 68.26% of the test data points, two standard deviations include 95.46%, and three standard deviations include 99.73%.

For analysis the data was grouped by prover size. The averaged results for the normal-flow tests yielded a calculated standard deviation for the large prover of 2.135 gallons or 493 cubic inches which means that 2 standard deviations (the 95% limits) is 986 cubic inches. The maintenance tolerance of H-44 for the 1545.51 gallon draft at normal flow is 798 in^3. The data then suggests that for the meters tested, 85 to 90 percent of the data points would be within H-44 tolerance. For the smaller prover the calculated standard deviation was 1.038 gallons or 240 cubic inches and 2 standard deviations is 480 cubic inches. The maintenance tolerance from H-44 for this prover size is 404 in^3. On the basis of this standard deviation, approximately 90 percent of the individual tests performed were within tolerance. Further, it was noted that the percentage error of a single determination at normal flow was the same for both provers.

The slow-flow test data yielded 3.117 gallons and 1.860 gallons standard deviation for the large and small prover respectively, and two standard deviations would be 1440 in^3 for the large prover and 859 in^3 for the small prover. The large prover special test tolerance from H-44 is 1546 in^3 and the small prover special test tolerance is 758 in^3. Thus, greater than 95 percent of the large prover tests were within tolerance and approximately 90-93 percent of the small prover tests were within tolerance.

16.3.3.2 <u>TEMPERATURE EFFECTS ON TEST DATA</u>. The observed and recorded temperatures were used to correct the volumes in the provers and the indicated volumes on the meter register.

The volume of the prover shell was corrected to the operating temperature by the equation:

$$V_{T_1} = V_{60} \left[1 + 18.6 \times 10^{-6}(T_1 - 60)\right]$$

where V_{T_1} = Volume at Temperature T_1

V_{60} = Volume at 60°F

T_1 = Operating Temperature

The volume of the product in the prover was corrected for temperature by the equation:

$$V_{T_2} = V_{T_1} \left[1 + k\,(60 - T_2)\right]$$

where T_2 = Product Temperature

V_{T_2} = Volume of Product Temperature

k = Volume Reduction Factor from ASTM D-1250, Table 24

and the meter register volume was corrected for temperature by the equation:

$$R_{T_3} = R\,[1 + k\,(60-T_3)]$$

where T_3 = Product Temperature at Meter

R_{T_3} = Corrected Volume for T_3

The analysis of data did not reveal any significant departure from the comparative analysis of the "uncorrected" values. One factor that did reveal itself was the problem of not being able to measure the product temperature at or near the meter in a large number of the meter systems tested. When the metered product temperature could not be measured, the storage tank temperature posted in the terminal was used. This temperature was often determined only once per week and the posted tank temperatures and the temperature measured in the prover were not always comparable.

16.3.3.3 <u>SUMMER VERSUS WINTER TESTS</u>. The data collected during each of the two distinct ambient temperature test periods were evaluated by dividing the data for normal flows into two groups, under and over 60°F for one and under 40°F and over 70°F for the other. For the normal-flow tests there was no evidence of significant differences between the low temperature and high temperature tests.

For slow-flow tests, significant differences in corrections to the meter were found between high and low temperatures when the large prover was used. The ambient temperature on the large prover became statistically significant with the 13 to 14 minute test duration or prover fill time.

16.3.4 SUMMARY OF TEST DATA ANALYSIS. Analysis and evaluation of the Field Test Data provided evidence that the volumetric field standards (provers) designed for these tests were sufficiently versatile and appropriate for the intended application. The equipment was convenient to operate and was flexible enough to adapt to most meter-proving situations encountered. The accuracy and repeatability of the meter-prover were within normally acceptable limits and few changes were required in the initial equipment specification to develop the specification presented in Appendix A.

The meter error comparisons with existing H-44 tolerances were within an acceptable range. The comparisons would have been improved if the values of the calculated two standard deviations had more closely coincided with the allowable tolerance. The data obtained, though the number of meters tested was relatively small, reflects that in normal meter testing the rejection or out-of-tolerance rate would be in the order of 10 to 15 percent. This is possibly a small amount higher than would be desired. The overall statistical analysis for all meter systems suggests that the field test program was conducted in a good state of system control if one uses a two standard deviation criteria and in an excellent state of system control using the three standard deviation theory.

17.0 VOLUMETRIC FIELD STANDARDS (PROVERS) DESIGN. The field tests conducted with the equipment designed and fabricated for the Research Associate Program provided an opportunity to evaluate the effectiveness of the equipment and appropriateness of the design.

From the information gathered and the experiences during the tests, a specification was prepared to reflect the desired or required criteria. Every attempt was made to produce a specification that would promote uniformity in equipment and subsequent measurement. The specification should establish equipment uniformity, regardless of manufacturer, if complied with during fabrication.

The specification is included as Appendix A of this report.

17.1 FEATURES OF THE EQUIPMENT SPECIFICATION. Certain of the features included in the specification require more discussion or clarification than provided in a specification document. Those portions of the specification that might conflict with previously accepted philosophy or practice have been examined.

17.1.1 NOMENCLATURE. The normally accepted designation for Volumetric Field Standards varies with segments or individuals throughout the entire user population. This report and the specification adopts the use of prover, standard or volumetric prover as synonymous with volumetric field standard.

17.1.2 ANTI-SWIRL PLATES. The anti-swirl plate or plates are considered to be necessary for all provers. The plates promote more uniform draining and eliminates excessive air entrainment in the product leaving the prover.

17.1.3 BOTTOM LOADING ADAPTER. The adapter is defined as to type and installation to promote uniformity and improve the operating characteristics of the prover. The type of adapter is consistent with the recommendation of the petroleum industry and proper installation will reduce the turbulent action of the inlet stream with subsequent reduction in evaporation loss or foaming.

17.1.4 THROTTLING VALVE FOR BOTTOM LOADING. A throttling valve is required downstream of the meter to establish a slow-flow condition for meter testing. Throttling upstream of the meter can produce a liquid-vapor mixture that passes through the meter with resulting measurement error.

17.1.5 SPECIAL MARKINGS. A conspicious information plate is required to properly identify each specific prover and provide permanent documentation and indentification of the size, manufacturer, material, material characteristics, etc.

17.1.6 GROUNDING LUG. When liquid is introduced into a vessel or tank static electricity is generated that must be dissipated to ground. The grounding lug represents the point where a connection is made to provide an electrical path, thus preventing "accidental discharge".

17.1.7 SCALE PLATES. The specification was prepared for Metric and U. S. Customary systems of measurement. Recognizing that the equipment may encounter dual applications, an allowance was made to provide for an alternate graduated scale plate in addition to the plate graduated in incremental values consistent with the primary volume size measurement system of the prover.

17.1.8 THERMOMETER WELL. Thermometer wells are considered to be more desirable than encapsulated dial-type thermometers and can promote more accurate temperature measurement if proper liquid-in-glass thermometers are inserted into the thermowell which has a conducting liquid inside.

The experience of the field tests indicated that a single temperature measurement at the vertical center of the prover is adequate. At no time, during the field tests, was there any indication of temperature stratification in the prover. The variation between temperature measurements in the top one-third, center, or bottom one-third was seldom greater than 0.1°F.

A dial-type thermometer will be more susceptible to damage that would require removal and replacement. Glass thermometers are expendable and the thermowell is considered to be permanent.

Additional thermowells may be required at the discretion of the purchaser and they are acceptable.

17.1.9 DRAIN LINE REQUIREMENTS. The drain line represents a conventional configuration with the exception of the sight-flow indicator. The indicator is necessary to visually determine flow during draining and time at which the prover is empty for beginning of 30-second drain down. With closed-fill meter proving there is no visible access at the prover top.

18.0 RECOMMENDED TEST PROCEDURE. In all device testing activities it is important that uniform test procedures be employed by everyone involved in the testing. To promote uniformity in meter testing it is necessary to develop a detailed written procedure to present in an orderly step-by-step manner. As with the tests conducted on motor fuel dispensers, the basis for preparing the procedure was shown in Exhibit 15 (2 pages) EPO No. 25. During the field tests of the Research Associate Program experience and information was collected to appropriately extend the EPO to yield the desired result. To supplement the test procedure it is necessary to have a "Checklist" similar to Exhibit 16.

