**API Standard 1101**
**First Edition**
**August 1960**
**(Supersedes 1952 Edition of API Code 1101)**

# MEASUREMENT OF PETROLEUM LIQUID HYDROCARBONS BY POSITIVE DISPLACEMENT METER



#3

AMERICAN PETROLEUM INSTITUTE
1271 Avenue of the Americas
New York 20, N. Y.

**Price $3.00**

SAMPLE

UNITED STATES DEPARTMENT OF COMMERCE
WASHINGTON

# National Bureau of Standards

## Certificate

FOR

Five Gallon Capacity Standard
(Graduated Neck Type)

Maker: Seraphin NBS No. yyy

submitted by

Joe Smith Oil Line Company
Prairie Dog Mound, Texas

This certifies that the capacity of the above described standard has been established at the National Bureau of Standards so that when the bottom of the meniscus of the water in the gage glass is in the horizontal plane determined by the zero line of the scale, the standard

delivers 4.999 U. S. gallons at 60° F

when drained for 10 seconds after cessation of the main flow.

For the Director,

X. X. XXXXXXXXX
Chief, Capacity, Density
and Fluid Meters Section
Mechanics Division

Test: 6.7/123456
Date: November 31, 1956

FIG. 31.



SAMPLE

UNITED STATES DEPARTMENT OF COMMERCE
WASHINGTON

# National Bureau of Standards

## REPORT

One Gallon Capacity Standard
(Graduated Neck Type)

Maker: Seraphin NBS No. xxx

submitted by

Okay Doaks Oily Company
Sand Hill, Louisiana

The capacity of the above described standard has been established at the National Bureau of Standards so that when the bottom of the meniscus of the water in the gage glass is in the horizontal plane determined by the zero line of the scale, the standard

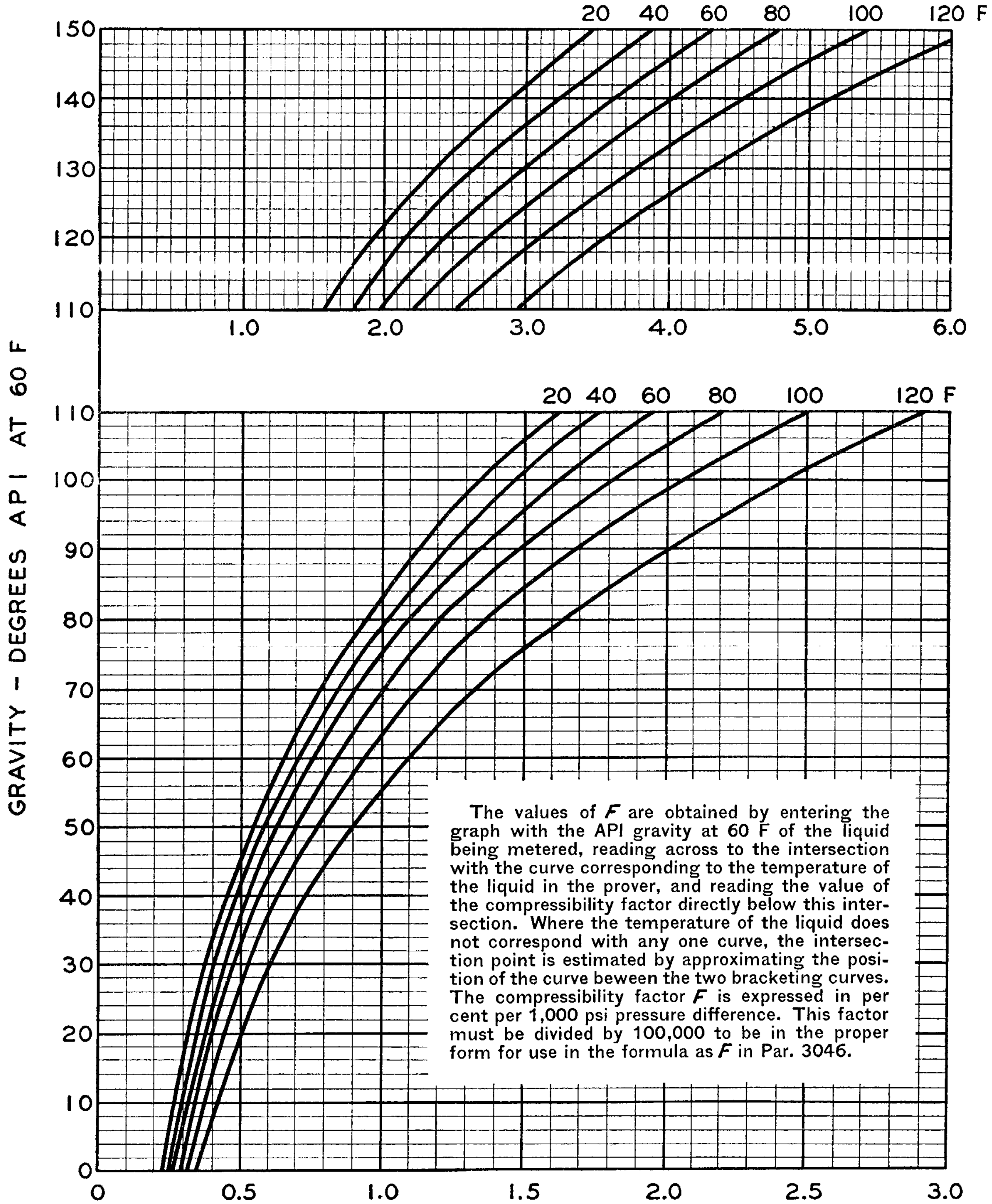
contains 0.9992 gallon at 60° F

For the Director,

Y. Y. YYYYYYY
Chief, Capacity, Density
and Fluid Meters Section
Mechanics Division

Test: 6.7/111111
Date: November 31, 1956

FIG. 32.




Data reported in following: E. W. Jacobson, E. E. Ambrosius, J. W. Dashiell, and C. L. Crawford, "Compressibility of Liquid Hydrocarbons," *Proc. API* **25** [IV] 39-41 (1945).

**FIG. 33—Mean Compressibility of Liquid Hydrocarbons Based on Data from Zero to 1,000 psig.**



NATIONAL BUREAU OF STANDARDS
CALIBRATION OF
LIQUID CAPACITY FIELD STANDARDS
**Graduated Neck Type**

To be acceptable for test and certification by the National Bureau of Standards, liquid capacity field standards of the graduated neck type should be so designed and constructed that they are suitable for their intended use. The Bureau reserves the right to decline to test any field standard of this type which is deemed to be unsatisfactory in design, construction, or condition.

Liquid capacity field standards of this type normally are associated with liquid petroleum products and are used "to deliver." In order that the results of calibrations made at the National Bureau of Standards may be, as nearly as possible, directly applicable to this normal method of use, unless otherwise requested, capacity field standards of this type are calibrated "to deliver." Calibrations are made at 60°F., with a drainage period, after the main flow ceases, of 10 seconds for field standards of 10 gallons and less, and 30 seconds for field standards above 10 gallons, and for meter provers.

The API, ASME, ASTM, and other national groups have adopted 60°F. as the reference temperature for the measurement of petroleum and petroleum products.

If, for a particular service, a different basis of calibration is required, a full description of the special requirements should be given in writing at the time the standard is submitted.

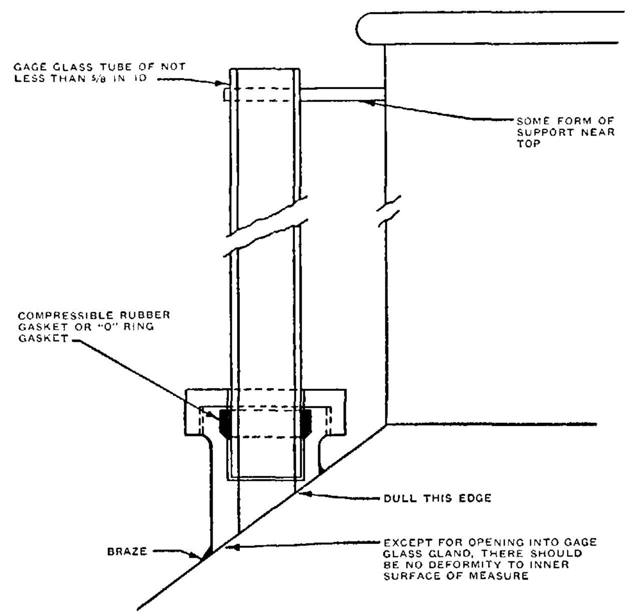
A National Bureau of Standards Certificate is issued to document the results of calibration of each liquid capacity field standard if the gage-scale can be so adjusted that the correction to the indicated capacity is not greater than one part in 2000 (0.05%). A National Bureau of Standards Report is issued when the correction is in excess of one part in 2000, but not greater than one part in 1000 (0.10%). If the gage-scale cannot be so adjusted that the correction is within one part in 1000, the results of calibration are reported in letter form only.

Attention is directed to National Bureau of Standards Handbook 45, Testing of Measuring Equipment, wherein testing procedures with liquid capacity field standards are described in full.

H. S. Bean, Chief,
Capacity, Density and
Fluid Meters Section,
Mechanics Division

Effective March 2, 1953

**FIG. 30.**




General features of a desirable method of mounting gage glass to graduated-neck liquid capacity standards.

**FIG. 27—Alternate Gage Glass Design.**

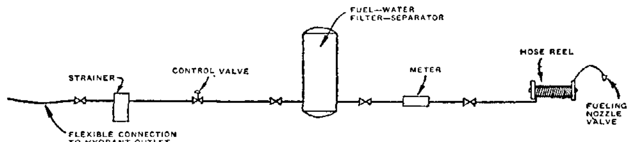



**FIG. 28—Schematic Operating Diagram of Hydrant Fueling Vehicle.**

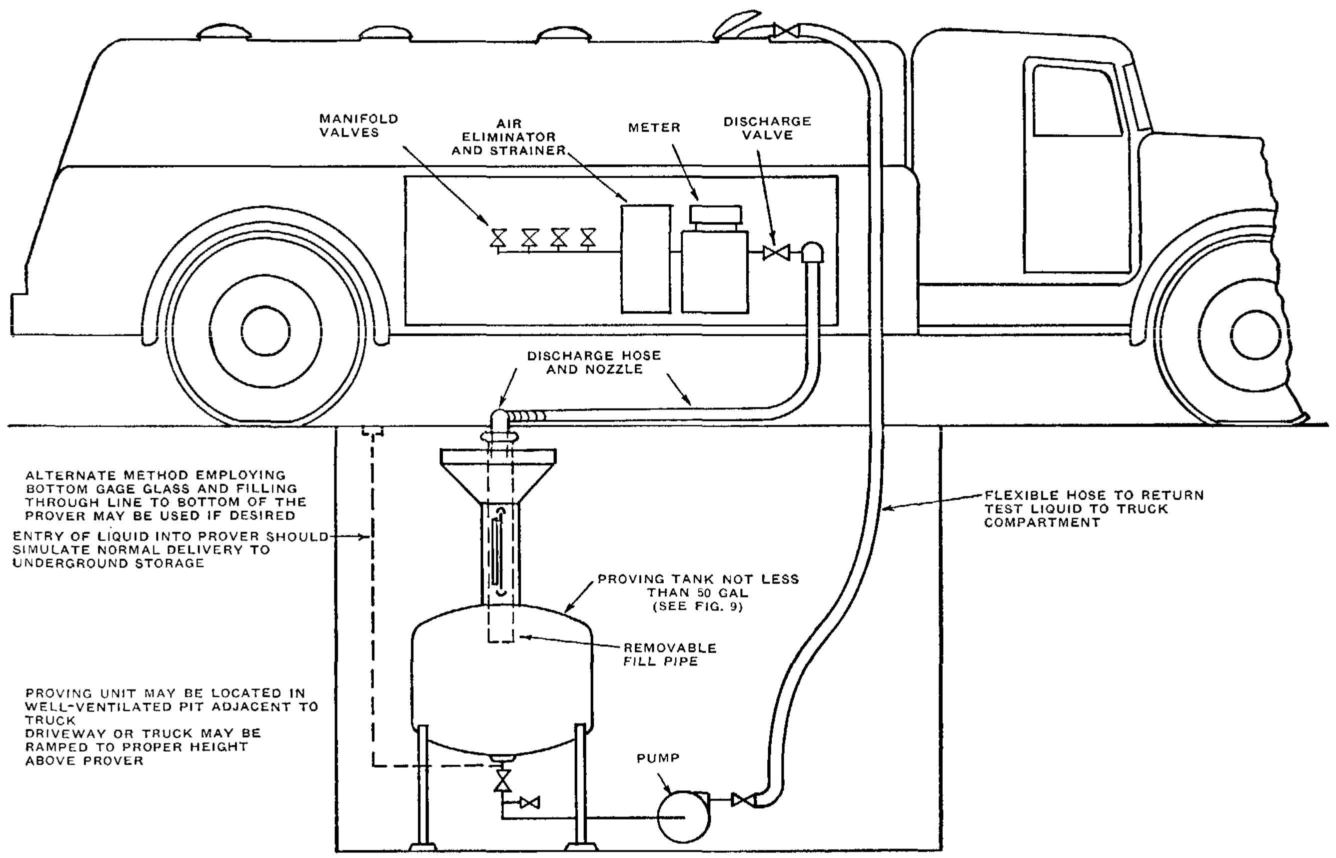



**FIG. 29—Schematic Operating Diagram—Gravity Tank Truck Meter Prover.**



**POSITIVE DISPLACEMENT METER-PROVING REPORT**

| | | | | | | |
|---|---|---|---|---|---|---|
| TYPE OF LIQUID | LOCATION | | | DATE | | REPORT NO. |
| MAKE OF METER | MODEL | TEMPERATURE-COMPENSATED? ☐ NO ☐ YES→GROUP NO.______ GRAVITY______ | | | | REGISTER NO. |
| METHOD OF PROVING ☐ PROVER TANK | SIZE | REGISTER NO. | PRESSURE ON PROVER TANK | | | |
| ☐ MASTER METER | MAKE | REGISTER NO. | SIZE | PREVIOUS PROVING→ DATA: DATE | TYPE OF LIQUID | FACTOR |

| PROVER TANK OR MASTER METER DATA | RUN NO.____ | RUN NO.____ | RUN NO.____ | RUN NO.____ | RUN NO.____ |
|---|---|---|---|---|---|
| Time of day | | | | | |
| Duration of run | | | | | |
| Gravity of liquid, API @ 60 F | | | | | |
| Prover tank temperature, deg F | | | | | |
| Average prover tank temp., deg F | | | | | |
| Closing reading, bbl | | | | | |
| Opening reading, bbl | | | | | |
| Gross barrels measured | | | | | |
| Temp. corr. factor for tank shell | | | | | |
| Temp. corr. factor for liquid | | | | | |
| Comb. liquid and shell corr. factor | | | | | |
| Master meter factor | | | | | |
| Net barrels measured | | | | | |
| **DATA ON METER CHECKED** | | | | | |
| Meter case pressure | | | | | |
| Rate of flow, bbl per hr | | | | | |
| Temp. of metered stream, deg F | | | | | |
| Closing meter reading, bbl | | | | | |
| Opening meter reading, bbl | | | | | |
| Gross barrels metered | | | | | |
| Temperature correction factor | | | | | |
| Net barrels metered | | | | | |
| Meter factor | | | | | |

| | | | |
|---|---|---|---|
| TOTALIZER READING | | AVERAGE METER FACTOR | |
| BARRELS METERED SINCE LAST RUN | | METER FACTOR TO BE USED | |

CALIBRATOR ADJUSTMENT: ☐ NO ☐ YES→AMOUNT______ RETARDED______ ADVANCED______

REMARKS (REPAIRS, ETC.): ______

| | | |
|---|---|---|
| SIGNED BY: | SIGNED BY: | CALCULATIONS VERIFIED BY: |
| FOR: | FOR: | SHEET NO. |

**FIG. 34.**

## METER PROVER REPORT NO. ______

GRAVIMETRIC METHOD

DATE ______________, 19____ LOCATION ______________________ METER NO. ______________

MAKE AND SIZE OF METER ______________________ TEMPERATURE-COMPENSATED? ______________

TYPE OF CRUDE OIL OR PRODUCT ______________________

| PROVER TANK MEASUREMENT DATA | RUN NO. 1 | RUN NO. 2 | RUN NO. 3 | RUN NO. 4 |
|---|---|---|---|---|
| 1. Rate, bbl per hr | | | | |
| 2. Observed liquid gravity and temperature | | | | |
| 3. Corrected gravity at 60 F | | | | |
| 4. Closing scale reading, lb | | | | |
| 5. Opening scale reading, lb | | | | |
| 6. Net weight measured in prover, lb | | | | |
| 7. Conversion factor, lb per bbl | | | | |
| 8. Corrected bbl measured in prover, *6* ÷ *7* | | | | |
| METERED VOLUME DATA | | | | |
| 9. Line pressure, psi | | | | |
| 10. Calibration pressure, psi | | | | |
| 11. Line temperature, deg F | | | | |
| 12. Closing meter reading | | | | |
| 13. Opening meter reading | | | | |
| 14. Barrels registered | | | | |
| 15. Temperature correction factor | | | | |
| 16. Pressure correction factor (use prover pressure) | | | | |
| 17. Net barrels metered, *14* × *15* × *16* | | | | |
| 18. Meter factor (for zero line pressure), *8* ÷ *17* | | | | |

19. Average meter factor ______________

REMARKS: ______________________

20. Average pressure correction factor ______________

21. Meter factor to be used, *19* × *20* ______________

SIGNED BY: ______________ SIGNED BY: ______________

FOR: ______________ FOR: ______________

SHEET NO. ______

Note: Figures in italics refer to items listed on left-hand side of this form.

FIG. 35.