The test procedure includes both visual and manual inspection and should proceed as follows:

1. Perform pre-test meter examination and complete the checklist provided.
2. Position the prover at the location to be tested. Level the prover, verify that the prover drain valve is closed, connect or position the loading adapter or delivery tube, connect the vapor recovery nozzle to the prover making positive that the interface valve between the recovery system and the prover is open, connect appropriate ground and/or safety interlock connections, and inspect the entire prover system to determine that it is ready to receive product.
3. With the meter register at zero from pre-test check, cause the set-stop to be set at one-half the volume of the prover

EPO No. 25

Examination Procedure Outline for

LOADING-RACK METERS

It is recommended that this outline be followed for all power-operated and gravity discharge loading-rack meters.

INSPECTION:	H-44 General and Liquid-Measuring Device Code References
1. Indicating and recording elements.	
Design	S.1.1.
Readability	G-S.5., S.1.2., S.1.3.
Advancement and Return to Zero	S.1.1.4.
2. Measuring elements.	
Air eliminator vent	S.2.1.
Automatic temperature compensation	S.2.6.
Security seals, adjusting mechanism, and automatic temperature compensator	G-UR.4.4., S.2.2., S.2.6.3.
3. Piping.	
Discharge line and valves	S.2.3., S.3.
Leaks	G-UR.4.1., S.3.1.
Fraud	G-S.2.
4. Marking requirements	G-S.1., S.4., G-S.6.
5. General considerations.	
Selection	G-UR.1.1., S.1.1.3.
Maintenance	G-UR.3.1., G-UR.4.1.
Installation	G-UR.2.1., UR.2.2.
Accessibility	G-UR.2.3.
Assistance	G-UR.4.3.

PRE-TEST DETERMINATIONS:

1. Determine that the test liquid available is the same liquid to be commercially measured or a liquid of the same general physical characteristics.	
2. Tolerances.	
Applicable requirements	G-T., T.1.
Basic values	T.2.3.
3. Note totalizer reading.	

TEST:

Wet prover. Allow 30-second drain period each time prover is emptied.

If meter is equipped with recording element, print a ticket after each run.

If computing type, check computation	G-S.5.6., S.1.5.2.

1. Nontemperature-compensated meters

1. Normal test—full flow—basic tolerance	N.2., N.4.1.1., N.5., T.2.3.
2. Special test—slow flow—special tolerance	N.2., N.4.2.4., N.5., T.2.3.

If any of the test results are close to or outside the applicable tolerances, repeat that test.

2. Temperature-compensated meters that indicate or record both gross gallons (uncompensated) and net gallons (compensated)

1. To determine the accuracy of the gross gallons, follow the test procedure for nontemperature-compensated meters.

2. To determine the accuracy of the net gallons, proceed as follows:
   - 2.1. Calculate average temperature for each test run. During each test run conducted when determining the accuracy of the gross gallons, read temperature of product at meter at one-third and two-thirds prover capacity. Add the two temperatures obtained together and divide by 2.
   - 2.2. Find factor for reducing volume to 60° F. It is necessary that either the specific gravity or the API gravity of the product is specified by the terminal operator. Dependent on which gravity is known, select either ASTM Petroleum Measurement Table No. 6 or No. 24 to find the appropriate factor.
   - 2.3. Correct volume in prover to 60° F. Multiply the factor obtained by the prover reading.

Example: (specific gravity known)

What is the volume at 60° F of 1000.2 gallons (prover reading) at an average temperature of 45° F of an oil whose specific gravity is .725?

Table 24

0.720-0.750 Volume Reduction to 60°F ASTM-IP

0-50 °F.

Observed Temperature, °F.	Specific Gravity 60/60 °F. 0.720		0.725		0.730		0.735		0.740		0.745		0.750
	Factor for Reducing Volume to 60°F.												
40	1.0131	2	1.0129	2	1.0127	2	1.0125	2	1.0123	1	1.0122	2	1.0120
41	1.0124	1	1.0123	2	1.0121	2	1.0119	2	1.0117	1	1.0116	2	1.0114
42	1.0118	2	1.0116	2	1.0114	1	1.0113	2	1.0111	2	1.0109	1	1.0108
43	1.0111	1	1.0110	2	1.0108	2	1.0106	1	1.0105	2	1.0103	1	1.0102
44	1.0195	2	1.0103	1	1.0102	2	1.0100	1	1.0099	2	1.0097	1	1.0096
45	1.0098	1	1.0097	2	1.0095	1	1.0094	1	1.0093	2	1.0091	1	1.0090
46	1.0092	2	1.0090	1	1.0089	1	1.0088	2	1.0086	1	1.0085	1	1.0084
47	1.0085	1	1.0084	1	1.0083	2	1.0081	1	1.0080	1	1.0079	1	1.0078
48	1.0079	2	1.0077	1	1.0076	1	1.0075	1	1.0074	1	1.0073	1	1.0072
49	1.0072	1	1.0071	1	1.0070	1	1.0069	1	1.0088	1	1.0067	1	1.0066

1.0097 (factor from Table 24) X 1000.2 (prover reading) = 1009.9 gallons

The error is the difference between the net gallon representation and 1009.9 gallons.

Example: (API gravity known)

What is the volume at 60° F of 749.7 gallons (prover reading) at an average temperature of 80° F of a gasoline whose API gravity is 2?

Table 6

ASTM-IP Volume Reduction to 60°F 0.9° API 50-100°F

Observed Temperature, °F.	API Gravity at 60 °F. 0	1	2	3	4	5	6	7	8	9
	Factor for Reducing Volume to 60 °F.									
75	.9951	.9950	.9950	.9949	.9949	.9948	.9948	.9947	.9947	.9946
76	.9948	.9947	.9946	.9946	.9945	.9945	.9944	.9944	.9943	.9942
77	.9944	.9944	.9943	.9943	.9942	.9941	.9941	.9940	.9939	.9939
78	.9941	.9940	.9940	.9939	.9939	.9938	.9937	.9937	.9936	.9935
79	.9938	.9937	.9936	.9936	.9935	.9934	.9934	.9933	.9932	.9932
80	.9934	.9934	.9933	.9932	.9932	.9931	.9930	.9930	.9929	.9928
81	.9931	.9930	.9930	.9929	.9928	.9928	.9927	.9926	.9925	.9925
82	.9928	.9927	.9926	.9926	.9925	.9924	.9923	.9923	.9922	.9921
83	.9925	.9924	.9923	.9922	.9921	.9921	.9920	.9919	.9918	.9917
84	.9921	.9921	.9920	.9919	.9918	.9917	.9916	.9916	.9915	.9914

.9933 (factor from Table 6) X 749.7 (prover reading) = 744.7 gallons

The error is the difference between the net gallon representation and 744.7 gallons.
If any of the test results are close to or outside the applicable tolerances, repeat that test.

3. Temperature-compensated meters

1. Normal test—full flow—basic tolerance ------------ N.2., N.4.1.1., N.5., T.2.3.
   (Do not deactivate temperature compensator.)

Deactivate temperature compensator. -------------------- N.4.1.

2. Normal test—full flow—basic tolerance ------------ N.2., N.4.1., N.5., T.2.3.

3. Special test—slow flow—special tolerance ----------- N.2., N.4.2., N.5., T.2.3.

If any of the test results are close to or outside the applicable tolerances, repeat that test.

Reactivate temperature compensator.

4. All devices

1. Check effectiveness of antidrain valve --------------- S.3.5., S.3.6.

   Check effectiveness of valve at nozzle if wet-hose system; otherwise check for complete drainage of discharge line.

2. Check automatic-stop mechanism -------------------- G-UR.4.1.

Security seal: Apply lead-and-wire seal to secure adjusting mechanism. Also seal register to meter.

Note final totalizer reading and record on the official report the number of gallons of product dispensed during test.

Exhibit 15 (continued)

TRUCK LOADING FACILITY PRE-TEST METER EXAMINATION CHECK-LIST
(Reference: NBS Handbook 44 & NBS Handbook 112, EPO 25)

LOCATION ______________________ PRODUCT METERED ______________________

METER: Size ______, Make & Model No. ____________, Serial No. ____________

	Yes	No
Equipment & installation suitable for application (G-UR.1.1 & G-UR.2.1)	____	____
Primary indicating and/or recording element (S.1.1)	____	____
Acceptable units and sub-division units (S.1.1)	____	____
One (1) gallon or equivalent unit (S.1.1)	____	____
Convenient indicator scale graduations (G-S.5 & S.1.2)	____	____
0.008" or more graduation width ____ 0.04" or more clear interval ____		
Indicator index symetrical with graduations, maximum 0.04" between index and graduation, 0.06" or less between graduation and index. (S.1.3)	____	____
Proper return to zero function or operation. (S.1.1.4)	____	____
Meter equipped with a vapor eliminator. (S.2.1)	____	____
Meter adjustment mechanism properly sealed. (S.2.2 & G-UR.4.4)	____	____
Meter equipped with ATC and properly sealed (S.2.6 & S.2.6.2)	____	____
Can ATC be properly deactivated. (S.2.6.2)	____	____
Is adequate thermowell provided for meter temperature (Special)	____	____
Automatic directional flow valves. (S.2.3)	____	____
Meter equipped with automatic set-stop mechanism. (S.2.4)	____	____
Piping prevents discharge of metered liquid to other than the delivery point (include leak check) (S.3 & G-UR.4.1)	____	____
System does not facilitate the perpetration of fraud. (G-S.2)	____	____
Is meter used for single product. (S.4 & G-S.1)	____	____
Legible markings and instructions. (G-S.6 & G-UR.3)	____	____

Maintenance tolerance of 25 in^3 plus 1/2 in^3 per indicated gallon on Normal Tests, 1 in^3 per indicated gallon on Special Tests, and 12.5 plus 1/4 in^3 per indicated gallon on Acceptance Tests. (G-UR.4.1, G-T, T.1, & T.2)

Vapor Recovery Yes ____ No ____

______________________ Inspector signature

______ Date

Exhibit 16

if the meter system is so equipped. Read and record the totalizer reading.

4. Have a ticket inserted in the printing head.
5. Cause flow through the meter into the prover to begin.
6. With a stop watch, determine the rate at which the product is being metered. Verify that the flow rate does not exceed manufacturers rating.
7. Observe the system for leaks, proper set-stop operation, and proper control valve function.
8. When the half-volume delivery is completed, cause the delivery valve to be closed immediately.
9. If the meter system is equipped with a set-stop, verify agreement between meter register and pre-set quantity.
10. Verify that the prover drain valve does not leak.
11. Repeat steps 3, 5, 6, 7, 8, 9, and 10.
12. Read the neck scale of the prover and the indicated volume on the meter register. Compare these values but don't record on the data sheet.
13. Connect the prover drain hose to the prover and pump-off connection designated by terminal representative.

    NOTE: Though not recommended, it may be necessary to move the prover to another location for product pump-off.
14. Initiate prover pump-off or draining. Observe and time the draining. When main flow ceases as observed in the sight-flow-indicator, time a 30-second drain-down before closing the prover valve.

15. Cause the register to be zeroed and the set-stop (if so equipped) to be set at the nominal volume of the prover.

NOTE: It may be required or desirable to print a delivery ticket for each prover test.

16. Repeat Steps 4 (if necessary) 5, 6, and 7.

17. When the delivery is completed, cause the delivery valve to be closed immediately.

18. Read and record the prover neck scale level to an accuracy of one tenth scale division.

19. Read and record the meter indication to the nearest one-tenth division.

20. Determine and record on the data sheet the temperature of the product in the prover to nearest 0.1 degree.

21 If the meter is non-temperature compensated or compensated with both gross and net indication, the accuracy of the non-compensated or gross indication is determined by comparison of data recorded in Steps 18 and 19. The meter tolerance can be found in NBS Handbook 44 or calculated by the appropriate equation as follows:

Acceptance Tolerance (in^3) = (±) 12.5 + 0.25 (Prover Volume-gallons)

Maintenance Tolerance (in^3) = (±) 25 + 0.5 (Prover Volume-gallons)

22. Determine the accuracy of the temperature compensated indication, if meter so equipped, by the method given in EPO No. 25.

23. Repeat Step 13 (if necessary) and 14.

24. If the test result is near or exceeds the allowable tolerance, the test must be repeated. If well within tolerance, proceed with the test.

25. A temperature compensated meter with both net and gross volume indication can be verified by comparing the value of the net indication with the corrected gross indication (correct as in Step 22 substituting "gross reading" for "prover reading").

26. Test the compensator of a temperature-compensated meter with net indication only by deactivating the compensator and repeating Steps 4, 15, 5, 6, 7, 17, 18, 19, 20, 21, 13, and 14.

27. Cause the "throttling valve" to be adjusted to achieve approximately 20 percent of flow rate determined in normal test or manufacturers recommended minimum flow rate. Minor adjustment may be necessary as flow begins.

28. Repeat Steps 4 and 15.

29. Cause flow through the meter into the prover to begin.

30. With a stop watch, determine the rate at which the product is being metered. Verify that the flow rate does not exceed manufacturers rating.

31. Observe the system for leaks, proper set-stop operation, and proper control valve function.

32. When the delivery is completed, cause the delivery valve to be closed immediately.

33. Read and record the prover neck scale level to an accuracy of one-tenth scale division.

34. Read and record the meter indication to the nearest one-tenth division.

35. Determine and record on the data sheet the temperature of the product in the prover to nearest 0.1 degree.

36. If the meter is non-temperature compensated or compensated with both gross and net indication, the accuracy of the non-compensated or gross indication is determined by comparison of data recorded in Steps 18 and 19. The meter tolerance can be found in NBS Handbook 44 or calculated by the appropriate equation as follows:

Special Test Tolerance (in^3) = (±) 1.0 (Prover Volume-gallons)

37. Determine the accuracy of the temperature compensated indication, if meter so equipped, by the method given in EPO No. 25.

38. If the test result is near or exceeds the allowable tolerance, the test must be repeated. If well within tolerance the meter test is complete.

39. Repeat Steps 13 (if necessary) and 14.

40. Reactivate temperature compensator if deactivated, affix security seals if appropriate, complete the report of test (data sheet), and record final totalizer reading.

18.1 RULES FOR TESTING. During any testing process, certain rules or guidelines must be established for the safety and protection of personnel, equipment, and property. From the experience of the Research Associate Program Field Tests certain rules have been identified that are considered important in testing petroleum product meters. These rules include:

1. Notify appropriate plant personnel of your presence.
2. Be completely familiar with plant safety requirements and comply with these requirements at all times.
3. Know plant emergency procedures.
4. Determine the location of plant safety equipment such as fire extinguishers, water hose, etc.
5. Have plant representative verify proposed piping configurations for testing, pump-off, etc.
6. Never manipulate, change or adjust plant valves, hoses, switches, etc. without the express knowledge and approval of the designated plant representative.
7. Maintain constant surveillance on the meter register, set-stop, etc. during periods when product is flowing through the meter into the prover. Set-stop malfunction is primary cause for overfilling of a prover and can be eliminated by the person watching the meter.
8. Be completely familiar with your test equipment.
9. Never attempt to pump-off or drain prover without appropriate approval to do so.

10. Never leave the test equipment unattended during testing, pump-off, etc.

11. Always leave the test site as you found it with respect to hoses, valve positions, etc.

12. Never discuss the results of your testing with other than designated or appropriate persons.

13. Always record a beginning and final totalizer reading to avoid fouling plant inventory records.

19.0 SUMMARY OF THE API/NBS RESEARCH ASSOCIATE PROGRAM. The Research Associate Program began on April 21, 1970. Two major areas of interest were examined in detail. The first phase of the program dealt with 1, 5, and 10 gallon test measures or field standards. The investigations included design evaluation, calibration method examination, and review of field test procedures. The results of the studies in this phase of the program and which are contained in this report include the following:

1. Development of a Recommended Inspection Procedure for all field standard sizes,
2. Development of information on Hydrocarbon Liquid Retention for certain geometric configuration,
3. Preparation of a specification for Improved Design Test Measure, and
4. Development of a Field Test Procedure for testing petroleum product retail dispensers with a field standard or test measure.

The second phase of the program was directed to volumetric field standards or provers normally used in testing truck-mounted meters and tank-truck loading terminal meters. A tentative equipment specification was written and used in obtaining a trailer-mounted meter proving system. The meter proving system was subjected to a series of field tests to evaluate the design configurations and meter-prover performance. The results of the large volume field standard phase of the program and contained in this report include:

1. Preparation of an Equipment Specification for 200 to 5600 Cubic Decimeter (53 to 1480 U.S. Gallons) Volumetric Field Standards,
2. Development of a field test procedure for testing meters in liquid hydrocarbon service, and
3. Investigation of meter performance and calibration in meter systems with vapor recovery.

The Research Associate Program was terminated on July 31, 1975 after a duration of 50 months. The results realized from the research efforts are expected to make a significant contribution to a uniform measurement process throughout the petroleum industry.