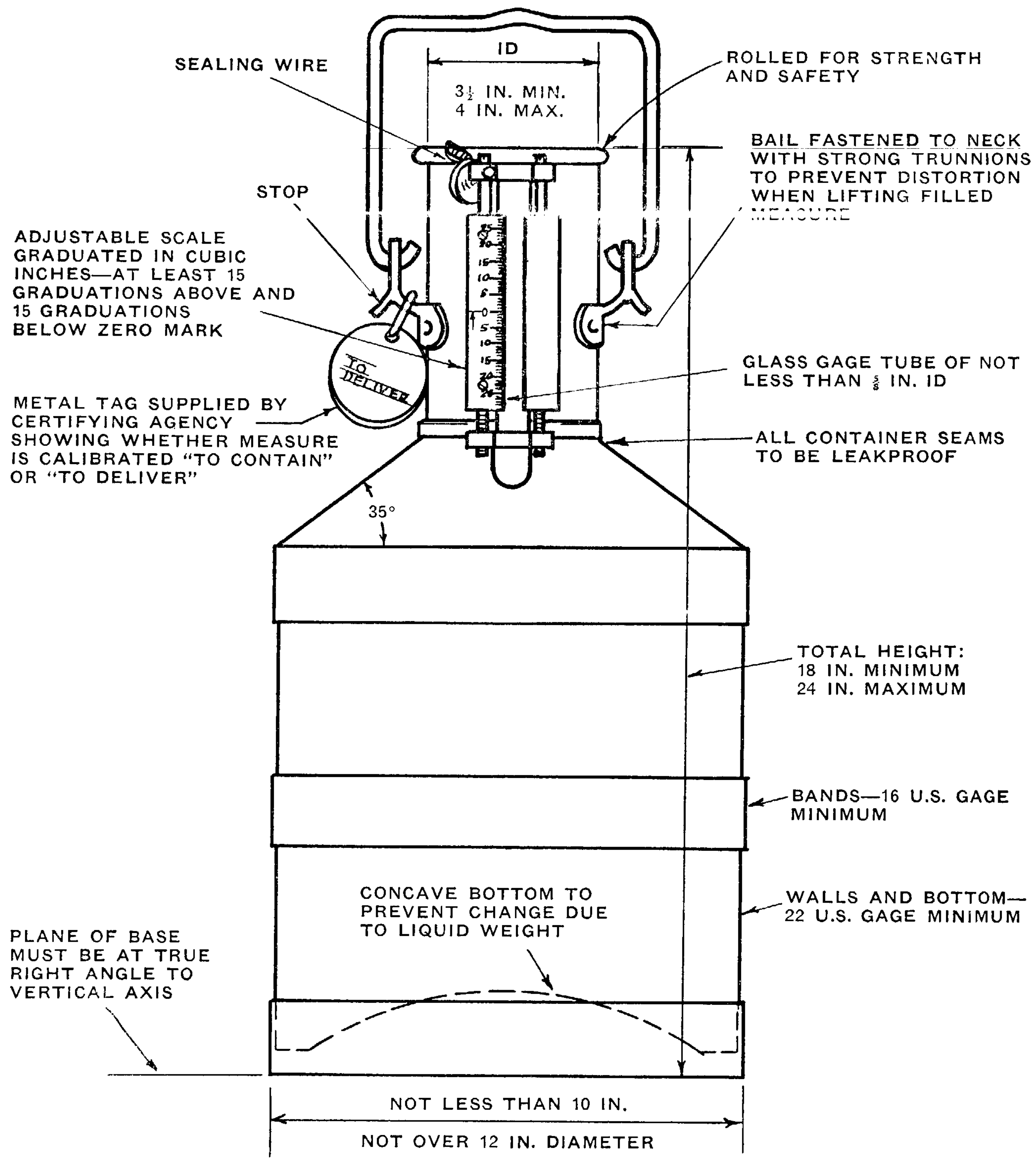
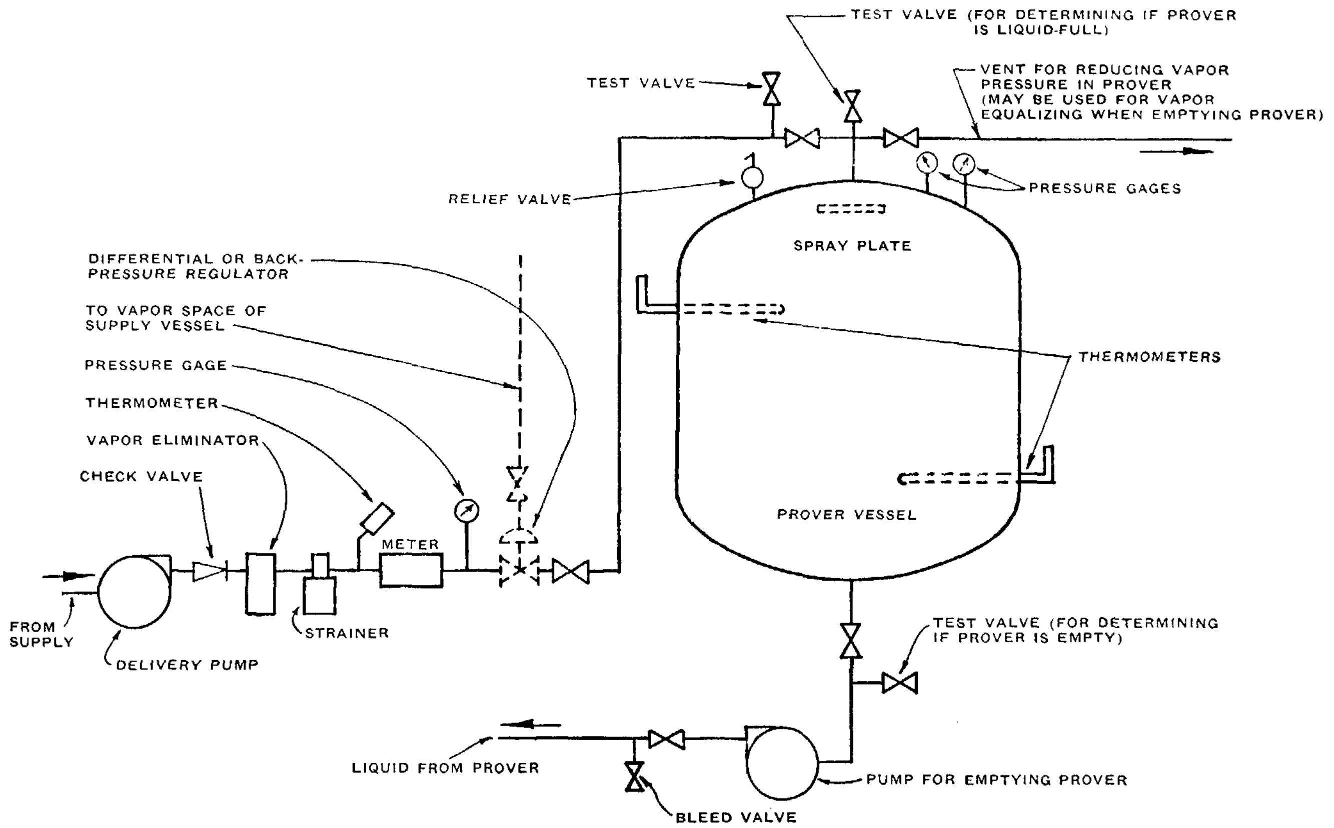



FIG. 26—Typical 5-Gal Test Measure (See Alternate Gage Glass Design, Fig. 27).




*Note:* Meter must operate above the vapor pressure of the liquid being metered. A differential or back-pressure regulator is usually used when piping from a supply vessel.

**FIG. 24—Schematic Operating Diagram of Vapor-Condensing Meter-Proving System.**

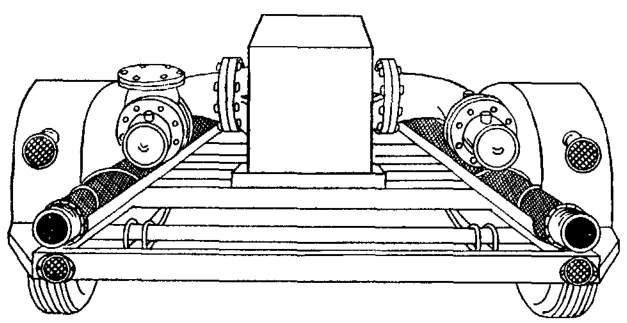


**FIG. 25—Portable Master Meter.**



**SCALE TEST REPORT**

LOCATION ______ DATE ______ DATE OF LAST INSPECTION ______

MAKE ______ TYPE ______ SERIAL NO. ______

TOTAL CAPACITY ______ DIAL CAPACITY ______ MINIMUM DIAL GRADUATIONS ______

| BEAM TESTS: | POUNDS |
|---|---|
| Tare beam at zero | |
| Tare beam at full capacity | |
| Capacity beam at zero | |
| Capacity beam at full capacity | |

| DIAL TEST: | POUNDS |
|---|---|
| Indication at zero | |
| Indication at ¼ range | |
| Indication at ½ range | |
| Indication at ¾ range | |
| Indication at full range | |

Dial to be checked between above ranges.

| UNIT WEIGHT ADDED | DIAL INDICATION AT ZERO | WEIGHT INDICATION AT FULL DIAL CAPACITY | PLUS OR MINUS ERROR |
|---|---|---|---|
| No unit weight | | | |
| 1st unit weight | | | |
| 2nd unit weight | | | |
| 3rd unit weight | | | |
| 4th unit weight | | | |
| 5th unit weight | | | |
| 6th unit weight | | | |
| 7th unit weight | | | |
| 8th unit weight | | | |
| 9th unit weight | | | |

REMARKS:

SCALE MECHANIC: ______ COMPANY: ______

WITNESSED BY: ______ REPRESENTING: ______

**FIG. 36.**

## METER-PROVING REPORT—BIDIRECTIONAL PISTON DISPLACEMENT METHOD

DATE________ LOCATION________ OWNER OF METER________

TRUCK NO.________ METER NO.________ SIZE________ MAKE________

PRODUCT USED FOR TEST________ PRODUCT SPECIFICATIONS________

FINAL TOTALIZER READING________ INITIAL TOTALIZER READING________ GALLONS USED________

| DESCRIPTION OF QUANTITIES | RUN NO. 1 | RUN NO. 2 | RUN NO. 3 | RUN NO. 4 | RUN NO. 5 |
|---|---|---|---|---|---|
| METER REGISTRATION DATA | | | | | |
| 1. Final meter reading | | | | | |
| 2. Initial meter reading | | | | | |
| 3. Registration by meter | | | | | |
| 4. Average temperature @ meter | | | | | |
| 5. Factor for meter temperature | | | | | |
| 6. Corrected registration by meter, *3 × 5* | | | | | |
| TEST VOLUME DATA | | | | | |
| 7. Quantity displaced | | | | | |
| 8. Temperature @ inlet end | | | | | |
| 9. Temperature @ outlet end | | | | | |
| 10. Average temperature displaced liquid | | | | | |
| 11. Factor for displaced liquid (temperature) | | | | | |
| 12. Average pressure displaced liquid | | | | | |
| 13. Average pressure @ source | | | | | |
| 14. Press. diff.: disp. liquid vs. source, *12 — 13* | | | | | |
| 15. Factor for displaced liquid (pressure) | | | | | |
| 16. Factor for prover volume (temperature) | | | | | |
| 17. Factor for prover volume (pressure) | | | | | |
| 18. Corrected test volume, *7 × 11 × 15 × 16 × 17* | | | | | |
| PERFORMANCE COMPUTATIONS | | | | | |
| 19. Elapsed time for run, min and sec | | | | | |
| 20. Elapsed time for run, min | | | | | |
| 21. Average rate of flow, *18 ÷ 20* | | | | | |
| 22. Meter accuracy, *6 ÷ 18* | | | | | |
| 23. Register adjustment prior to run | | | | | |

SIGNED BY________ PROVING OPERATOR________

WITNESSED BY________ METER OWNER________

CHECKED BY________

METER ACCURACY AS LEFT________ PER CENT AT RATE OF FLOW OF________ GPM AND________ PSI

Note: Figures in italics refer to items listed on left-hand side of this form.

FIG. 37.



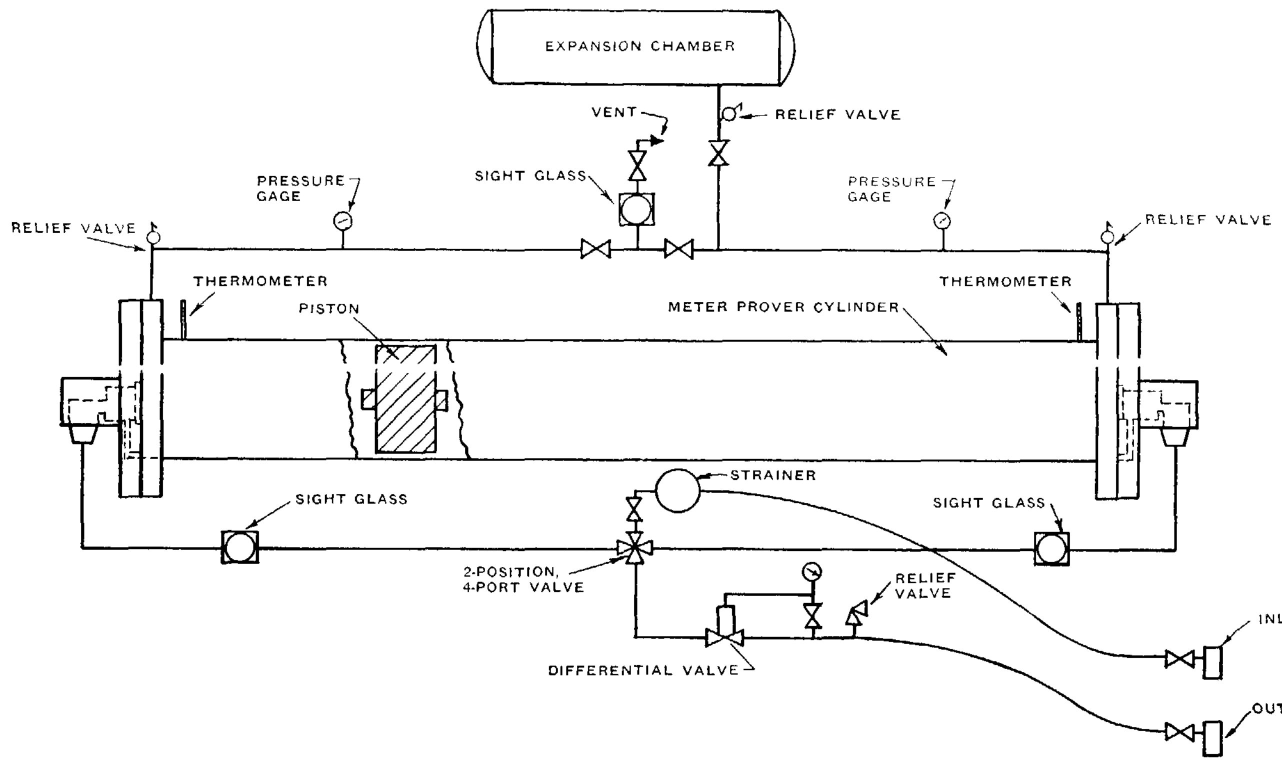
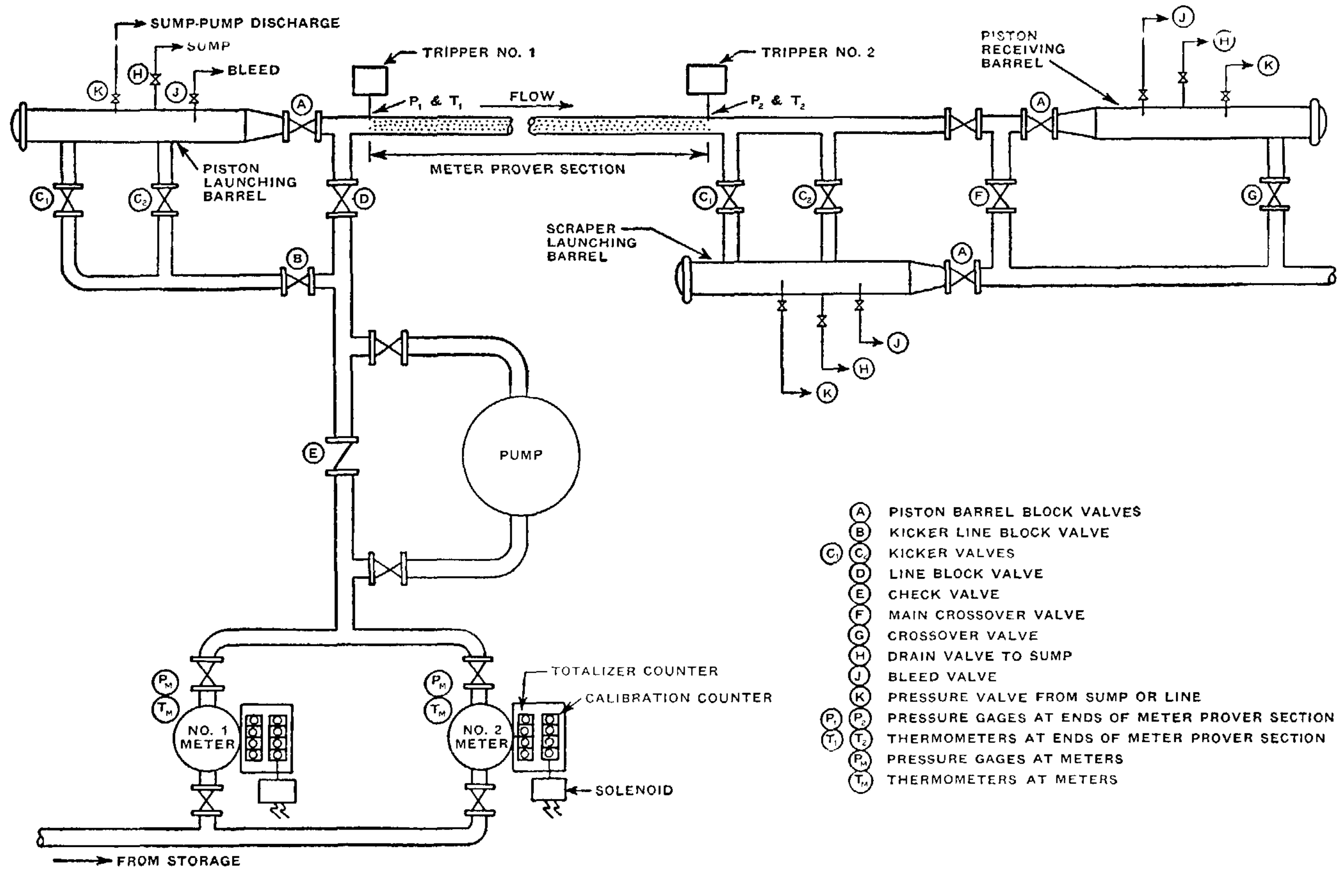



**FIG. 22—Schematic Operating Diagram of Bidirectional Piston Displacement Prover.**




*Note:* May be installed upstream from meters with appropriate changes in piping.