20.0 <u>CONCLUSIONS AND RECOMMENDATIONS</u>. The Research Associate Program was not defined by any document when started in 1970. The first assigned responsibility in the program was to develop a scope outline for the subsequent research activity. From the initial outline, annual program reviews extended the scope of intended research with corresponding time extensions. What started as a two-year program to evaluate 1, 5, and 10 gallon measures evolved to over 5 years and encompassed all sizes of volumetric field standards. The API Research Associate Program has become one of the longer duration projects since the Research Associate Program was initiated at NBS in 1919. A wide variety of subjects have been included in the activity of the Research Associate Program. In many cases the studies on the various segments associated with the program have resulted in solutions. In other cases the problems were identified but solutions never reached.

The information developed within the project is expected to be of considerable value to both weights and measures jurisdictions and the petroleum industry. Prior to developing specifications for test measures and provers, no uniform specification existed in the United States. The same is true for the detailed test procedures that are presented. They replace nothing equivalent in open literature. Attempts early in the program to find specifications and/or detailed procedures that might be in existence yielded very little useful information. Implementation of the procedures and specifications will greatly enhance meter calibration uniformity and should subsequently contribute to advancing the state-of-the art for liquid hydrocarbon metering and meter calibration.

As previously mentioned, several problem areas were identified but never subjected to research that might yield solutions. These problems are presented for consideration of research that must be completed in the future. They include:

1. Truck-mounted Meter Field Test Program. The equipment (provers) to perform these tests was included in the trailer-mounted prover system designed and fabricated for the program. Extensive tests will be required to evaluate the performance of the provers, test procedures, and tolerances for the meter.

2. Tank-Truck Loading Terminal Design Recommendation. This problem was clearly identified during the Field Test Program. A number of design features were found to be necessary for a modern loading terminal. The solution to the problem could be realized by further evaluation of existing terminal facilities to establish user requirements for facilitating proper operation and meter calibration.

3. Vapor Return System Research. The tests conducted on meters with vapor recovery during the program represented a relatively small quantity of metering systems but did provide evidence of significant problems. Since virtually all loading terminals will be required to have vapor recovery or disposal systems within several years, the meter performance in vapor recovery systems must be extensively examined. Testing or calibrating of meters in vapor-recovery

systems with open provers cannot be predicted to have either credibility or legal base.

4. Meter Tolerance Evaluation. The field tests conducted with the volumetric provers provided only a very small sample for evaluating meter performance. The tests were designed to evaluate the provers rather than the meters. Additional testing would examine meter accuracy, time and/or volume limits for meter test interval requirements, and meter repeatability.

5. Upstream Versus Downstream Throttling to Control Flow Rate. To conduct slow-flow tests for meters it is necessary to use a valve to throttle flow to the desired rate. Investigations during the Field Test Program provided evidence that throttling flow through a valve upstream of the meter could promote metering of a liquid-vapor stream for some products. The findings prompted the recommended throttling valve between the prover and bottom-loading adapter included in the equipment specification.

The comparison between upstream and downstream throttling effects needs additional investigation. The research could be included with item 4 above.

6. Test Procedure Demonstration/Training Seminars. The single best and most reliable means to implement a recommended procedure is considered to be by demonstration to those individuals normally expected to use the procedure in routine job performance.

It is proposed that a coast-to-coast itinerary be established to conduct seminars at numerous convenient locations. The seminars would acquaint weights and measures and petroleum industry personnel with appropriate meter testing procedures. The conduct of the proposed training seminars should be a combined effort by NBS Office of Weights and Measures and API representatives and should be planned to include a maximum attendance at all seminars.

7. Liquid Retention of Volumetric Provers. Liquid retention is a feature of volumetric provers that requires further investigation. Due to limited facilities, the tests that were conducted were on small volume devices and did not provide sufficient information to allow extrapolation to large volumes.

The completion of the items listed above should bring the research program to a logical conclusion and provide information sufficient to evaluate existing or proposed meter installations.

21.0 ACKNOWLEDGEMENT. Appreciation is expressed to the American Petroleum Institute for my appointment as a Research Associate at the National Bureau of Standards. The support of API membership and staff has been extremely gratifying.

I would also like to express my sincere appreciation to the staff of the Office of Weights and Measures for their enthusiastic support and assistance in the project. Particular thanks go to Blayne C. Keysar who, as project supervisor, provided valuable guidance and assistance throughout the project.

The work at NBS has been greatly enhanced and made more pleasureable by the cooperative attitude encountered in contacts with employees throughout NBS.

A special thanks goes to P. R. deBruyn of the Office of Industrial Liaison, NBS. He has provided a great deal of moral support and assistance from the beginning of the API Research Associate Project.

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APPENDIX A

VOLUMETRIC FIELD STANDARDS SPECIFICATIONS

SPECIFICATIONS FOR 200 TO 5600 CUBIC DECIMETER (53 TO 1480 U.S. GAL.) VOLUMETRIC FIELD STANDARDS

EQUIPMENT SPECIFICATION

This specification is prepared for volumetric provers intended for:

1. Use in testing meters in low viscosity and low vapor pressure liquid service, or

2. Use as field reference standards for water calibrations.

1.0 FABRICATING VOLUMETRIC PROVERS.

1.1 SCOPE: This work shall consist of the fabricating of the volumetric provers herein described. The work shall include testing, packaging, and shipping as specified.

1.2 MATERIALS: The material used in the fabrication of the provers must be impervious to the liquids for which the prover will be used. The material of all wetted surfaces (excluding the gage glass and other removable hardware) must be identical throughout the prover. The piping of the prover shall conform to the latest revision of API Standard 5L or equal. Material selection for the prover shall be one of the following:

1. Stainless steel, 300 series,

2. Low-carbon steel, painted exterior, epoxy coating on interior,

3. Low-carbon steel, terne or galvanized, painted exterior, or

4. Low-carbon steel, painted exterior, interior coating of material certified compatible with intended liquid service.

1.3 MANUFACTURING METHODS:

A. STORAGE: Storage shall protect the material from rust, dirt, and all other potential physical and chemical damage during fabrication.

B. WORKMANSHIP AND FINISH: The workmanship and finish shall be that which can be produced by skilled workmen using modern tools in a modern fabrication shop.

C. WELDING:

(1) General: Welding shall be done according to the best modern practices, by qualified welding operators. All welding shall be performed in accordance with American Welding Society, "Welding Handbook".

The same materials, processes, and type of equipment as required for the execution of the fabrication shall be used in qualifying welders and welding operators. If a fabrication shop prequalifies its metal-arc welding operators according to the standard qualification procedure of the American Welding Society and certifies to the purchaser that an operator has been prequalified within 12 months prior to the beginning of work on the subject structures, the purchaser may consider such operator qualified.

(2) Preparation of Material for Welding: Surfaces to be welded shall be smooth, uniform, and free from fins, tears, and other defects which would adversely affect the quality of the weld. The surfaces to be welded shall also be free

from loose scale, slag, rust, grease, or other foreign matter that would affect proper welding. Mill scale that withstands vigorous wire-brushing or a light film of drying oil or rust inhibitive coatings may remain. Oxygen cutting shall, wherever possible, be done by machine oxygen cutting. Machine cut edges shall be substantially as smooth and regular as those produced by edge planing and shall be free of slag. Manual oxygen cutting shall be permitted only where machine oxygen cutting is not practicable, and only with approval of the purchaser. The edges resulting from manual oxygen cutting shall be inspected and smoothed with care. All re-entrant corners shall be filleted to a radius of at least 20 millimeters (0.75 inch). The cut lines shall not extend beyond the fillet, and all cutting shall follow closely the lines prescribed.

(3) Assembly for Welding: Abutting parts to be joined by butt welds shall be carefully aligned. The parts are to be effectively restrained against bending, a maximum offset of 10 percent of the thickness of the thinner part joined, but in no case more than 3.5 millimeters (0.125 inch), may be permitted as a departure from the theoretical alignment. Measurement of offset shall be based on centerline of parts unless shown on plans.

Tack welds that are to be incorporated in the final welds shall be subject to the same quality requirements as the final welds. Such tack welds shall be as small as practicable and where encountered in the final welding, shall be cleaned and fused thoroughly with the final weld. Multiple-pass tack welds shall have cascaded ends. Defective, cracked, or broken tack welds shall be removed prior to the final welding.

(4) Procedure for Manual Shield Metal Arc Welding: The work shall be positioned for flat welding wherever practicable. The classification and size of electrode, arc length, voltage, and amperage shall be suited to the thickness of the metal, type of groove, positions of work, and other circumstances attending the work.

When welding in the vertical position, the progression of all passes shall be in the *up* direction.