**FIG. 23—Unidirectional Piston Displacement Prover Installation Downstream from Meters.**

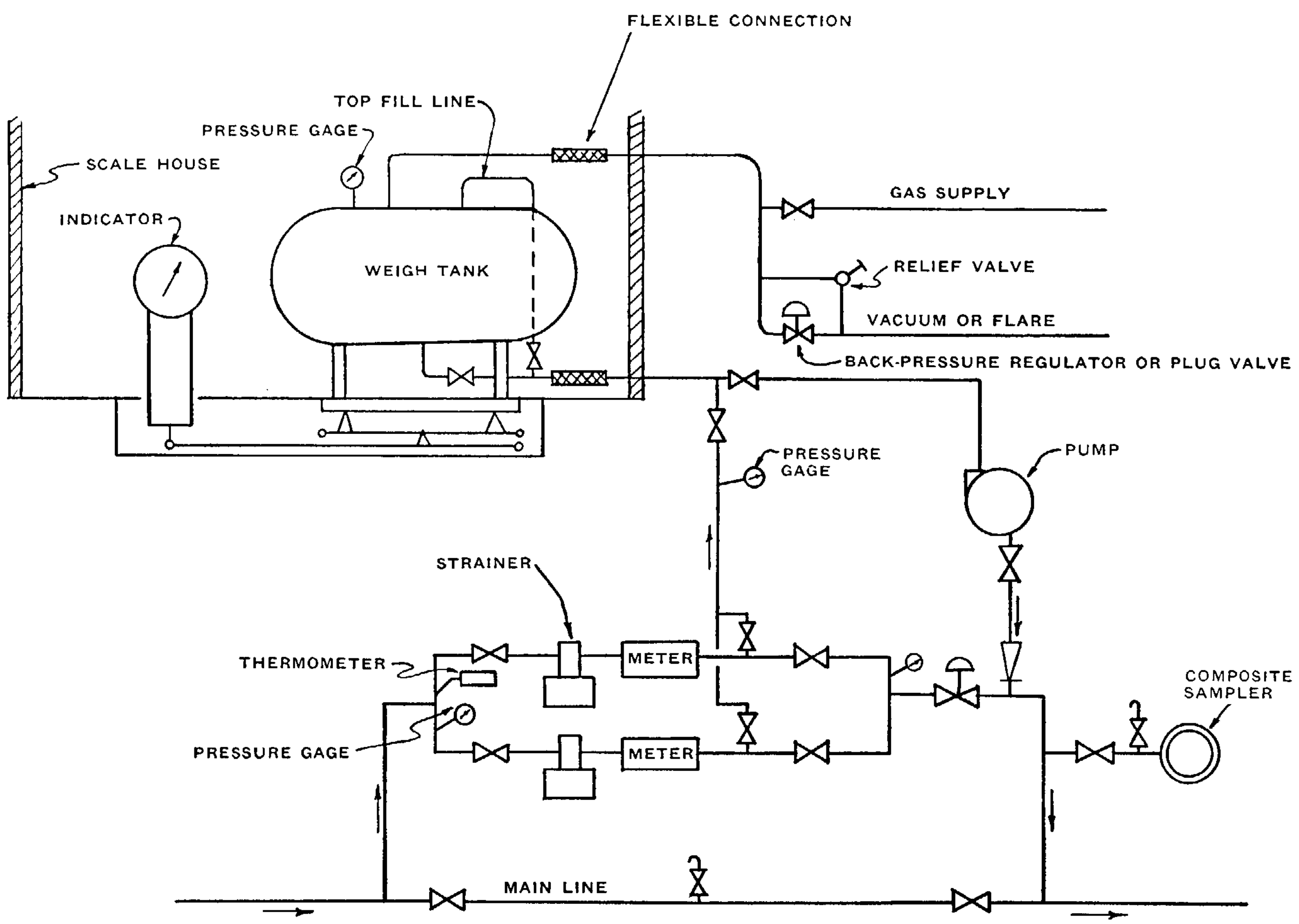



**FIG. 20—Schematic Operating Diagram of Closed Gravimetric System.**

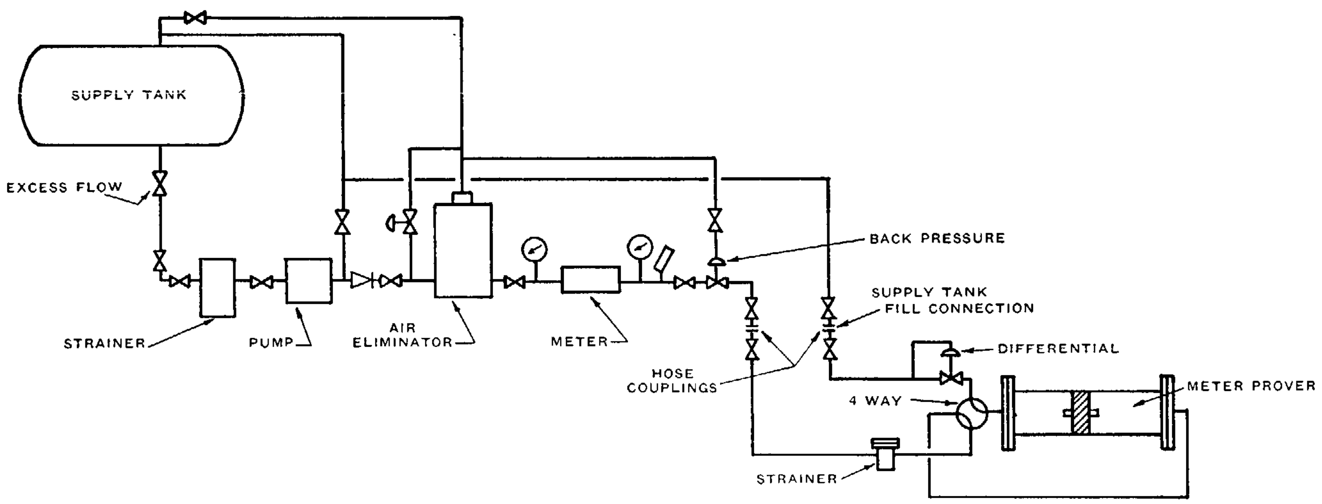



**FIG. 21—Schematic Operating Diagram of Bidirectional Piston Displacement Prover System.**

## METER-PROVING REPORT—UNIDIRECTIONAL PISTON METHOD

STATION OR DELIVERY POINT ______ REPORT NO. ______

METER NO. ______ SERIAL NO. ______ DATE ______

METER MAKE ______ SIZE ______ BATCH NO. ______

INITIAL TOTALIZER READING ______ PRODUCT ______

DATE METER LAST REPAIRED ______ OCTANE ______ API GRAVITY ______

| DESCRIPTION OF QUANTITIES | RUN NO. 1 | | RUN NO. 2 | |
|---|---|---|---|---|
| | METER ______ | METER ______ | METER ______ | METER ______ |
| METER REGISTRATION DATA | | | | |
| 1. Final meter reading | | | | |
| 2. Initial meter reading | | | | |
| 3. Registration by meter, bbl: *1* — *2* | | | | |
| 4. Total registration for run, bbl | | | | |
| 5. Temperature of stream at meter, deg F | | | | |
| 6. Factor for meter temp. (Table 6, D 1250) | | | | |
| 7. Corrected meter registration, *4* × *6* | | | | |
| 8. Meter case pressure—inlet and outlet | | AVERAGE | | AVERAGE |
| PROVER SECTION VOLUME DATA | | | | |
| 9. Pressures at Trip No. 1 and Trip No. 2 | | | | |
| 10. Prover pressure (average), sum of *9* ÷ *2* | | | | |
| 11. Temperatures at Trip No. 1 and Trip No. 2 | | | | |
| 12. Prover temperature (average), sum of *11* ÷ *2* | | | | |
| 13. Base prover volume, bbl | | | | |
| 14. Factor for prover pressure (see Par. 2122) | | | | |
| 15. Factor for prover temp. (see Par. 3045) | | | | |
| 16. Factor for liquid pressure (see Par. 3046) | | | | |
| 17. Factor for liquid temp. (Table 6, D 1250) | | | | |
| 18. Net prover volume, bbl: *13* × *14* × *15* × *16* × *17* | | | | |
| PERFORMANCE COMPUTATIONS | | | | |
| 19. Time piston launched | | | | |
| 20. Elapsed time for run, min and sec | | | | |
| 21. Elapsed time for run, hr: $\frac{(60 \times \text{min}) + \text{sec}}{3{,}600}$ | | | | |
| 22. Rate of flow during run, bbl per hr: *4* × *24* ÷ *21* | | | | |
| 23. Meter factor (with compensator), *18* ÷ *4* | | | | |
| 24. Meter factor (without compensator), *18* ÷ *7* | | | | |
| 25. Amt. corr. for factor 1.0000: (1.0000) — *24* | | | | |

SIGNED BY ______ FACTOR TO BE APPLIED ______ @ ______ BPH

AND ______ PSI METER CASE PRESSURE

WITNESSED BY ______

FOR ______ CHECKED BY ______ FOR ______

*Note: Figures in italics refer to items listed on left-hand side of this form.*

**FIG. 38.**

## VAPOR-CONDENSING METER PROVER TEST REPORT

STATION: TYPE OF SERVICE: PRODUCT: TEST NO.: DATE:

METER MAKE: SIZE: MODEL: SERIAL NO.: DATE LAST CALIBRATION:

CALIBRATED PROVER VOLUME: MANUFACTURER SERIAL NO.: TYPE: CERTIFICATE NO.: DATE LAST CALIBRATION:

| | RUN NO. 1 | RUN NO. 2 | RUN NO. 3 | RUN NO. 4 | AVERAGE | REMARKS |
|---|---|---|---|---|---|---|
| 1. Vapor temperature after venting | | | | | | |
| 2. Temp. @ meter @ 15% prover capacity | | | | | | |
| 3. Temp. @ meter @ 50% prover capacity | | | | | | |
| 4. Temp. @ meter @ 85% prover capacity | | | | | | |
| 5. Average temperature @ meter | | | | | | |
| 6. Prover temperature @ end of test | | | | | | |
| 7. Temp. difference between *5* and *6* | | | | | | |
| 8. Press. @ meter @ 15% prover capacity | | | | | | |
| 9. Press. @ meter @ 50% prover capacity | | | | | | |
| 10. Press. @ meter @ 85% prover capacity | | | | | | |
| 11. Average pressure @ meter | | | | | | |
| 12. Prover pressure @ end of test | | | | | | |
| 13. Press. difference between *11* and *12* | | | | | | |
| 14. Correction for temp. difference, *7* | | | | | | |
| 15. Correction for condensed vapor | | | | | | |
| 16. Correction for compress. of liquid, *13* | | | | | | |
| 17. Total correction | | | | | | |
| 18. Calibrated volume of prover | | | | | | |
| 19. Corrected prover volume, *18* ± *17* | | | | | | |
| 20. Final meter reading | | | | | | |
| 21. Initial meter reading | | | | | | |
| 22. Meter registration, *20* — *21* | | | | | | |
| 23. Meter error, gal: *22* — *19* | | | | | | |
| 24. Meter error, per cent: *23* ÷ *19* | | | | | | |
| 25. Meter factor, *19* ÷ *22* | | | | | | |
| 26. Elapsed time run, min and sec | | | | | | |
| 27. Elapsed time run, min | | | | | | |
| 28. Average flow rate, *19* ÷ *26* | | | | | | |

SIGNED BY: ______________ SIGNED BY: ______________

FOR: ______________ FOR: ______________

Note: Figures in italics refer to items listed on left-hand side of this form.

FIG. 39.

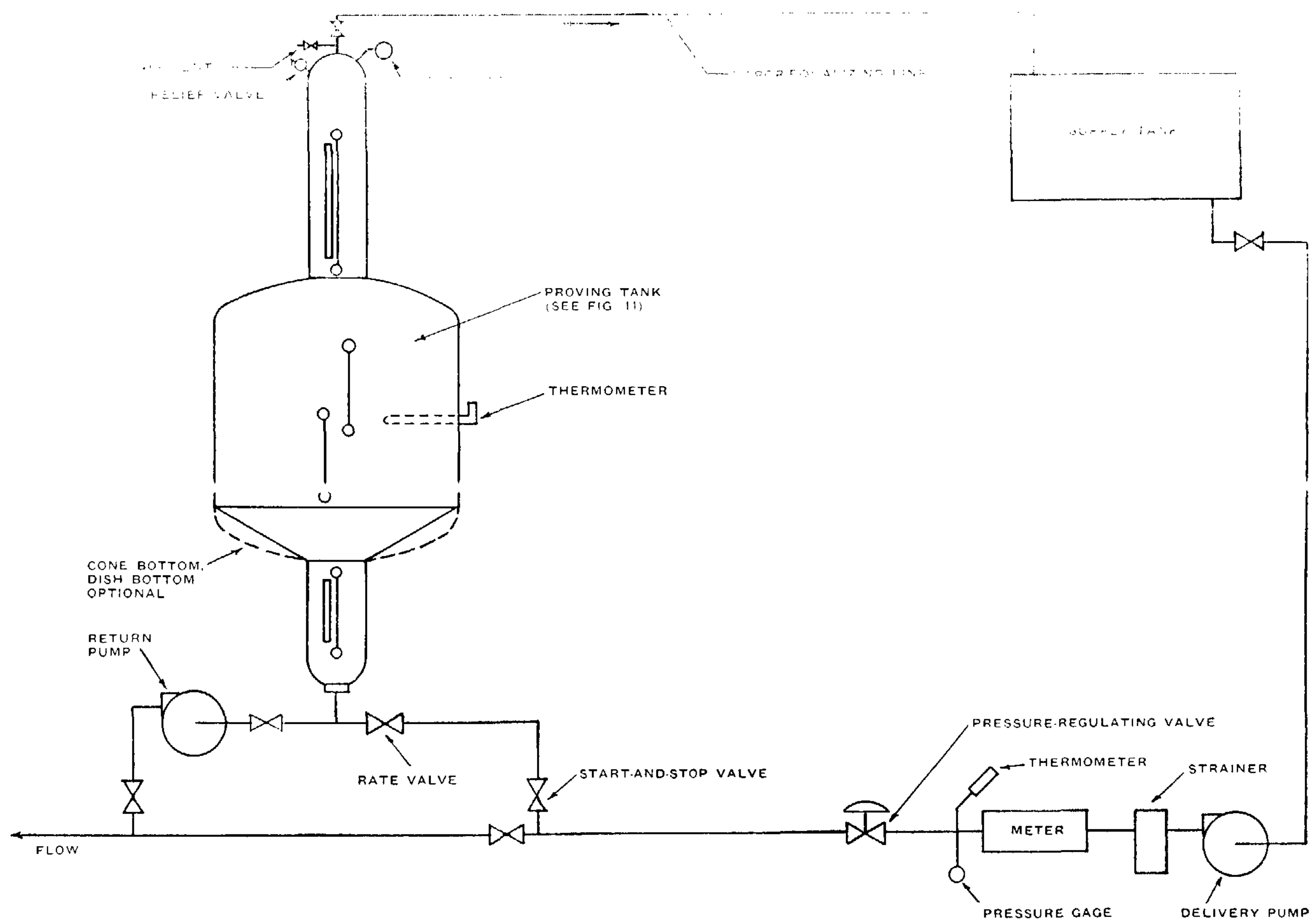



FIG. 18—Schematic Operating Diagram of Volumetric Prover for Vapor Displacement.

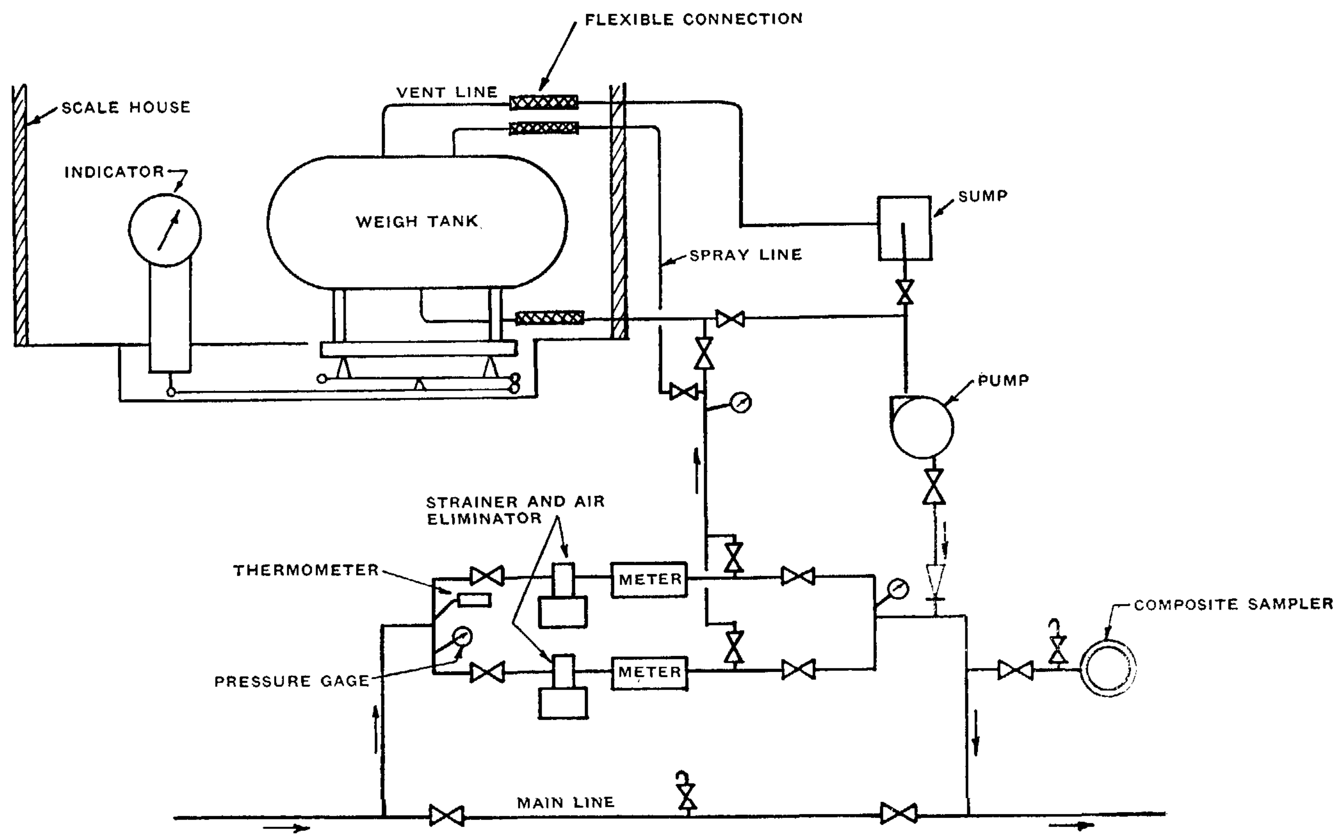



FIG. 19—Schematic Operating Diagram of Open Gravimetric System.

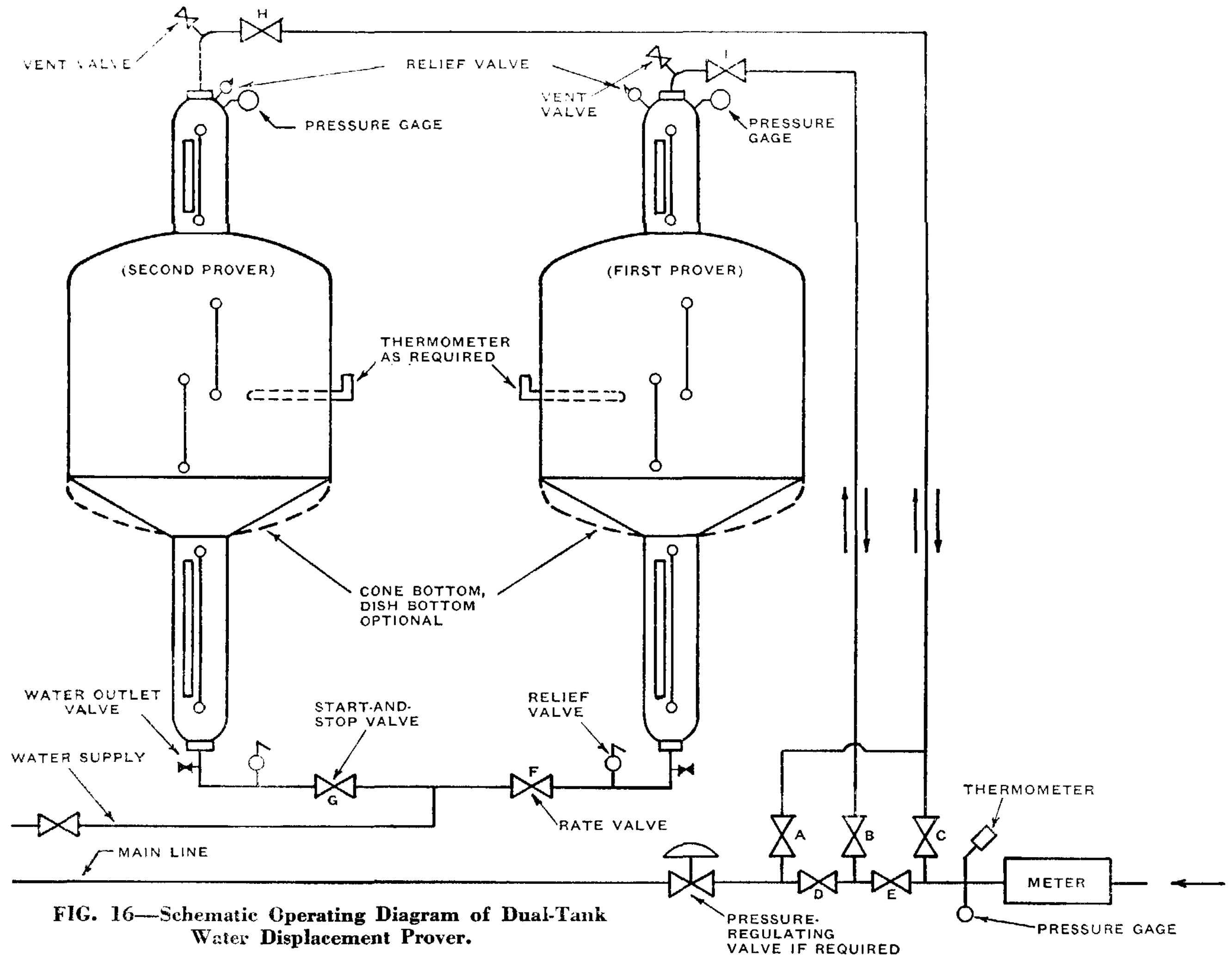



FIG. 16—Schematic Operating Diagram of Dual-Tank Water Displacement Prover.

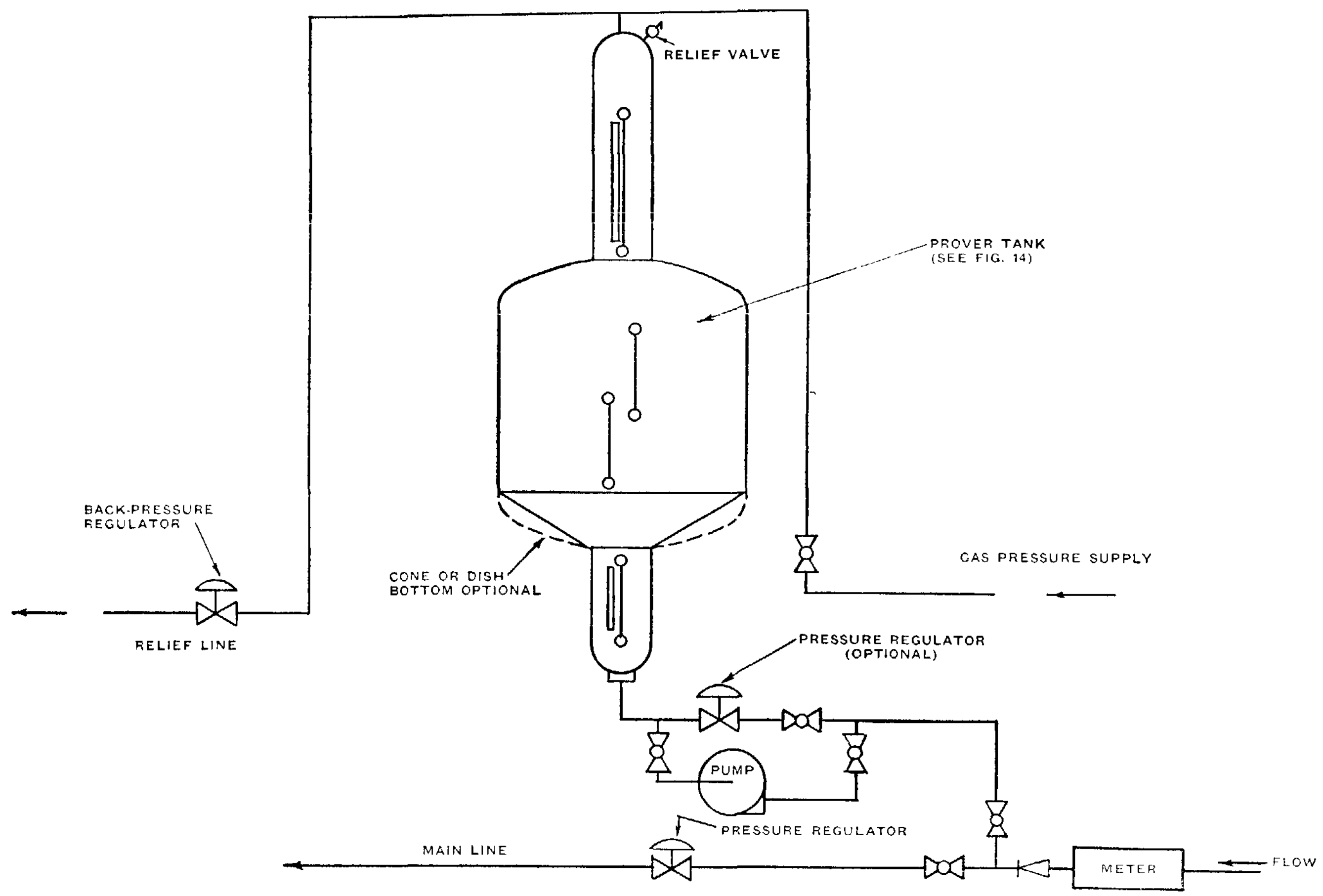



FIG. 17—Schematic Operating Diagram of Prover for Gas Displacement.





**METER-PROVING REPORT NO. ______**

MASTER METER METHOD

DATE __________, 19______ LOCATION ______________ METER NO. ______

MAKE AND SIZE OF METER ______________ TEMPERATURE-COMPENSATED? ______

PRODUCT ______________ BATCH NO. ______

MASTER METER NO. ______ MAKE AND SIZE ______ TEMPERATURE-COMPENSATED? ______

DATE OF LAST PROVING ______________ PRODUCT ______

FLOW RATE ______________ METER FACTOR ______

| MASTER METER DATA | RUN NO. | RUN NO. | RUN NO. | RUN NO. |
|---|---|---|---|---|
| 1. Time of run, min | | | | |
| 2. Rate, bbl per hr | | | | |
| 3. API gravity @ 60 F | | | | |
| 4. Closing meter reading | | | | |
| 5. Opening meter reading | | | | |
| 6. Gross metered volume | | | | |
| 7. Temperature correction factor | | | | |
| 8. Pressure correction factor | | | | |
| 9. Test meter factor | | | | |
| 10. Net metered volume | | | | |
| | | | | |
| LINE METER DATA | | | | |
| 11. Closing meter reading | | | | |
| 12. Opening meter reading | | | | |
| 13. Gross metered volume | | | | |
| 14. Temperature correction factor | | | | |
| 15. Net metered volume | | | | |
| 16. Meter factor, *10* ÷ *15* | | | | |
| | | | | |

| | |
|---|---|
| TOTALIZER READING | |
| BARRELS METERED SINCE LAST RUN | |

| | |
|---|---|
| AVERAGE METER FACTOR | |
| METER FACTOR TO BE USED | |

REMARKS:

SIGNED BY ______________ SIGNED BY ______________

FOR ______________ FOR ______________

SHEET NO. ______

*Note:* Figures in italics refer to items listed on left-hand side of this form.

FIG. 40.

SHEET________ OF________

____________________ COMPANY

**REPORT OF CALIBRATION OF UNIDIRECTIONAL PISTON PROVER**

SECTION CALIBRATED________________ PRODUCT USED__________ DESCRIPTION OF MASTER METERS EMPLOYED__________

TEST NO.________DATE MADE________ BATCH NO.__________ __________, WHERE LAST PROVED__________

CALIBRATED BY________________ API GRAVITY @ 60 F__________ METER PERFORMANCES TAKEN FROM TEST METER CURVES NO.________

BASE VOLUME BY PRIOR TEST__________ OCTANE__________ (ATTACH TEST METER CURVES HERETO.)

DATE______AND PRODUCT USED FOR PRIOR TEST______ TYPES OF PISTON__________ REMARKS____________________

| | RUN NO. 1 | | | | RUN NO. 2 | | | | RUN NO. 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DESCRIPTION OF QUANTITIES | METER "A" | METER "B" | METER "C" | TOTALS ALL METERS | METER "A" | METER "B" | METER "C" | TOTALS ALL METERS | METER "A" | METER "B" | METER "C" | TOTALS ALL METERS |
| 1. Final meter reading—totalizer register | | | | | | | | | | | | |
| 2. Initial meter reading—totalizer register | | | | | | | | | | | | |
| 3. Registration by meter—totalizer register | | | | | | | | | | | | |
| 4. Final meter reading—calibration register | | | | | | | | | | | | |
| 5. Initial meter reading—calibration register | | | | | | | | | | | | |
| 6. Registration by meter—calibration register | | | | | | | | | | | | |
| 7. Time piston received | Hr | Min | Sec | | Hr | Min | Sec | | Hr | Min | Sec | |
| 8. Time piston launched | Hr | Min | Sec | | Hr | Min | Sec | | Hr | Min | Sec | |
| 9. Elapsed time for piston run, min | Hr | Min | Sec | = Min | Hr | Min | Sec | = Min | Hr | Min | Sec | = Min |
| 10. Rate of flow during run, gpm: *6* ÷ *9* | | | | | | | | | | | | |
| 11. Meter factor from factor vs. rate curve | | | | | | | | | | | | |
| 12. Registration corr. by meter factor, *6* × *11* | | | | | | | | | | | | |
| 13. Meter pressure during this run | | | | | | | | | | | | |
| 14. Meter pressure during proof | | | | | | | | | | | | |
| 15. Diff. in meter operating press., *13* — *14* | | | | | | | | | | | | |
| 16. Factor for press. diff. (see Par. 3046) | | | | | | | | | | | | |
| 17. Temperature @ meter during this run | | | | | | | | | | | | |
| 18. Factor for meter temp. (Table 6, D 1250) | | | | | | | | | | | | |
| 19. Registration @ 60 F and 0 psig, *12* × *16* × *18* | | | | | | | | | | | | |
| 20. Prover pressures @ Trip No. 1 and No. 2 | At No. 1 | At No. 2 | Average | | At No. 1 | At No. 2 | Average | | At No. 1 | At No. 2 | Average | |
| 21. Prover temp. @ Trip No. 1 and No. 2 | At No. 1 | At No. 2 | Average | | At No. 1 | At No. 2 | Average | | At No. 1 | At No. 2 | Average | |
| 22. Factor for prover pressure (see Par. 2122) | | | | | | | | | | | | |
| 23. Factor for prover temp. (see Par. 3045) | | | | | | | | | | | | |
| 24. Factor for liquid pressure (see Par. 3046) | | | | | | | | | | | | |
| 25. Factor for liquid temp. (Table 6, D 1250) | | | | | | | | | | | | |
| 26. Base prover volume, gal @ 60 F and 0 psi | | | | | | | | | | | | |
| 27. Base prover volume, bbl @ 60 F and 0 psi | | | | | | | | | | | | |

FORMULAS: *9* = (hr × 60) + min + (sec ÷ 60)

*16* = *11* [1.00 + (*14* — *13*)(F)], where *F* is from Table II, Appendix B

*19* = *12* × *16* × *18*

*26* = *19* ÷ *22* × *23* × *24* × *25*

*27* = *26* ÷ (42.00)

Note Figures in italics refer to items listed on left-hand side of this form.