Before welding over previously deposited metal, the slag shall be removed and the weld and adjacent base metal shall be brushed clean. This requirement shall apply not only to successive layers but also to successive beads and to the crater area when welding is resumed after any interruption. It shall not, however, restrict the making of plug and slot welds.

All butt welds, except when produced with the aid of backing, shall have the root of the initial weld gouged, chipped, or otherwise cleaned to sound metal before the welding is started from the second side. Butt welds made with the use of backing of the same material as the base metal shall have the weld metal thoroughly fused with the backing. Butt welds shall be extended beyond the edges of the parts to be joined by means of extensions providing a similar joint preparation and having a width not less than the thickness of the thicker part nor less than 25 millimeters (1 inch). Each weld pass shall be terminated at least 19 millimeters (0.75 inch) from the edge of the parts to be joined. Extensions shall be removed upon completion and cooling of the weld and the ends of the weld made smooth and flush with the edges of the abutting parts.

(5) Dimensional Tolerances in Welding: The dimensions of welded structural members shall be within the tolerances permitted by the general specifications governing the work.

(6) Quality of Welds: Weld metal shall be sound throughout. There shall be no porosity or cracks on the surface of any weld or weld pass. There shall be complete fusion between the weld metal and the base metal and between successive passes throughout the joint. Welds shall be free from overlap and the base metal free from undercutting.

(7) Cleaning and Protective Coating of Welds: Welded joints that are to be painted shall not be painted until the welding has been accepted. Welds that are to be galvanized or otherwise coated with metal shall be treated to remove every particle of slag.

D. FORMING OR SHAPING: All formed sections must be smooth continuous surfaces. Pockets, dents, or crevices that could entrap air, liquid, or contaminents shall not be considered acceptable. The vertical section (barrel) must also be free from any dents or irregularities.

1.4 INSPECTION: Inspection shall be performed in compliance with American Petroleum Institute "Guide for Inspection of Refinery Equipment, Appendix for Inspection of Welding", second edition, 1971 or latest edition.

1.5 TESTING: The prover and piping shall be tested by the hydrostatic test procedure published by the American Society of Mechanical Engineers' Steel Pipe, Flanges, and Flanged Fittings, USAS B16.5-1968.

The purchaser reserves the right to observe testing. The seller shall furnish all covers, gaskets, bolts, and test equipment. Gaskets to be shipped with the prover shall not be used for any hydrostatic testing.

1.6 INTERIOR EPOXY COATING: If the interior of the prover is to be coated with epoxy, such epoxy shall be certified by the manufacturer to be impervious to liquid hydrocarbons and solvents. The epoxy shall be applied in compliance with the recommendations of the manufacturer. This shall include consideration of the surface preparation prior to coating.

1.7 METHOD OF ACCEPTANCE: Acceptance shall be based on the satisfactory completion of the job herein described. Satisfactory completion shall include calibration traceable to National Bureau of Standards and performed by a competent agency, and verification of the operating characteristics of the prover.

2.0 PAINTING

2.1 SCOPE: This work shall consist of painting of prover and piping fabricated of other than stainless steel.

2.2 MATERIALS: All materials shall be of high quality and manufactured by a company known to the purchaser. The paint materials must be intended for application to the surfaces of the fabricated prover and be relatively impervious to petroleum products.

2.3 PAINTING METHODS:

A. SCHEDULE OF PAINT COATS: The prover shall be painted with three coats of paint as specified below. The paint for each coat shall be as specified in 2.2.

(1) Primer Coat

(2) First Coat

(3) Second Coat

B. PREPARATION OF METAL SURFACES FOR PAINTING: Preparation of surfaces for painting shall comply with the standards as given in U.S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads, "Standard Specification for Construction of Roads and Bridges on Federal Highway Projects", FP-69, 1969. Available from Superintendent of Documents, Washington, D.C.

C. PAINTING PROCEDURES: Painting shall comply with the standards set forth for painting metal surfaces as given in U.S. Department of Transportation specifications cited in 2.3 B.

2.4 INSPECTION: Inspection shall be made by the purchaser. Inspection shall be with consideration of the painting methods specified in

Section 2.3.

2.5 TESTING: Testing shall consist of random tests on the painted surface with a dry film thickness gage of the electro-magnetic type. The required dry film thickness shall be as follows:

Primer Coat . . . 0.051 ± 0.006 millimeters (.002 ± .00025 inch)

Finish Coats . . . 0.102 ± 0.010 millimeters (.004 ± .0005 inch)

Total Dry Film . 0.153 ± 0.015 millimeters (.006 ± .0006 inch)

2.6 METHOD OF ACCEPTANCE: Acceptance shall be the satisfactory completion of the painting herein described.

3.0 EQUIPMENT DESCRIPTION

3.1 SCOPE: This section describes the type and design of volumetric provers covered by Sections 1.0 and 2.0.

3.2 GENERAL DESCRIPTION: The volumetric prover is a vessel which has a barrel of uniform circular cross-section with a cone-shaped top which has attached to its apex a small diameter neck of uniform cross-section with an appropriate liquid level gage. The bottom of the prover is a cone-shaped section with a drain pipe affixed to the apex. The prover must be provided with adequate means of support. *Adequate means* shall consist of, but not be limited to, an external bottom reinforcing band and/or legs. Level change between the empty and full prover must be prevented.

3.2.1 CAPACITIES: The capacity of the prover shall be as indicated on Table 1 or 2.

3.2.1.1 ANTI-SWIRL PLATE: An anti-swirl plate or plates must be attached to the bottom cone of the prover to minimize liquid swirl during emptying. Refer to Figure 1 or Figure 2.

3.2.1.2 BOTTOM LOADING ADAPTER: A bottom loading adapter may be required by the purchaser. This adapter shall be attached to the lower portion of the vertical section (barrel) of the prover, just above the bottom conical section. The vertical dimension, above grade, of the adapter should not exceed 122 centimeters (48 inches). Penetration of the vessel should be accomplished with a weld elbow as shown in Figure 2. The elbow shall direct the flow around the periphery of the prover and slightly downward. A small diameter bleed hole, 3 millimeters (0.128 inch) shall be drilled in the top of the elbow (inside of prover) to eliminate trapping of air when adapter is not used for loading. The bottom loading adapter must comply with API RP 1004, "Bottom Loading and Vapor Recovery for MC-306 Tank Motor Vehicles", Third Edition, 1975 or latest edition.

3.2.1.3 THROTTLING VALVE FOR BOTTOM LOADING: A throttling valve to achieve reduced flow rate for a *Slow-Flow Test* may be required by purchaser. This valve, if required, shall be of the wafer-type and be installed between the flange of the Bottom Load Adapter and the flange on the elbow attached to the barrel. The valve shall be of the butter-fly type with a 12 millimeter (0.5 inch) hole drilled in the gate to prevent blocking total flow if closed. The valve handle shall be provided with a notched, indexing mechanism to mechanically hold the valve in the selected open position.

3.2.1.4 REINFORCING BANDS: External reinforcing bands, at least equal to the barrel thickness, shall be attached to the barrel for strength and/or to prevent vessel distortion. A top reinforcing band shall be provided which extends D/2 (see Figures 1 and 2) above the barrel to top cone joint. Drain provision for trapped liquid is required.

3.2.1.5 LIFTING BAILS OR LUGS: Lifting bails or lugs shall be provided such that the empty prover may be moved with a crane or hoist. The bails or lugs (three required), located on the top reinforcing band, must be spaced to prevent prover distortion during lifting and promote uniform bail or lug loading.

3.2.1.6 SPECIAL MARKINGS: Each prover shall bear a permanent, conspicuous plate upon which the following information appears:

1. Name of Manufacturer
2. Address of Manufacturer
3. Material Identification (ASTM No. and Grade).
4. Material Thickness
5. Manufacturers Model Number
6. Non-repetitive Serial or Identification Number
7. Cubic Coefficient of Thermal Expansion of Material per degree C (F)
8. Nominal Volume at Zero Level on the Neck Scale
9. Drain Time After Flow Cessation: 30 Seconds (unless a different time value is requested by purchaser).

3.2.1.7 SPIRIT LEVELS: Each prover shall be equipped with two shielded style, ground vial levels, similar to Starrett #98. The top surface of the prover neck or flange must be a reinforced ground surface that will provide an indication of prover level to facilitate installation of the levels and/or replacement in the event of damage to levels. The levels should be mounted on the top cone at 90° to each other and approximately half-way between the outer edge of the prover and neck.

3.2.1.8 VAPOR RETURN TUBE: For provers sized from Table 2 and when required by purchaser, a 4" (maximum) vapor return tube shall enter just below the reinforced top of the neck and extend, tangent to the prover surface, to a point in the same approximate horizontal plane as the bottom load adapter. The tube shall terminate with a threaded tee to allow installation of a proper vapor return fitting and a valve to serve as a vacuum breaker during unloading. The tube must be attached to the prover shell as required for rigidity. NOTE: *The vapor return line size is not standardized. A size smaller than 4" may be required by the purchaser if adequate for this intended application.*

3.2.1.9 GROUNDING LUG: A grounding lug to protect against accidental discharge of static electricity is required. The lug shall be a threaded lug securely attached to the skirt of the prover and on the same side of the prover as the vapor return line and bottom load adapter.

3.2.1.10 LADDER AND PLATFORM: A ladder, when required to read gage scale, reaching from the base of the prover to the top cone, shall be fabricated of 1" pipe or equal. A level platform of expanded metal (mesh) shall be provided, if necessary, to allow reading of the liquid level. The ladder shall be securely attached to the prover for safety and on the same side as the liquid level gage. See Figure 3.

3.2.1.11 <u>PROVER COVER</u>: All provers shall be provided with a hinged, vapor-tight cover.

Provers sized from Table 1 shall have a 2" half-coupling welded on the hinged cover or in the top of the neck just below the cover to accommodate vapor recovery applications. The cover shall have a sealing gasket.

Provers sized from Table 2 shall have a cover which consists of an outer ring flange bolted to the prover neck and an inner hinged cover for the 25 centimeter (10 inch) inside diameter opening of the ring flange. The ring flange and hinged cover shall have sealing gaskets. A gasketed clamping ring may be substituted for bolting of ring flange. A Pressure Activated Fill (PAF) Manhole Cover as used on tank trucks is highly acceptable for the hinged cover and will eliminate the need for a pressure rupture disc.

3.2.1.12 <u>GAGE ASSEMBLY</u>: The prover shall be provided with a gage assembly that consists of 16 millimeter I.D. (0.625 inch) clear borosilicate glass tube, holding brackets, adjusting rods, O-ring seals, and scale plates graduated above and below zero. The assembly shall penetrate the top cone near the neck and terminate with entry into the neck near the top. The top fitting shall have a removable plug to facilitate cleaning of the gage glass with a brush. The assembly must be rigid and must be provided with means of affixing a lead-and-wire seal.

3.2.1.12.1 Scale Plates: Corrosion resistant scale plates shall be mounted approximately on a tangent to the front of or directly behind the gage glass. In either mounting, the scale plate shall not be more than 6 millimeters (0.25 inch) from the gage glass. If the scale plate is mounted behind the gage glass, protection of the glass in the form of a shield is required. The protective shield must allow removal of the gage glass for cleaning or replacement without any difficulty.

The basic scale on all volumetric provers shall be cubic centimeters or cubic inches. A single scale shall have only one measurement system markings, e.g. cubic centimeters, decimal cubic decimeters cubic inches, or decimal gallons. Dual scales are permitted only by providing two scales and will be possible only when the scales are mounted tangent to the front of the gage glass. The primary scale must always be mounted on the left side of the gage glass.

3.2.1.12.1.1 Scale Plate Markings: Special requirements govern the markings on all scale plates. These requirements include, but are not limited to, the following:

1. All scale markings must be of a color contrasting to that of the plate.

2. Scale plates shall be graduated above and below zero. The volume indicated by the markings, either above or below zero, shall not be less than one and one-half times the meter maximum acceptance tolerance as determined by the prover size.

3. Convenient major division lines, consistent to the measurement system used, shall be longer than sub-division lines and be numbered for volume indication.

4. Graduation lines shall be of uniform width and not more than 0.6 mm (.025 inch) or less than 0.38 mm (.015 inch) wide.

5. Scale plates mounted tangent to the front of the gage glass shall have the length of the major graduations (numbered) no less than 6.5 mm (.25 inch) and intermediate graduations length no less than 3 mm (.125 inch). All lines shall extend to the edge of the scale plate nearest the gage glass.

6. Scale plates mounted behind the gage glass shall have major graduations at least 19 mm (.75 inch) and sub-division lines at least 12 mm (.5 inch) in length.

7. The zero line of all scale plates shall extend across the entire width of the plate and be clearly identified.

8. The minimum distance between any graduation lines shall be 1.6 mm (0.0625 inch).

3.2.1.13 <u>THERMOMETER WELL</u>: A thermowell (length shown in Figure 1 or 2) shall be installed in the prover. The well is to point inward and downward at an angle of approximately 15°. The end of the thermowell inside the prover should be at the approximate center of the cylindrical section height.

3.2.1.14 <u>PRESSURE RELIEF PROTECTION</u>: All provers built with vapor-recovery provisions must be equipped with a pressure relief fitting (minimum 2 inch pipe size) of 20-35 kPa (3-5 psig) rating and a rupture disc of 35 kPa (5 psig) burst rating. (See 3.2.1.11).

3.2.1.15 <u>VACUUM RELIEF PROTECTION</u>: All provers built with vapor-recovery provisions must be equipped with protection against vacuum during unloading. This protection may be the valve in the vapor-return line plus a 2-inch vacuum relief fitting or by a check-valve (not spring loaded) in the tee at the termination of the vapor return line plus a rupture disc of 20 kPa (3 psig) vacuum rating.

3.2.1.16 DRAIN LINE REQUIREMENTS: The drain line, welded to the bottom cone, shall have a downward slope of 7° (nominal). The drain line shall consist of a length of pipe, a fast-acting valve (butterfly or equal), a sight-flow-indicator, and a fitting to connect the drain hose. For provers less than 2000 dm^3 (528 GAL.), the drain line should be 2-inch pipe (minimum). For provers 2000 dm^3 (528 gal.) and larger, the drain line should be 4-inch pipe. The sight-flow-indicator should have a moving element to allow verification of flow. Adequate support of the drain line shall be provided.

3.2.1.17 DIMENSIONS AND DESIGN DETAILS: The dimensions and design details shall comply with the appropriate values of Figure 1 and Table 1 or Figure 2 and Table 2 and any additional details furnished by the purchaser.

3.2.1.18 OPERATING CONDITIONS: The Volumetric Provers described in this specification are intended for, but not necessarily limited to, the following liquids:

1. Gasoline
2. Jet Fuel
3. Kerosine or Stove Oil
4. Diesel Oil
5. Alcohol
6. Water
7. Commercial Solvents

3.2.1.19 SUBMERGED FILL TUBE: One or more submerged fill tubes may be required by the purchaser. The size requirements for the tube/s/ will normally be for a 4-inch submerged pipe to extend from the top of the prover neck, through the cone, to within 10 to 15 cm (4 to 6 inch) of the bottom cone. The tube may be installed inside the prover neck or adjacent to the neck depending on space limitations. If the submerged fill tube is installed adjacent to the prover neck it will not nullify the requirements of 3.2.1.12.1.1. Submerged fill tubes for provers of less than 2000 cubic decimeter (528 gal.) volume may be sized less than 4-inch.

3.2.1.20 SPECIAL ACCESSORIES: Special applications and/or installation of the provers covered by this specification may require that certain other features be added. Such requirements are beyond the scope of this specification and must be supplied to the manufacturer by the purchaser.

4.0 PREPARATION FOR SHIPMENT: The prover, valves, piping, etc. shall be free of slag, scale, weld spatter, grit, dirt, water, and any other foreign matter before shipment.

Prover shall be adequately supported and braced to prevent damage during transit.

Stud bolts and threaded connection plugs or caps shall be thoroughly lubricated with a graphite impregnated paste before installation.

Exposed flange faces shall be protected with securely fastened wood cover plates and threaded connections with pipe plugs or caps.

All hinged covers, gage assembly, valves, etc. shall be properly installed and provided with adequate protection for shipment.