SIGNED BY________FOR____ BASE VOLUME FROM RUN NO. 1 – ________

SIGNED BY________FOR____ BASE VOLUME FROM RUN NO. 2 – ________

WITNESSED BY________FOR____ BASE VOLUME FROM RUN NO. 3 – ________

CHECKED O.K. BY______FOR____ AVERAGE B.V. TO BE USED = ____ ÷ ____ = ____BBL @ 60 F AND 0 PSIG

**FIG. 41.**

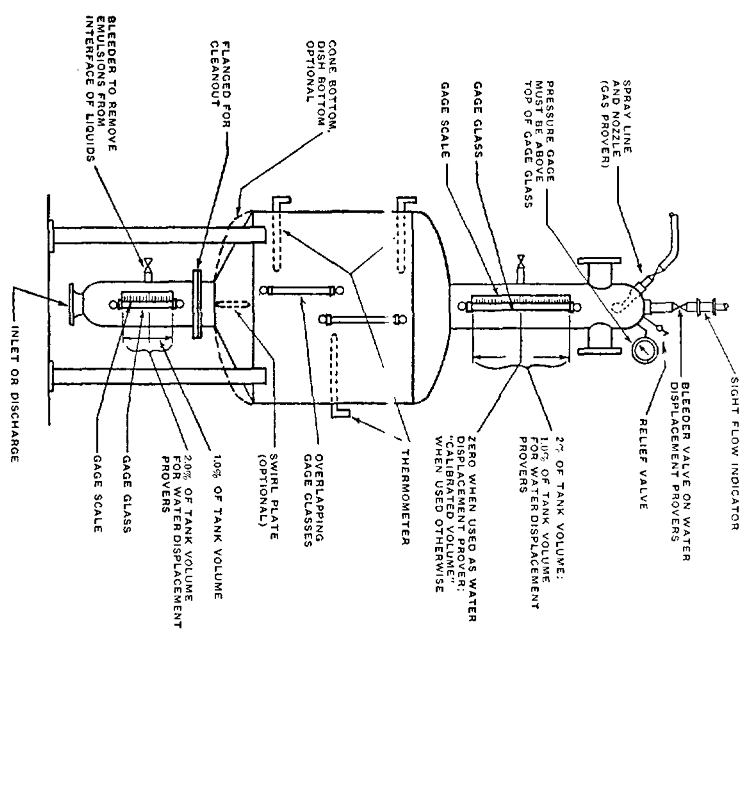



**FIG. 14—Closed Stationary Prover Tank.**

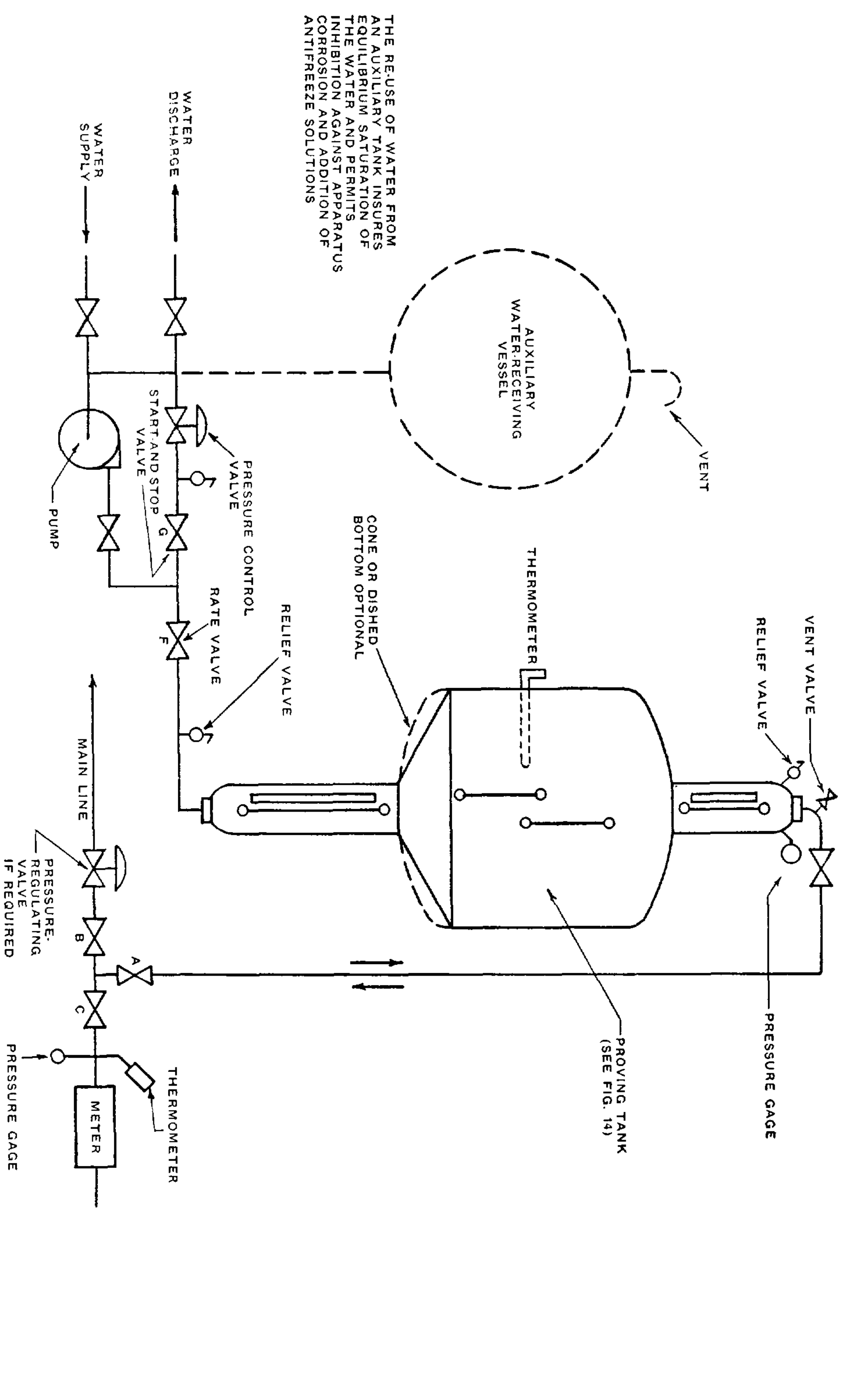
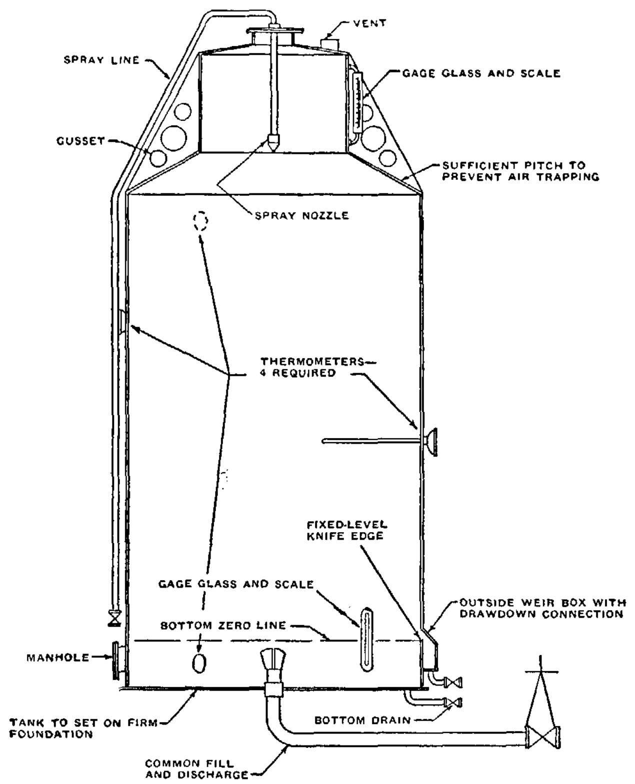



**FIG. 15—Schematic Operating Diagram of Single-Tank Water Displacement Prover.**




*Note:* Tank to be all-welded construction. All welds to be ground flush on inside surfaces.

**FIG. 11—Open Single-Weir Prover Tank.**

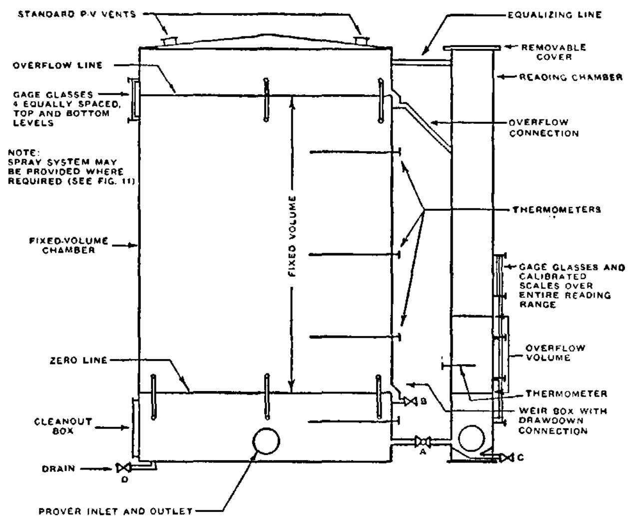



**FIG. 12—Double-Weir Prover Tank. Measured Volume = Fixed Volume + Overflow Volume.**

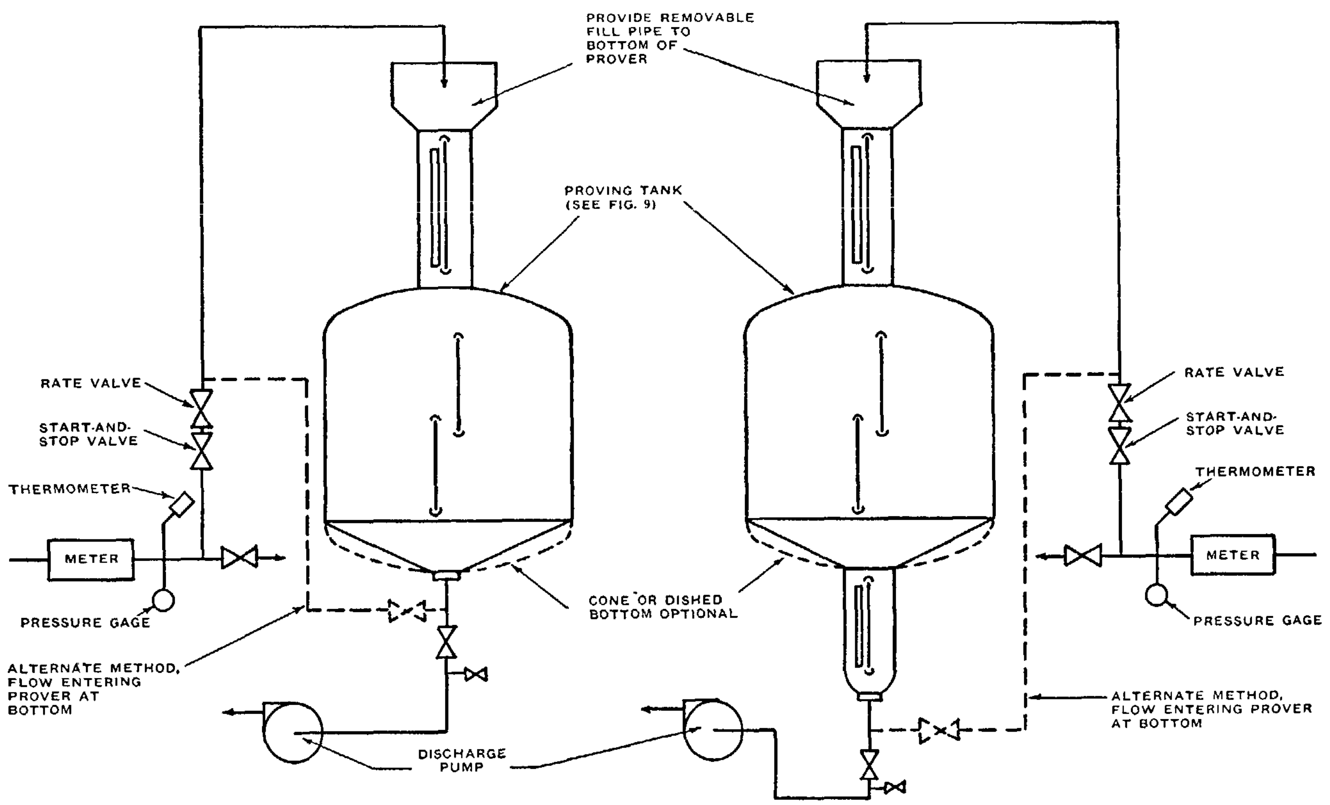



**FIG. 13—Schematic Operating Diagram—Four Methods for Using Open Volumetric Provers.**



VOLUMETRIC PROVER TANK CALIBRATION CERTIFICATE

DATE__________ CERTIFICATE NO.__________

LOCATION__________ STATION NO.__________

TANK MANUF.__________ NOMINAL TANK CAPACITY (GAL)__________

On the above date, we, the undersigned, calibrated the above prover tank, using water as a medium, and established the volume which the tank would contain* / deliver at 60 F and atmospheric pressure. The volumes shown have been corrected in accordance with provisions outlined in Sect. II of API Standard 1101.

Gallons above upper zero point __________

Gallons between upper and lower zero points __________

Gallons below zero point __________

Total capacity (at 60 F and atmospheric pressure) __________

In calibrating the necks, test measures of ______ gallons capacity were used, and in calibrating the main body of the tank, test measures of ______ gallons capacity were used. The test measures were* / were not certified by the National Bureau of Standards.

SIGNED BY:__________

FOR:__________

SIGNED BY:__________

FOR:__________

SIGNED BY:__________

FOR:__________

REMARKS:__________

* Strike out inapplicable term.

**FIG. 42.**

# APPENDIX B

## TABLE I—Volumetric Corrections for Use in Water Calibrations of Prover Tanks

Temperature in Measure *Lower* than in Prover by Degrees Fahrenheit

(Multiply Measured Volume by Correction Factor to Give Volume at Prover Temperature)

| Temperature of Water in Prover (Degrees Fahrenheit) | *10* | *9* | *8* | *7* | *6* | *5* | *4* | *3* | *2* | *1* | Temperature of Water in Prover (Degrees Fahrenheit) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 35 | | | | | | | | | | | 35 |
| 36 | | | | | | | 0.99989 | 0.99993 | 0.99996 | 0.99998 | 36 |
| 37 | | | | | | 0.99988 | 0.99992 | 0.99995 | 0.99997 | 0.99998 | 37 |
| 38 | | | | | 0.99987 | 0.99991 | 0.99994 | 0.99996 | 0.99997 | 0.99999 | 38 |
| 39 | | | | 0.99987 | 0.99991 | 0.99994 | 0.99996 | 0.99997 | 0.99998 | 0.99999 | 39 |
| 40 | | 0.99983 | 0.99987 | 0.99991 | 0.99994 | 0.99996 | 0.99997 | 0.99998 | 0.99999 | 1.00000 | 40 |
| 41 | 0.99984 | 0.99987 | 0.99992 | 0.99995 | 0.99996 | 0.99998 | 0.99999 | 1.00000 | 1.00000 | 1.00000 | 41 |
| 42 | 0.99988 | 0.99993 | 0.99996 | 0.99997 | 0.99999 | 1.00000 | 1.00001 | 1.00001 | 1.00001 | 1.00000 | 42 |
| 43 | 0.99994 | 0.99997 | 0.99999 | 1.00000 | 1.00002 | 1.00002 | 1.00003 | 1.00003 | 1.00002 | 1.00001 | 43 |
| 44 | 0.99999 | 1.00001 | 1.00002 | 1.00003 | 1.00004 | 1.00005 | 1.00004 | 1.00004 | 1.00003 | 1.00001 | 44 |
| 45 | 1.00003 | 1.00005 | 1.00006 | 1.00007 | 1.00007 | 1.00007 | 1.00006 | 1.00005 | 1.00004 | 1.00002 | 45 |
| 46 | 1.00008 | 1.00009 | 1.00010 | 1.00010 | 1.00010 | 1.00009 | 1.00008 | 1.00007 | 1.00005 | 1.00002 | 46 |
| 47 | 1.00012 | 1.00013 | 1.00013 | 1.00013 | 1.00012 | 1.00011 | 1.00010 | 1.00008 | 1.00005 | 1.00002 | 47 |
| 48 | 1.00017 | 1.00017 | 1.00017 | 1.00016 | 1.00015 | 1.00014 | 1.00012 | 1.00009 | 1.00006 | 1.00003 | 48 |
| 49 | 1.00021 | 1.00021 | 1.00021 | 1.00020 | 1.00018 | 1.00016 | 1.00014 | 1.00011 | 1.00008 | 1.00004 | 49 |
| 50 | 1.00026 | 1.00025 | 1.00024 | 1.00023 | 1.00021 | 1.00018 | 1.00015 | 1.00012 | 1.00008 | 1.00004 | 50 |
| 51 | 1.00030 | 1.00029 | 1.00028 | 1.00026 | 1.00023 | 1.00020 | 1.00017 | 1.00014 | 1.00009 | 1.00005 | 51 |
| 52 | 1.00035 | 1.00034 | 1.00032 | 1.00030 | 1.00027 | 1.00024 | 1.00020 | 1.00015 | 1.00011 | 1.00006 | 52 |
| 53 | 1.00040 | 1.00038 | 1.00036 | 1.00033 | 1.00030 | 1.00026 | 1.00021 | 1.00017 | 1.00012 | 1.00005 | 53 |
| 54 | 1.00045 | 1.00042 | 1.00039 | 1.00036 | 1.00033 | 1.00028 | 1.00024 | 1.00018 | 1.00012 | 1.00006 | 54 |
| 55 | 1.00048 | 1.00045 | 1.00042 | 1.00039 | 1.00034 | 1.00030 | 1.00024 | 1.00018 | 1.00012 | 1.00006 | 55 |
| 56 | 1.00052 | 1.00049 | 1.00045 | 1.00041 | 1.00036 | 1.00031 | 1.00025 | 1.00019 | 1.00012 | 1.00006 | 56 |
| 57 | 1.00057 | 1.00053 | 1.00048 | 1.00044 | 1.00039 | 1.00033 | 1.00027 | 1.00020 | 1.00014 | 1.00007 | 57 |
| 58 | 1.00060 | 1.00056 | 1.00051 | 1.00046 | 1.00040 | 1.00034 | 1.00027 | 1.00021 | 1.00015 | 1.00007 | 58 |
| 59 | 1.00064 | 1.00060 | 1.00054 | 1.00048 | 1.00042 | 1.00036 | 1.00030 | 1.00023 | 1.00015 | 1.00008 | 59 |
| 60 | 1.00069 | 1.00063 | 1.00057 | 1.00051 | 1.00045 | 1.00039 | 1.00032 | 1.00024 | 1.00017 | 1.00009 | 60 |
| 61 | 1.00073 | 1.00067 | 1.00061 | 1.00054 | 1.00048 | 1.00041 | 1.00033 | 1.00026 | 1.00018 | 1.00008 | 61 |
| 62 | 1.00076 | 1.00070 | 1.00063 | 1.00057 | 1.00050 | 1.00042 | 1.00035 | 1.00027 | 1.00018 | 1.00009 | 62 |
| 63 | 1.00079 | 1.00073 | 1.00067 | 1.00060 | 1.00052 | 1.00045 | 1.00036 | 1.00027 | 1.00018 | 1.00009 | 63 |
| 64 | 1.00083 | 1.00076 | 1.00070 | 1.00062 | 1.00055 | 1.00046 | 1.00037 | 1.00028 | 1.00019 | 1.00009 | 64 |
| 65 | 1.00087 | 1.00080 | 1.00073 | 1.00065 | 1.00057 | 1.00048 | 1.00039 | 1.00030 | 1.00020 | 1.00010 | 65 |
| 66 | 1.00091 | 1.00084 | 1.00076 | 1.00068 | 1.00059 | 1.00050 | 1.00041 | 1.00031 | 1.00021 | 1.00011 | 66 |
| 67 | 1.00095 | 1.00087 | 1.00079 | 1.00070 | 1.00061 | 1.00052 | 1.00042 | 1.00032 | 1.00021 | 1.00010 | 67 |
| 68 | 1.00098 | 1.00090 | 1.00081 | 1.00072 | 1.00063 | 1.00053 | 1.00043 | 1.00033 | 1.00021 | 1.00011 | 68 |
| 69 | 1.00101 | 1.00092 | 1.00083 | 1.00074 | 1.00064 | 1.00054 | 1.00043 | 1.00032 | 1.00021 | 1.00010 | 69 |
| 70 | 1.00105 | 1.00096 | 1.00087 | 1.00077 | 1.00067 | 1.00056 | 1.00045 | 1.00034 | 1.00023 | 1.00012 | 70 |
| 71 | 1.00108 | 1.00099 | 1.00089 | 1.00079 | 1.00069 | 1.00057 | 1.00047 | 1.00035 | 1.00025 | 1.00012 | 71 |
| 72 | 1.00112 | 1.00102 | 1.00092 | 1.00082 | 1.00071 | 1.00060 | 1.00049 | 1.00038 | 1.00025 | 1.00013 | 72 |
| 73 | 1.00115 | 1.00105 | 1.00095 | 1.00084 | 1.00073 | 1.00062 | 1.00051 | 1.00038 | 1.00026 | 1.00012 | 73 |
| 74 | 1.00118 | 1.00108 | 1.00097 | 1.00086 | 1.00075 | 1.00064 | 1.00051 | 1.00039 | 1.00025 | 1.00012 | 74 |
| 75 | 1.00121 | 1.00110 | 1.00099 | 1.00088 | 1.00077 | 1.00064 | 1.00052 | 1.00038 | 1.00025 | 1.00012 | 75 |
| 76 | 1.00124 | 1.00113 | 1.00102 | 1.00091 | 1.00078 | 1.00066 | 1.00053 | 1.00040 | 1.00027 | 1.00014 | 76 |
| 77 | 1.00128 | 1.00117 | 1.00106 | 1.00093 | 1.00081 | 1.00068 | 1.00055 | 1.00042 | 1.00029 | 1.00015 | 77 |
| 78 | 1.00131 | 1.00120 | 1.00107 | 1.00095 | 1.00082 | 1.00069 | 1.00056 | 1.00043 | 1.00029 | 1.00014 | 78 |
| 79 | 1.00135 | 1.00122 | 1.00110 | 1.00097 | 1.00084 | 1.00071 | 1.00058 | 1.00044 | 1.00029 | 1.00015 | 79 |
| 80 | 1.00137 | 1.00125 | 1.00112 | 1.00099 | 1.00086 | 1.00073 | 1.00059 | 1.00044 | 1.00029 | 1.00014 | 80 |
| 81 | 1.00140 | 1.00127 | 1.00114 | 1.00101 | 1.00088 | 1.00074 | 1.00059 | 1.00045 | 1.00029 | 1.00015 | 81 |
| 82 | 1.00142 | 1.00129 | 1.00116 | 1.00103 | 1.00089 | 1.00074 | 1.00060 | 1.00045 | 1.00030 | 1.00015 | 82 |
| 83 | 1.00145 | 1.00132 | 1.00119 | 1.00105 | 1.00090 | 1.00076 | 1.00061 | 1.00046 | 1.00031 | 1.00016 | 83 |
| 84 | 1.00148 | 1.00135 | 1.00121 | 1.00106 | 1.00092 | 1.00077 | 1.00062 | 1.00047 | 1.00032 | 1.00016 | 84 |
| 85 | 1.00152 | 1.00138 | 1.00123 | 1.00109 | 1.00094 | 1.00079 | 1.00064 | 1.00049 | 1.00033 | 1.00016 | 85 |
| 86 | 1.00156 | 1.00141 | 1.00127 | 1.00112 | 1.00097 | 1.00082 | 1.00067 | 1.00051 | 1.00035 | 1.00018 | 86 |
| 87 | 1.00157 | 1.00143 | 1.00128 | 1.00113 | 1.00098 | 1.00083 | 1.00067 | 1.00051 | 1.00034 | 1.00016 | 87 |
| 88 | 1.00161 | 1.00146 | 1.00131 | 1.00116 | 1.00101 | 1.00085 | 1.00069 | 1.00052 | 1.00034 | 1.00017 | 88 |
| 89 | 1.00163 | 1.00148 | 1.00133 | 1.00118 | 1.00102 | 1.00086 | 1.00069 | 1.00051 | 1.00035 | 1.00017 | 89 |
| 90 | 1.00166 | 1.00151 | 1.00136 | 1.00120 | 1.00104 | 1.00087 | 1.00069 | 1.00053 | 1.00035 | 1.00018 | 90 |