D. J. Hine, API Research Associate

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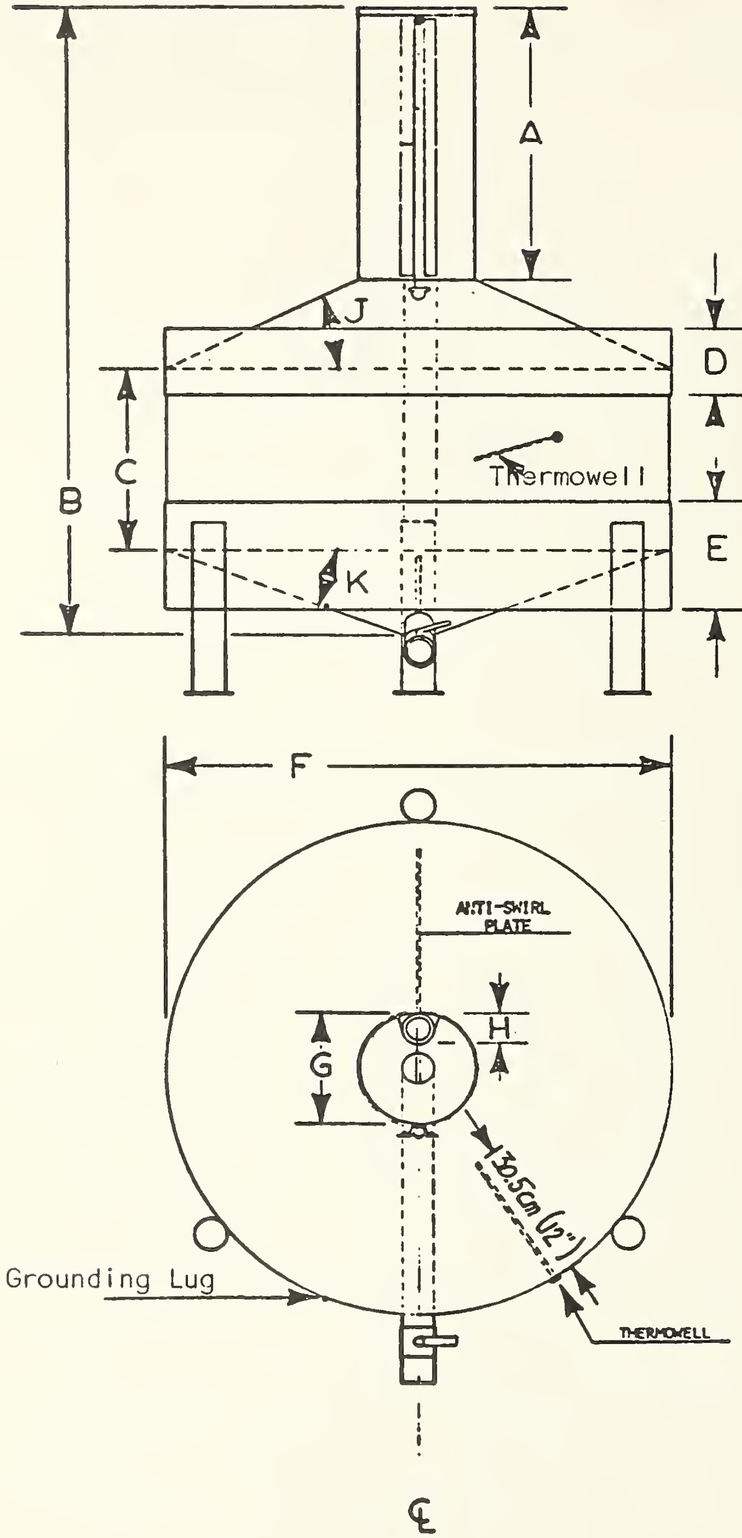
A
J
D
C
B
Thermowell
E
K
F
ANTI-SWIRL PLATE
H
G
30.5cm (12")
Grounding Lug
THERMOWELL
℄

FIGURE 1

TABLE 1

ITEM	SYMBOL REFER FIG. 1	UNIT	VALUE		
NOMINAL CAPACITY	-	CUBIC DECIMETER (Gallon)	200 (53)	500 (132)	1000 (264)
MAX. ALLOWABLE ERROR (Nominal Versus Calibrated Capacity)	-	cm^3 (in^3)	100 (6)	245 (15)	490 (30)
PROVER-INSIDE DIAMETER	F	mm (in.)	762 (30)	914 (36)	1270 (50)
PROVER-TOTAL HEIGHT	B	mm (in.)	1041 (41)	1443 (56.8)	1552 (61)
NECK-INSIDE DIAMETER	G	mm (in.)	152 (6)	203 (8)	254 (10)
NECK-HEIGHT	A	mm (in.)	460 (18)	508 (20)	508 (20)
PROVER-THICKNESS (Nominal)	-	mm (in.)	2.65 (.1046)	2.65 (.1046)	3.5 (.1345)
NECK-THICKNESS (Nominal)	-	mm (in.)	3.4 (.135)	4.2 (.164)	6.4 (.250)
HEIGHT OF BARREL	C	mm (in.)	336 (13.25)	635 (25.0)	620 (24.4)
TOP BAND WIDTH	D	mm (in.)	100 (4)	100 (4)	125 (5)
LOWER BAND WIDTH	E	mm (in.)	125 (5)	125 (5)	150 (6)
TOP CONE ANGLE	J	Degrees	25	25	25
BOTTOM CONE ANGLE	K	Degrees	20	20	20
DRAIN LINE ANGLE	-	Degrees	7	7	7
SUBMERGED TUBE I.D.	H	mm (in.)	- (3)	- (3)	- (3)
SCALE GRADUATIONS	-	cm^3 (in^3)	75 (5)	150 (10)	150 (10)
NOMINAL + AND - SCALE READING	-	cm^3 (in^3)	2500 (150)	4650 (275)	8300 (525)

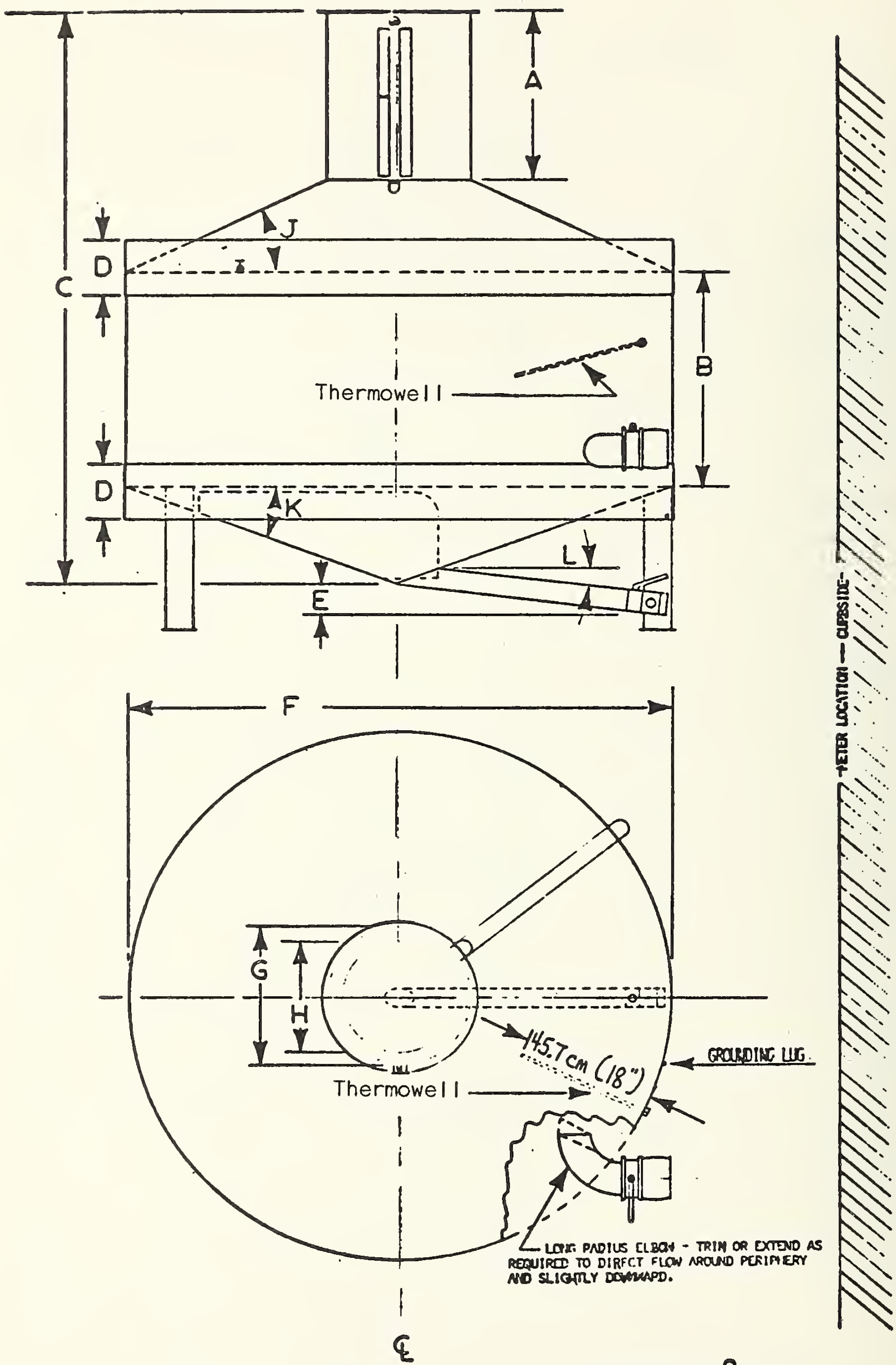
A
J
D
C
B
Thermowell
D
K
L
E
F
G
H
45.7 cm (18")
GROUNDING LUG
Thermowell
LONG RADIUS ELBOW - TRIM OR EXTEND AS REQUIRED TO DIRECT FLOW AROUND PERIPHERY AND SLIGHTLY DOWNWARD.
METER LOCATION — CURBSIDE
℄

FIGURE 2.

TABLE 2

ITEM	SYMBOL REFER FIG. 2	UNIT	VALUE		
NOMINAL CAPACITY	-	CUBIC DECIMETER (Gallon)	2000 (528)	2800 (740)	5600 (1480)
MAX. ALLOWABLE ERROR (Nominal Versus Calibrated Capacity)	-	cm^3 (in^3)	1000 (62.5)	1400 (87.5)	2800 (175)
PROVER-INSIDE DIAMETER	F	mm (in.)	1830 (72)	2235 (88)	2415 (95)
PROVER-TOTAL HEIGHT	C	mm (in.)	1780 (70)	2040 (80)	2415 (104)
NECK-INSIDE DIAMETER	G	mm (in.)	336 (13.25)	336 (13.25)	387 (15.25)
NECK-HEIGHT	A	mm (in.)	660 (26)	864 (34)	915 (36)
PROVER-THICKNESS (Nominal)	-	mm (in.)	4 (.165)	5 (.1875)	5 (.1875)
NECK-THICKNESS (Nominal)	-	mm (in.)	9.5 (.250)	9.5 (.250)	9.5 (.250)
HEIGHT OF BARREL	B	mm (in.)	520 (20.5)	416 (16.4)	902 (35.5)
TOP BAND WIDTH	D	mm (in.)	150 (6)	150 (6)	150 (6)
LOWER BAND WIDTH	D	mm (in.)	150 (6)	150 (6)	150 (6)
TOP CONE ANGLE	J	Degrees	25	25	25
BOTTOM CONE ANGLE	K	Degrees	20	20	20
DRAIN LINE ANGLE	L	Degrees	7	7	7
DRAIN LINE ELEVATION	E	mm (in.)	100 (4)	130 (5)	150 (6)
SCALE GRADUATIONS	-	cm^3 (in^3)	400 (25)	400 (25)	400 (25)
NOMINAL + AND - SCALE READING	-	cm^3 (in^3)	15600 (950)	22800 (1400)	46000 (2600)
RING FLANGE OPENING	H	cm^3 (in^3)	25 (10)	25 (10)	25 (10)

LADDER & PLATFORM DETAILS

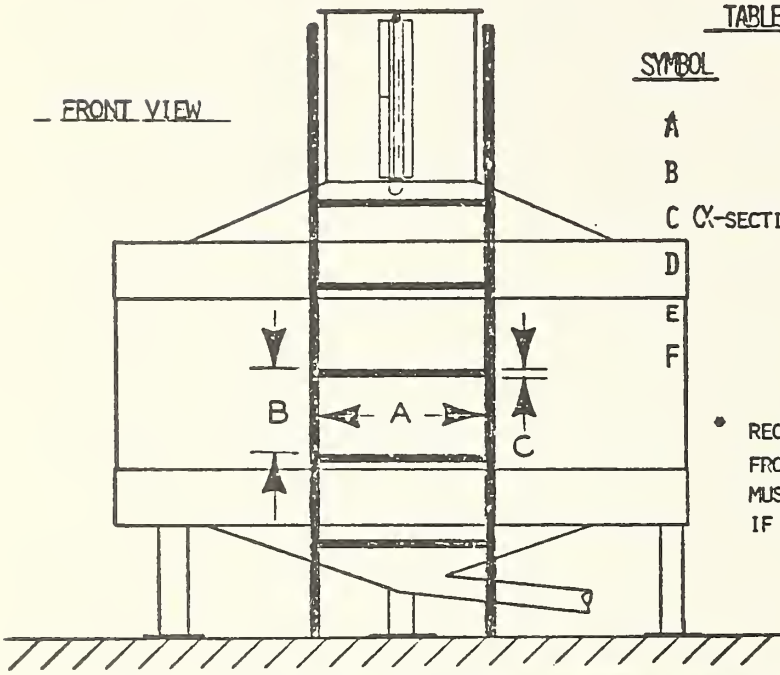

TABLE OF DIMENSIONS *

SYMBOL	MILLIMETERS	INCHES
A	406 (MIN.)	16
B	305 (MAX.)	12
C (X-SECTION)	19 (MIN.)	0.75
D	1067 (MIN.)	42
E	178 (MIN.)	7
F	762 (MIN.)	30

* RECOMMENDED DESIGN DIMENSIONS FROM ANSI A14.3-1974. DESIGN MUST CONFORM TO OSHA REGULATIONS IF APPLICABLE.

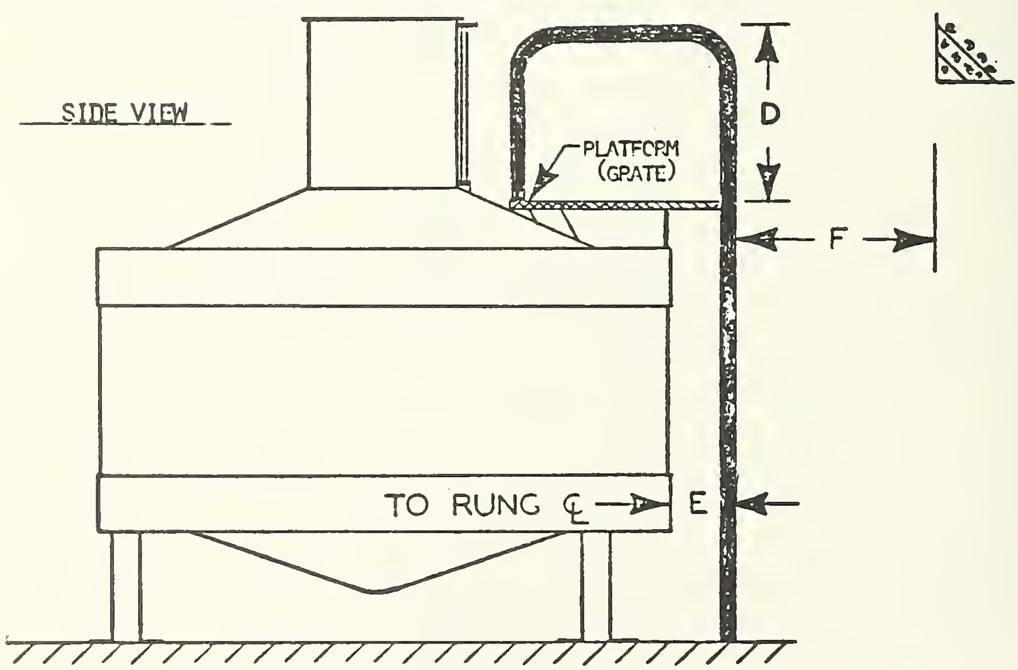

FIGURE 3

NBS-114A (REV. 7-73)

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American Petroleum Institute
2101 L Street, Northwest
Washington, D.C. 20037

13. Type of Report & Period Covered

Final - 4/70 to 7/75

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Weights and measures jurisdictions and the petroleum industry have, for many years, used metal volumetric standards in the measurement of petroleum liquid hydrocarbons. As a result of several surveys, it was learned that a need existed to establish uniform application procedures and investigate measurement accuracy. To answer this need, a joint project under the Research Associate Program of the U.S. National Bureau of Standards was established with the American Petroleum Institute as the sponsoring agency. Equipment and techniques were evaluated and the program resulted in an equipment specification, a recommended procedure for inspection, and a recommended procedure for the calibration of metal volumetric standards used by weights and measures jurisdictions and the petroleum industry.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)* Accuracy; design analysis; equipment specification; field standard; gravimetric calibration; liquid retention or clingage tests; precision; prover Research Associate Program; standards inspection procedure; test measure; test measure evaluation; temperature correction; "to contain; to deliver"; volumetric calibration

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