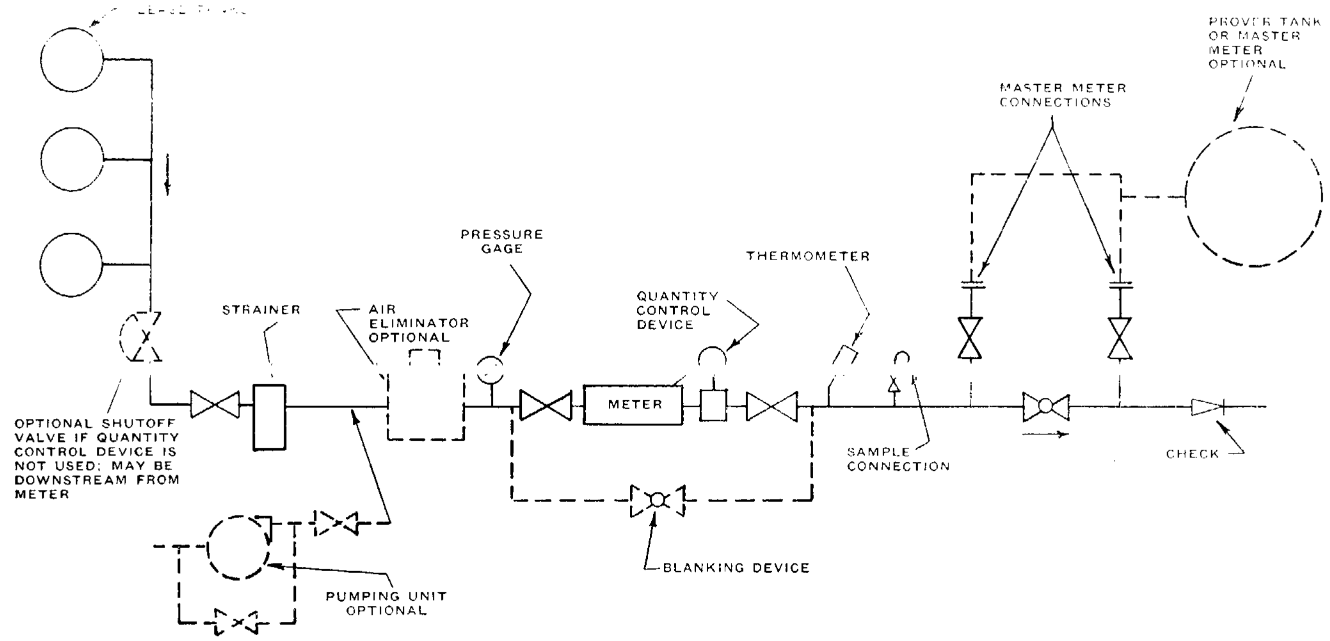



FIG. 8—Schematic Operating Diagram of Metered Pipeline Gathering System—Flow by Pump or Gravity.

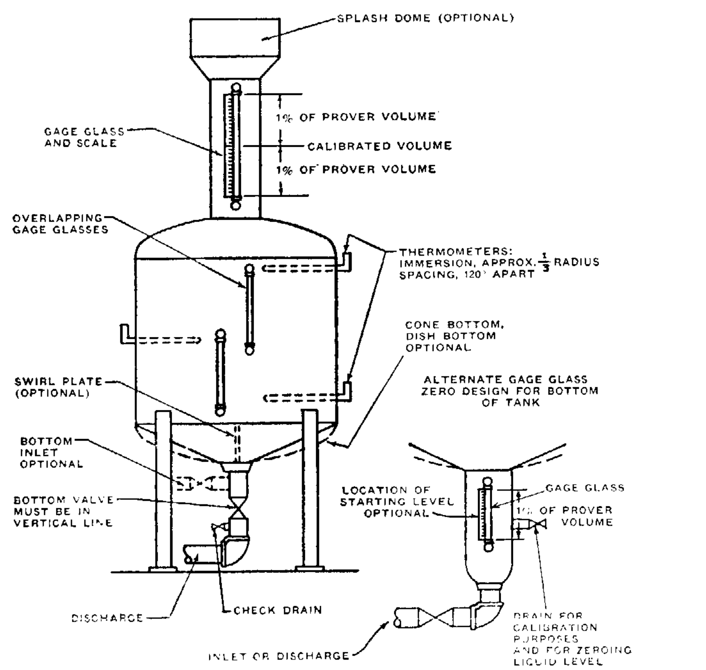



FIG. 9—Open Stationary Prover Tank—Drain to Zero or Bottom Gage Glass Type.

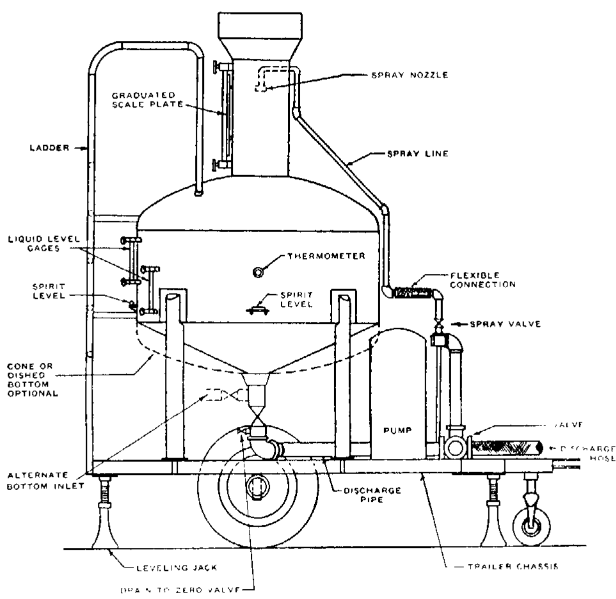



FIG. 10—Open Portable Prover Tank.

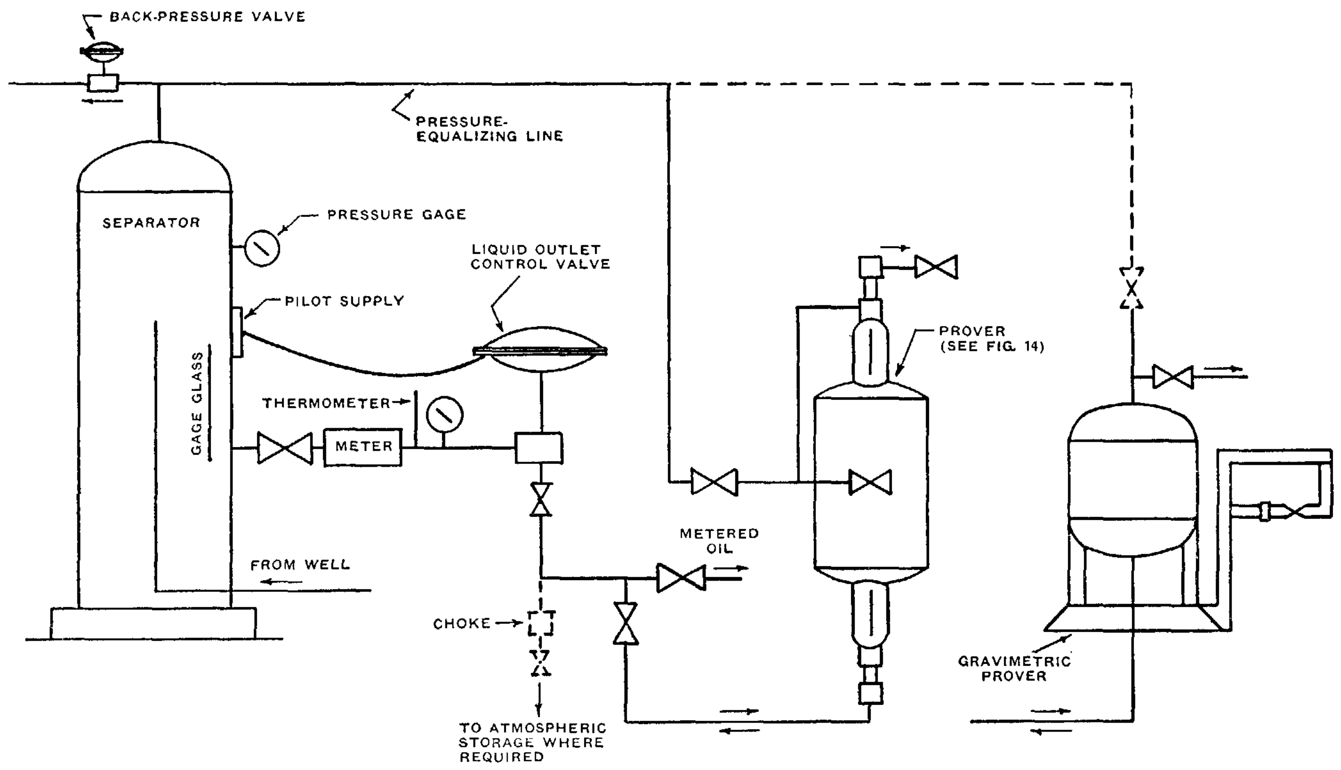



**FIG. 6—Schematic Operating Diagram of Oil Well Production Meter Installation Using Gas Displacement or Gravimetric Prover.**

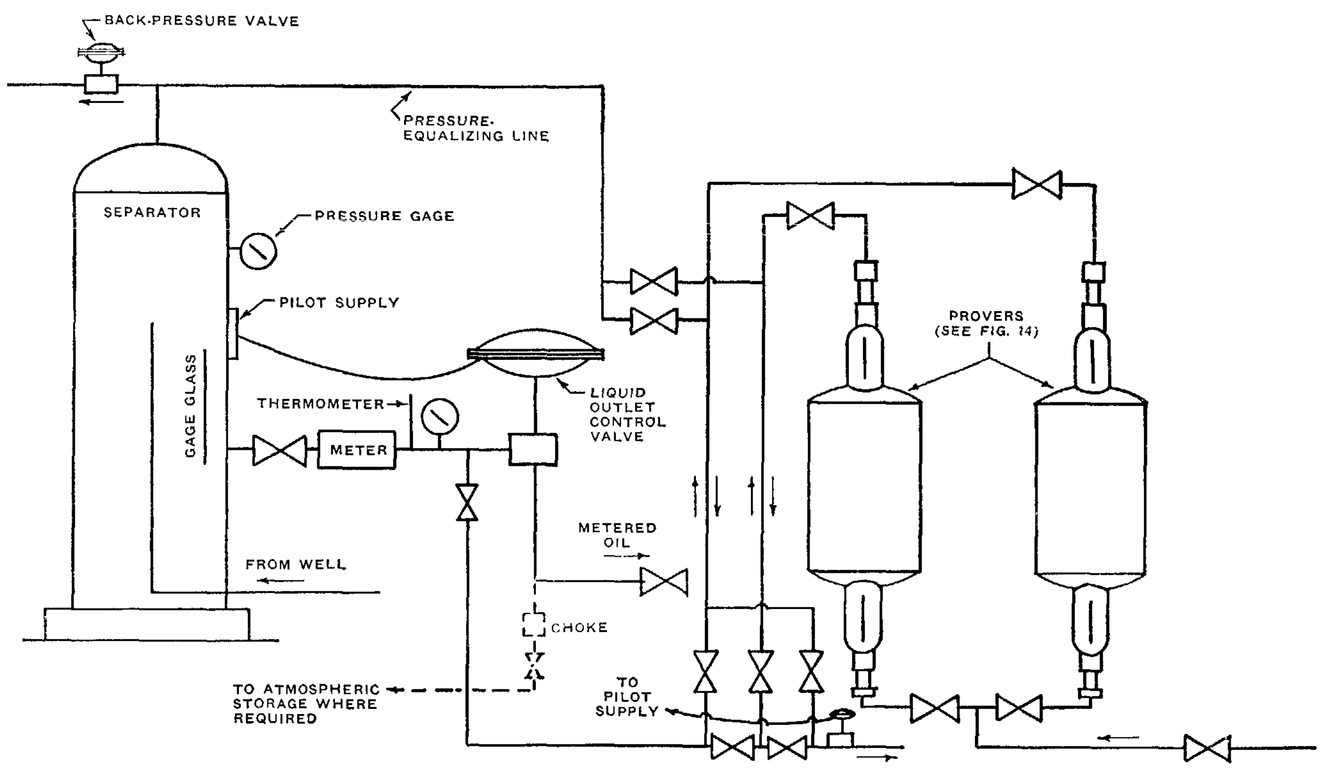



**FIG. 7—Schematic Operating Diagram of Oil Well Production Meter Installation Using Dual-Tank Water Displacement Prover.**



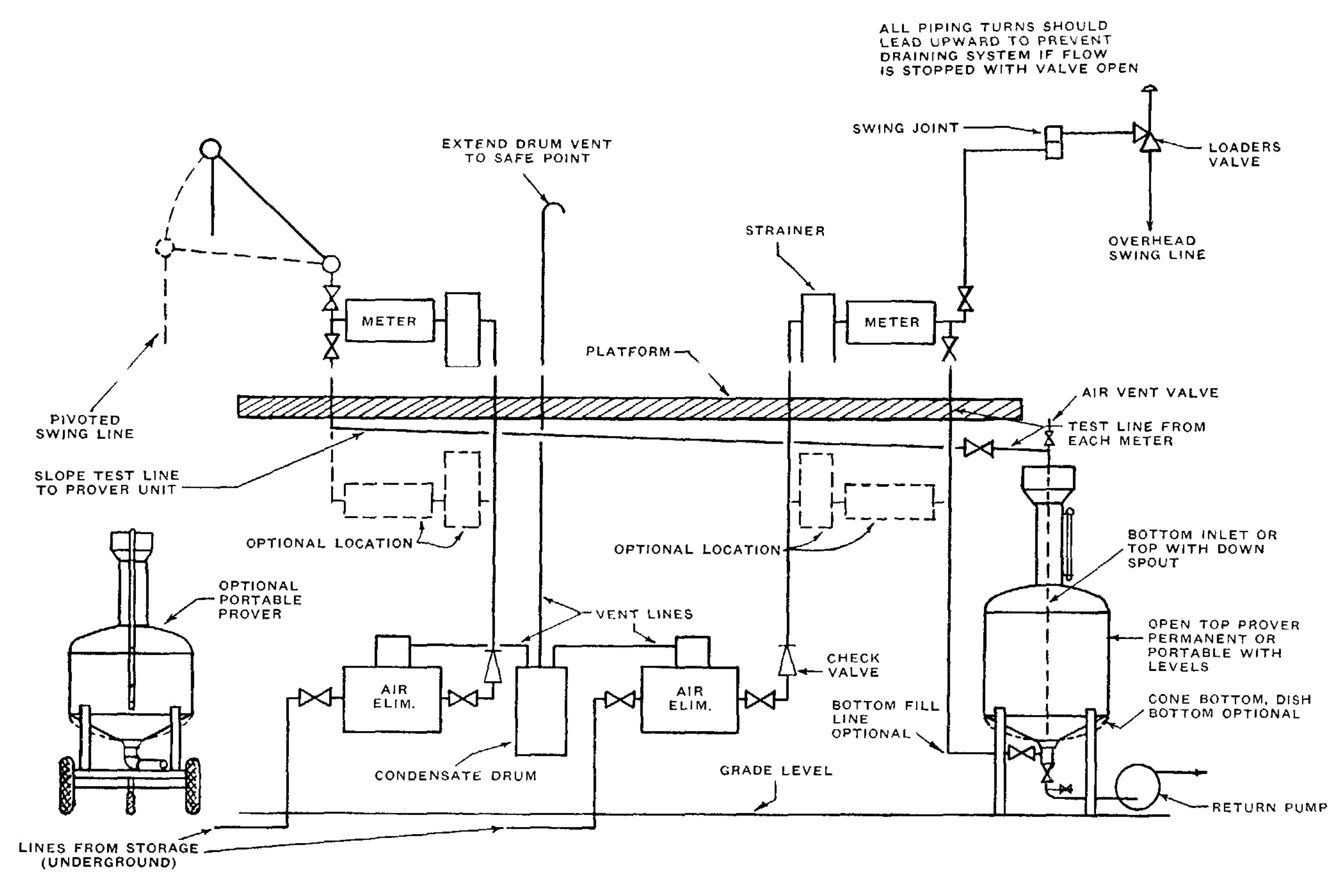
**TABLE I (Continued)**

Temperature in Measure *Higher* than in Prover by Degrees Fahrenheit

(Multiply Measured Volume by Correction Factor to Give Volume at Prover Temperature)

| Temperature of Water in Prover (Degrees Fahrenheit) | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | Temperature of Water in Prover (Degrees Fahrenheit) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 35 | 1.00001 | 1.00002 | 1.00003 | 1.00003 | 1.00003 | 1.00003 | 1.00002 | 1.00000 | 0.99998 | 0.99996 | 35 |
| 36 | 1.00001 | 1.00002 | 1.00002 | 1.00002 | 1.00001 | 1.00000 | 0.99999 | 0.99997 | 0.99994 | 0.99991 | 36 |
| 37 | 1.00000 | 1.00001 | 1.00001 | 1.00000 | 0.99999 | 0.99997 | 0.99996 | 0.99993 | 0.99990 | 0.99987 | 37 |
| 38 | 1.00000 | 1.00000 | 0.99999 | 0.99998 | 0.99997 | 0.99995 | 0.99992 | 0.99989 | 0.99986 | 0.99982 | 38 |
| 39 | 0.99999 | 0.99999 | 0.99998 | 0.99996 | 0.99994 | 0.99992 | 0.99989 | 0.99986 | 0.99982 | 0.99978 | 39 |
| 40 | 0.99999 | 0.99998 | 0.99996 | 0.99995 | 0.99992 | 0.99989 | 0.99986 | 0.99982 | 0.99978 | 0.99973 | 40 |
| 41 | 0.99999 | 0.99997 | 0.99995 | 0.99993 | 0.99990 | 0.99987 | 0.99983 | 0.99978 | 0.99974 | 0.99969 | 41 |
| 42 | 0.99998 | 0.99996 | 0.99994 | 0.99991 | 0.99988 | 0.99984 | 0.99979 | 0.99975 | 0.99970 | 0.99964 | 42 |
| 43 | 0.99998 | 0.99995 | 0.99992 | 0.99989 | 0.99985 | 0.99981 | 0.99976 | 0.99971 | 0.99965 | 0.99959 | 43 |
| 44 | 0.99997 | 0.99994 | 0.99991 | 0.99987 | 0.99983 | 0.99978 | 0.99973 | 0.99967 | 0.99961 | 0.99954 | 44 |
| 45 | 0.99997 | 0.99994 | 0.99990 | 0.99985 | 0.99981 | 0.99976 | 0.99970 | 0.99964 | 0.99957 | 0.99951 | 45 |
| 46 | 0.99997 | 0.99993 | 0.99988 | 0.99984 | 0.99979 | 0.99973 | 0.99967 | 0.99960 | 0.99954 | 0.99947 | 46 |
| 47 | 0.99996 | 0.99991 | 0.99987 | 0.99982 | 0.99976 | 0.99970 | 0.99963 | 0.99957 | 0.99950 | 0.99943 | 47 |
| 48 | 0.99995 | 0.99991 | 0.99985 | 0.99979 | 0.99973 | 0.99967 | 0.99961 | 0.99954 | 0.99946 | 0.99939 | 48 |
| 49 | 0.99995 | 0.99990 | 0.99984 | 0.99978 | 0.99971 | 0.99965 | 0.99958 | 0.99951 | 0.99943 | 0.99935 | 49 |
| 50 | 0.99994 | 0.99988 | 0.99982 | 0.99976 | 0.99970 | 0.99963 | 0.99955 | 0.99948 | 0.99940 | 0.99931 | 50 |
| 51 | 0.99994 | 0.99988 | 0.99981 | 0.99975 | 0.99968 | 0.99961 | 0.99953 | 0.99945 | 0.99936 | 0.99927 | 51 |
| 52 | 0.99993 | 0.99987 | 0.99981 | 0.99974 | 0.99966 | 0.99959 | 0.99951 | 0.99942 | 0.99933 | 0.99924 | 52 |
| 53 | 0.99993 | 0.99987 | 0.99980 | 0.99972 | 0.99965 | 0.99957 | 0.99948 | 0.99939 | 0.99930 | 0.99920 | 53 |
| 54 | 0.99993 | 0.99987 | 0.99979 | 0.99972 | 0.99963 | 0.99954 | 0.99945 | 0.99936 | 0.99927 | 0.99917 | 54 |
| 55 | 0.99993 | 0.99985 | 0.99978 | 0.99969 | 0.99960 | 0.99951 | 0.99942 | 0.99933 | 0.99923 | 0.99912 | 55 |
| 56 | 0.99992 | 0.99984 | 0.99976 | 0.99967 | 0.99958 | 0.99949 | 0.99939 | 0.99930 | 0.99919 | 0.99908 | 56 |
| 57 | 0.99992 | 0.99984 | 0.99975 | 0.99966 | 0.99957 | 0.99947 | 0.99937 | 0.99927 | 0.99915 | 0.99905 | 57 |
| 58 | 0.99991 | 0.99982 | 0.99973 | 0.99964 | 0.99954 | 0.99945 | 0.99934 | 0.99923 | 0.99912 | 0.99901 | 58 |
| 59 | 0.99990 | 0.99981 | 0.99972 | 0.99963 | 0.99953 | 0.99942 | 0.99931 | 0.99920 | 0.99909 | 0.99899 | 59 |
| 60 | 0.99990 | 0.99981 | 0.99972 | 0.99962 | 0.99951 | 0.99940 | 0.99929 | 0.99918 | 0.99908 | 0.99895 | 60 |
| 61 | 0.99990 | 0.99981 | 0.99971 | 0.99960 | 0.99949 | 0.99938 | 0.99927 | 0.99917 | 0.99904 | 0.99892 | 61 |
| 62 | 0.99990 | 0.99980 | 0.99969 | 0.99958 | 0.99947 | 0.99936 | 0.99926 | 0.99913 | 0.99901 | 0.99887 | 62 |
| 63 | 0.99990 | 0.99979 | 0.99968 | 0.99957 | 0.99946 | 0.99935 | 0.99923 | 0.99911 | 0.99897 | 0.99884 | 63 |
| 64 | 0.99989 | 0.99978 | 0.99967 | 0.99956 | 0.99945 | 0.99932 | 0.99920 | 0.99907 | 0.99894 | 0.99881 | 64 |
| 65 | 0.99988 | 0.99978 | 0.99966 | 0.99956 | 0.99943 | 0.99931 | 0.99917 | 0.99904 | 0.99892 | 0.99879 | 65 |
| 66 | 0.99989 | 0.99978 | 0.99967 | 0.99954 | 0.99942 | 0.99928 | 0.99916 | 0.99903 | 0.99890 | 0.99876 | 66 |
| 67 | 0.99988 | 0.99978 | 0.99965 | 0.99953 | 0.99939 | 0.99926 | 0.99913 | 0.99900 | 0.99886 | 0.99871 | 67 |
| 68 | 0.99989 | 0.99976 | 0.99964 | 0.99950 | 0.99937 | 0.99925 | 0.99912 | 0.99897 | 0.99882 | 0.99868 | 68 |
| 69 | 0.99987 | 0.99975 | 0.99961 | 0.99948 | 0.99935 | 0.99922 | 0.99908 | 0.99893 | 0.99879 | 0.99864 | 69 |
| 70 | 0.99987 | 0.99974 | 0.99961 | 0.99948 | 0.99935 | 0.99921 | 0.99906 | 0.99892 | 0.99877 | 0.99862 | 70 |
| 71 | 0.99986 | 0.99973 | 0.99960 | 0.99947 | 0.99933 | 0.99918 | 0.99904 | 0.99889 | 0.99874 | 0.99859 | 71 |
| 72 | 0.99987 | 0.99974 | 0.99961 | 0.99946 | 0.99931 | 0.99917 | 0.99902 | 0.99887 | 0.99872 | 0.99857 | 72 |
| 73 | 0.99987 | 0.99974 | 0.99959 | 0.99944 | 0.99930 | 0.99915 | 0.99900 | 0.99885 | 0.99870 | 0.99854 | 73 |
| 74 | 0.99987 | 0.99972 | 0.99957 | 0.99943 | 0.99928 | 0.99913 | 0.99898 | 0.99883 | 0.99867 | 0.99851 | 74 |
| 75 | 0.99985 | 0.99970 | 0.99956 | 0.99941 | 0.99926 | 0.99911 | 0.99896 | 0.99880 | 0.99864 | 0.99847 | 75 |
| 76 | 0.99984 | 0.99970 | 0.99955 | 0.99940 | 0.99925 | 0.99910 | 0.99894 | 0.99878 | 0.99861 | 0.99843 | 76 |
| 77 | 0.99985 | 0.99970 | 0.99955 | 0.99940 | 0.99925 | 0.99909 | 0.99893 | 0.99876 | 0.99858 | 0.99842 | 77 |
| 78 | 0.99984 | 0.99970 | 0.99954 | 0.99939 | 0.99923 | 0.99907 | 0.99890 | 0.99872 | 0.99856 | 0.99838 | 78 |
| 79 | 0.99985 | 0.99970 | 0.99954 | 0.99938 | 0.99922 | 0.99905 | 0.99887 | 0.99871 | 0.99853 | 0.99836 | 79 |
| 80 | 0.99984 | 0.99969 | 0.99953 | 0.99937 | 0.99920 | 0.99902 | 0.99886 | 0.99868 | 0.99851 | 0.99833 | 80 |
| 81 | 0.99984 | 0.99968 | 0.99952 | 0.99935 | 0.99917 | 0.99901 | 0.99883 | 0.99866 | 0.99848 | 0.99830 | 81 |
| 82 | 0.99983 | 0.99967 | 0.99950 | 0.99932 | 0.99916 | 0.99898 | 0.99881 | 0.99863 | 0.99845 | 0.99826 | 82 |
| 83 | 0.99983 | 0.99967 | 0.99948 | 0.99932 | 0.99914 | 0.99897 | 0.99879 | 0.99861 | 0.99842 | 0.99824 | 83 |
| 84 | 0.99983 | 0.99964 | 0.99948 | 0.99930 | 0.99913 | 0.99895 | 0.99877 | 0.99858 | 0.99840 | 0.99821 | 84 |
| 85 | 0.99981 | 0.99965 | 0.99947 | 0.99930 | 0.99912 | 0.99894 | 0.99875 | 0.99857 | 0.99838 | 0.99818 | 85 |
| 86 | 0.99983 | 0.99965 | 0.99948 | 0.99930 | 0.99912 | 0.99893 | 0.99875 | 0.99856 | 0.99836 | 0.99816 | 86 |
| 87 | 0.99982 | 0.99964 | 0.99946 | 0.99928 | 0.99909 | 0.99891 | 0.99872 | 0.99852 | 0.99832 | 0.99814 | 87 |
| 88 | 0.99982 | 0.99964 | 0.99946 | 0.99927 | 0.99909 | 0.99890 | 0.99870 | 0.99850 | 0.99832 | 0.99812 | 88 |
| 89 | 0.99981 | 0.99963 | 0.99944 | 0.99926 | 0.99907 | 0.99887 | 0.99867 | 0.99849 | 0.99829 | 0.99808 | 89 |
| 90 | 0.99981 | 0.99962 | 0.99944 | 0.99925 | 0.99905 | 0.99885 | 0.99867 | 0.99847 | 0.99826 | 0.99805 | 90 |

Table I is based on data from Smithsonian Institution tables for relative density and volume of water.




*Note:* All sections of line which may be blocked between valves should have provision for pressure relief.

**FIG. 4—Installation Diagram—Metered Tank Truck Loading Rack.**

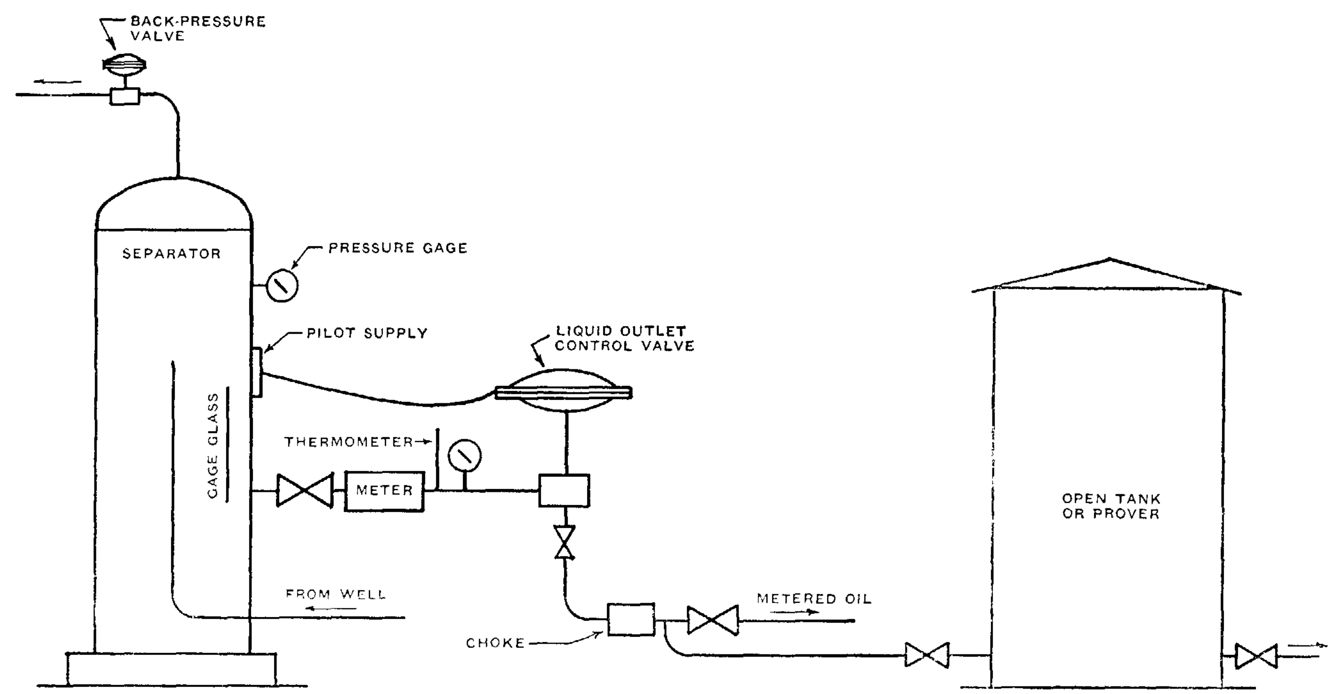



**FIG. 5—Schematic Operating Diagram of Oil Well Production Meter Installation Using Stock Tank or Open Prover.**

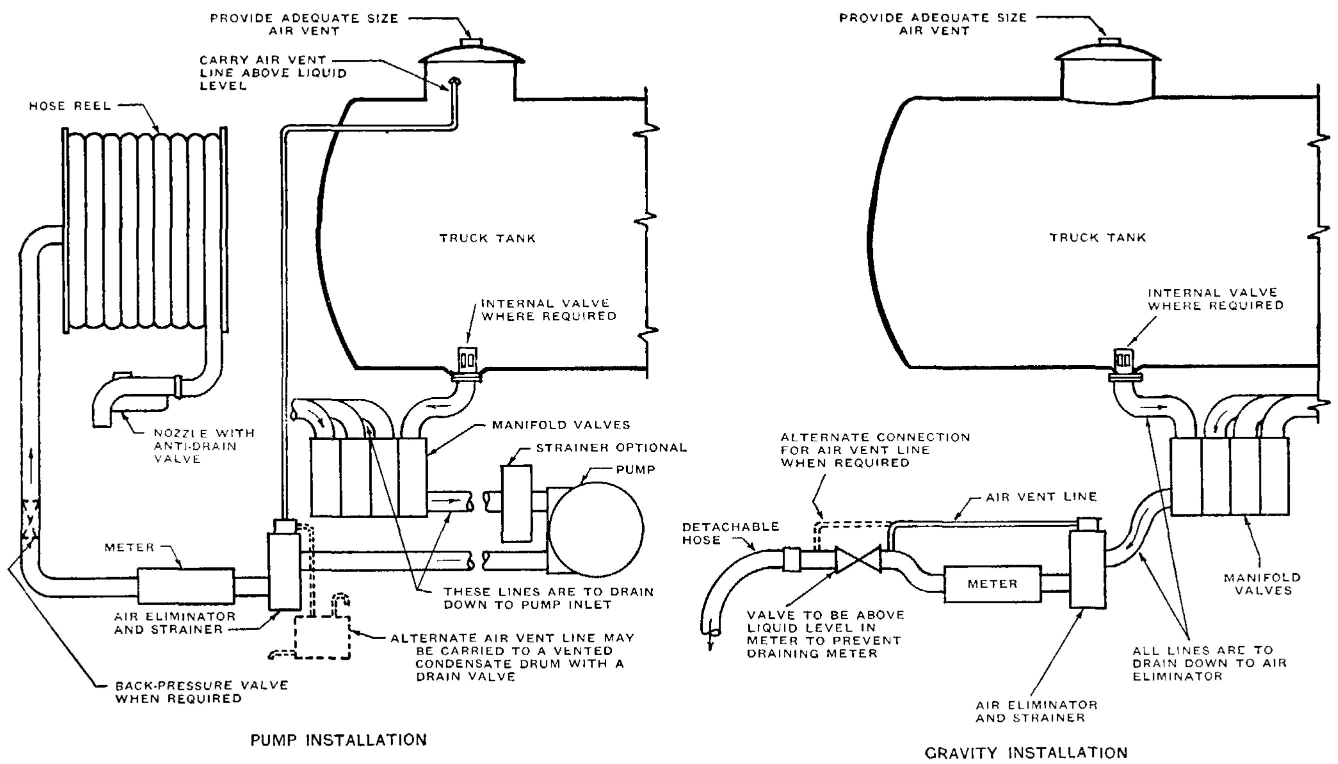



**FIG. 2—Installation Diagram—Tank Truck Metering Equipment (Excluding LPG).**

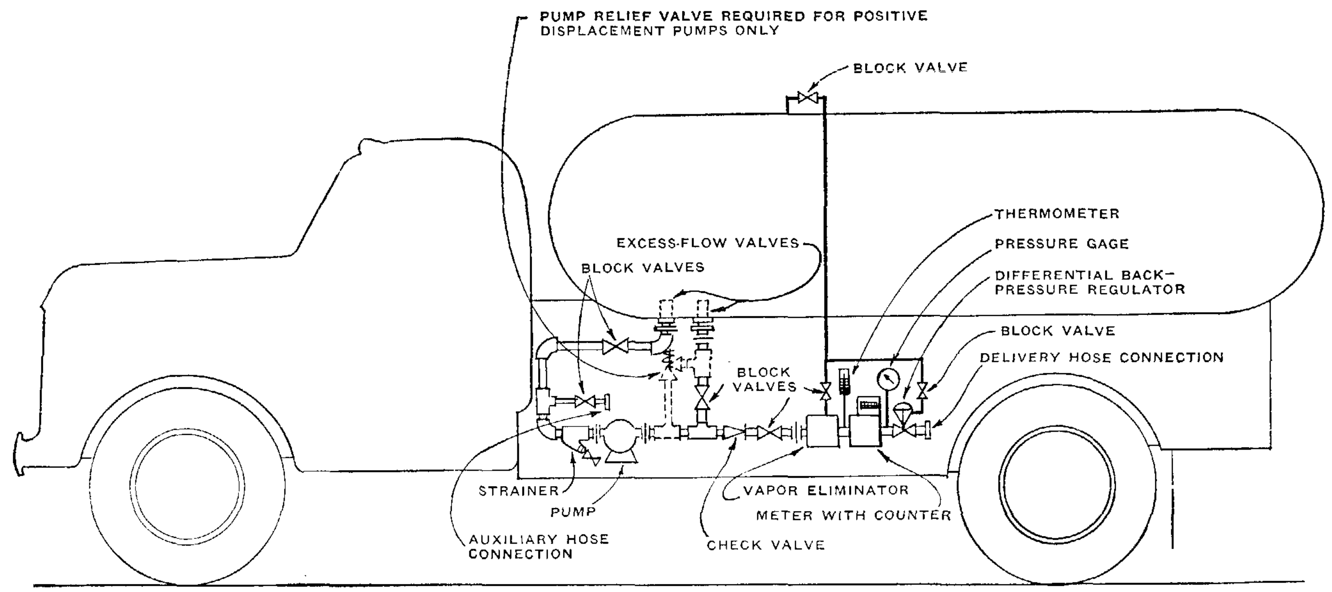



**FIG. 3—Typical LPG Truck Meter Installation.**



**TABLE II—Compressibility Factors per Pound per Square Inch from Fig. 33 ***

The following formulae are taken from Par. 3046:

$$V_h = V_e\,[1-(P_h-P_e)\,F]$$

$$V_e = \frac{V_h}{1-(P_h-P_e)\,F}$$

$$V_l = \frac{1-(P_l-P_e)\,F}{1-(P_h-P_e)\,F}(V_h)$$

$$V_h = \frac{1-(P_h-P_e)\,F}{1-(P_l-P_e)\,F}(V_l)$$

*Where:*

$V_h$ = volume at higher pressure $P_h$.
$V_l$ = volume at lower pressure $P_l$.
$V_e$ = volume at equilibrium pressure $P_e$.
$F$ = compressibility factor per pound per square inch gage from Fig. 33 or from this table.

*Note:* All factors given in this table must have 0.0000 placed in front of the figures published.

This table may be used for determining the change in meter factor when the meter is operated under varying internal case pressures in accordance with information contained in Par. 3046, 4010, and 4011. It may also be used to reduce the volume of liquid confined in closed provers under some observed pressure to the corresponding volume at some other desired pressure, in accordance with the information contained in Par. 3046.

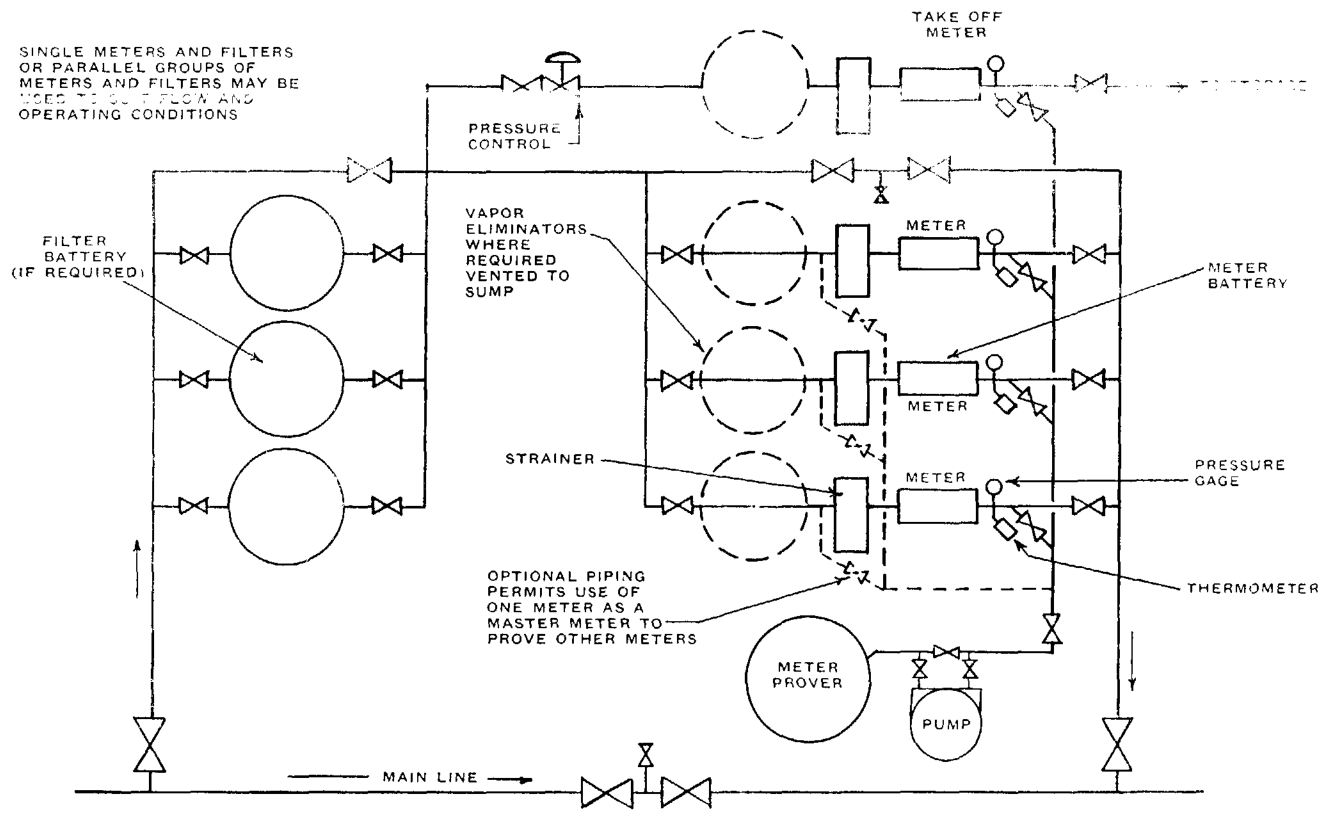
* Compiled by: M. L. Barrett, Jr., Shell Oil Co., Indianapolis, Ind.

**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | API Gravity 60F/60F | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 20 | 023 | 023 | 024 | 024 | 025 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 031 | 032 |
| 21 | 023 | 023 | 024 | 024 | 025 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 |
| 22 | 023 | 023 | 024 | 024 | 025 | 025 | 026 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 |
| 23 | 023 | 024 | 024 | 024 | 025 | 025 | 026 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 |
| 24 | 023 | 024 | 024 | 024 | 025 | 025 | 026 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 |
| 25 | 023 | 024 | 024 | 024 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 028 | 029 | 030 | 030 | 031 | 031 | 031 | 032 | 033 |
| 26 | 023 | 024 | 024 | 025 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 |
| 27 | 023 | 024 | 024 | 025 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 |
| 28 | 023 | 024 | 024 | 025 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 |
| 29 | 023 | 024 | 024 | 025 | 025 | 026 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 |
| 30 | 024 | 024 | 024 | 025 | 025 | 026 | 026 | 027 | 027 | 027 | 028 | 028 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 |
| 31 | 024 | 024 | 024 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 |
| 32 | 024 | 024 | 024 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 |
| 33 | 024 | 024 | 025 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 034 |
| 34 | 024 | 024 | 025 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 034 |
| 35 | 024 | 024 | 025 | 025 | 026 | 026 | 027 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 |
| 36 | 024 | 024 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 |
| 37 | 024 | 024 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 |
| 38 | 024 | 024 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 034 | 034 |
| 39 | 024 | 024 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 034 | 034 |
| 40 | 024 | 025 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 032 | 032 | 033 | 033 | 034 | 034 |
| 41 | 024 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 034 |
| 42 | 024 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 |
| 43 | 024 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 034 | 034 | 035 |
| 44 | 024 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 034 | 034 | 035 |
| 45 | 024 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 033 | 033 | 034 | 034 | 035 |
| 46 | 024 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 |
| 47 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 |
| 48 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 |
| 49 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 034 | 034 | 035 | 035 |
| 50 | 025 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 033 | 033 | 034 | 034 | 035 | 035 |
| 51 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 036 |
| 52 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 |
| 53 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 |
| 54 | 025 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 034 | 034 | 035 | 035 | 036 |
| 55 | 025 | 026 | 027 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 |
| 56 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 036 | 036 |
| 57 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 | 036 |
| 58 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 | 036 |
| 59 | 026 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 034 | 034 | 035 | 035 | 036 | 037 |
| 60 | 026 | 026 | 027 | 028 | 028 | 028 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 036 | 036 | 037 |
| 61 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 036 | 036 | 037 |
| 62 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 | 036 | 037 |
| 63 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 | 036 | 037 |
| 64 | 026 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 034 | 034 | 035 | 035 | 036 | 037 | 037 |
| 65 | 027 | 027 | 028 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 037 | 037 |
| 66 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 036 | 036 | 037 | 037 |
| 67 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 | 036 | 037 | 037 |
| 68 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 | 036 | 037 | 038 |
| 69 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 034 | 034 | 035 | 035 | 036 | 037 | 037 | 038 |
| 70 | 027 | 027 | 028 | 028 | 029 | 029 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 036 | 036 | 037 | 037 | 038 |
| 71 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 |
| 72 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 |
| 73 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 034 | 034 | 035 | 035 | 036 | 037 | 037 | 038 | 038 |
| 74 | 027 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 036 | 036 | 037 | 037 | 038 | 038 |








*Note:* All sections of line which may be blocked between valves should have provision for pressure relief.

**FIG. 1—Schematic Operating Diagram of a Pipeline Meter Station.**

# APPENDIX A







**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | API Gravity 60F/60F | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 75 | 028 | 028 | 028 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 036 | 036 | 037 | 037 | 038 | 039 |
| 76 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 |
| 77 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 |
| 78 | 028 | 028 | 029 | 029 | 030 | 030 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 037 | 037 | 038 | 038 | 039 |
| 79 | 028 | 028 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 |
| 80 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 039 |
| 81 | 028 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 037 | 037 | 038 | 038 | 039 | 040 |
| 82 | 028 | 029 | 029 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 036 | 036 | 037 | 037 | 038 | 038 | 039 | 040 |
| 83 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 |
| 84 | 029 | 029 | 030 | 030 | 031 | 031 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 |
| 85 | 029 | 029 | 030 | 030 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 040 |
| 86 | 029 | 030 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 |
| 87 | 029 | 030 | 030 | 031 | 031 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 039 | 040 | 041 |
| 88 | 029 | 030 | 030 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 040 | 041 |
| 89 | 029 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 040 | 041 |
| 90 | 030 | 030 | 031 | 031 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 |
| 91 | 030 | 030 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 |
| 92 | 030 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 |
| 93 | 030 | 031 | 031 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 |
| 94 | 030 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 042 |
| 95 | 031 | 031 | 032 | 032 | 033 | 033 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 |
| 96 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 |
| 97 | 031 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 |
| 98 | 031 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 043 |
| 99 | 032 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 042 | 043 | 044 |
| 100 | 032 | 033 | 033 | 034 | 034 | 034 | 035 | 036 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 041 | 041 | 042 | 043 | 043 | 044 |
| 101 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 |
| 102 | 032 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 042 | 043 | 044 | 045 |
| 103 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 041 | 041 | 042 | 043 | 043 | 044 | 045 |
| 104 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 |
| 105 | 033 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 |
| 106 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 041 | 041 | 042 | 043 | 043 | 044 | 045 | 046 |
| 107 | 033 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 044 | 045 | 046 |
| 108 | 033 | 034 | 034 | 035 | 035 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 046 |
| 109 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 |
| 110 | 034 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 |
| 111 | 034 | 034 | 035 | 035 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 046 | 047 |
| 112 | 034 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 047 |
| 113 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 |
| 114 | 034 | 035 | 036 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 047 | 047 | 048 |
| 115 | 035 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 048 |
| 116 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 |
| 117 | 035 | 036 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 047 | 048 | 049 |
| 118 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 049 |
| 119 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 050 |
| 120 | 035 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 048 | 049 | 050 |
| 121 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 049 | 050 |
| 122 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 047 | 047 | 048 | 049 | 050 | 051 |
| 123 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 049 | 049 | 050 | 051 |
| 124 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 050 | 051 | 052 |
| 125 | 037 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 047 | 047 | 048 | 049 | 050 | 051 | 052 |
| 126 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 049 | 050 | 051 | 053 |
| 127 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 053 |
| 128 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 048 | 049 | 050 | 051 | 052 | 053 |

**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | API Gravity 60F/60F | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| 20 | 033 | 033 | 034 | 034 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 044 | 045 |
| 21 | 033 | 033 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 042 | 043 | 044 | 044 | 045 |
| 22 | 033 | 033 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 |
| 23 | 033 | 034 | 034 | 035 | 035 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 041 | 041 | 042 | 043 | 043 | 044 | 045 | 045 |
| 24 | 033 | 034 | 034 | 035 | 035 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 043 | 044 | 045 | 046 |
| 25 | 033 | 034 | 034 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 |
| 26 | 033 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 042 | 043 | 044 | 044 | 045 | 046 |
| 27 | 033 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 |
| 28 | 034 | 034 | 035 | 035 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 045 | 046 |
| 29 | 034 | 034 | 035 | 035 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 046 |
| 30 | 034 | 034 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 044 | 045 | 046 | 047 |
| 31 | 034 | 034 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 044 | 045 | 046 | 047 |
| 32 | 034 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 |
| 33 | 034 | 035 | 035 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 046 | 047 |
| 34 | 034 | 035 | 035 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 041 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 047 | 047 |
| 35 | 034 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 |
| 36 | 034 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 |
| 37 | 035 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 |
| 38 | 035 | 035 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 046 | 047 | 048 |
| 39 | 035 | 035 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 041 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 047 | 047 | 048 |
| 40 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 049 |
| 41 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 049 |
| 42 | 035 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 |
| 43 | 035 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 |
| 44 | 035 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 047 | 048 | 049 |
| 45 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 049 | 049 |
| 46 | 036 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 |
| 47 | 036 | 036 | 037 | 038 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 |
| 48 | 036 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 050 |
| 49 | 036 | 037 | 037 | 038 | 038 | 039 | 040 | 041 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 047 | 047 | 048 | 049 | 050 |
| 50 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 049 | 049 | 050 |
| 51 | 036 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 | 050 |
| 52 | 036 | 037 | 038 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 | 051 |
| 53 | 036 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 050 | 051 |
| 54 | 037 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 048 | 049 | 050 | 051 |
| 55 | 037 | 037 | 038 | 038 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 049 | 049 | 050 | 051 |
| 56 | 037 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 | 051 | 051 |
| 57 | 037 | 038 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 050 | 051 | 052 |
| 58 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 047 | 047 | 048 | 049 | 050 | 051 | 052 |
| 59 | 037 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 048 | 049 | 050 | 051 | 052 |
| 60 | 037 | 038 | 038 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 049 | 050 | 050 | 051 | 052 |
| 61 | 037 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 | 051 | 051 | 052 |
| 62 | 038 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 052 |
| 63 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 047 | 047 | 048 | 049 | 050 | 051 | 052 | 052 |
| 64 | 038 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 049 | 049 | 050 | 051 | 052 | 053 |
| 65 | 038 | 038 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 049 | 050 | 050 | 051 | 052 | 053 |
| 66 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 052 | 053 |
| 67 | 038 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 053 |
| 68 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 047 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 053 |
| 69 | 038 | 039 | 040 | 040 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 049 | 049 | 050 | 051 | 052 | 053 | 054 |
| 70 | 038 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 | 051 | 051 | 052 | 053 | 054 |
| 71 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 053 | 054 |
| 72 | 039 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 054 |
| 73 | 039 | 040 | 040 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 047 | 048 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 |
| 74 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 049 | 050 | 050 | 051 | 052 | 053 | 054 | 055 |



*h.* Operation of standby or spare meters.

*i.* Minimum and maximum meter flow rates and other operating conditions, such as pressure and temperature.

*j.* Sealing of meters and bypass valves.

*k.* Procedure for volume adjustment in the event of meter failure or mismeasurement.

*l.* Taking of samples.

*m.* Procedures for items not included in the foregoing but which may be important for a specific location.

**5005** The frequency with which any particular type of meter should be proved is difficult to express in chronological or throughput terms. The service under which a meter operates should be studied and, through experience, a frequency of meter proving should be established which will maintain the accuracy of the meter within the tolerance limit of the user. Meter-proving reports, if analyzed, should indicate the following:

*a.* Maintenance interval.

*b.* Proving interval.

*c.* Constancy of performance.

**5006** Meters should be maintained in accordance with the manufacturers' instructions. A definite maintenance schedule should be established to provide adequate servicing of the meter and auxiliary equipment. Meters should always be proved after servicing. Meters stored for a long period should be kept under cover and should have their working parts oiled to minimize corrosion.

## MAINTENANCE OF ACCURACY OF PROVER SYSTEMS

**5007** Any change (additions, deletions, or repairs) of volumetric prover appurtenances in or connected to the calibrated prover volume, or any internal corrosion or accumulation of foreign material, will affect the calibrated volume of the prover. The prover should be recalibrated after any significant change in gage glasses, thermometer wells, spray lines, or other appurtenances. It should be inspected frequently for internal corrosion; and for accumulation of sediment, rust, valve lubricant, and other foreign material. Gage scales should be inspected frequently and the prover recalibrated if there is any indication of gage scale movement. The piston used in a piston displacement prover must be maintained in satisfactory condition to provide an adequate seal against the cylindrical chamber through which it moves.

**5008** With gravimetric provers it is possible that the accuracy of the scales can be affected by such things as physical damage, corrosion of critical operating parts, connection interference, settlement, wind effects, wear of the knife edges, and friction.

*c.* Obtain the meter factor to be used to correct the meter registration to the actual volume measured. Observed volume in prover, corrected to temperature and pressure conditions in the meter, divided by the registration equals the meter factor:

$$16.2838 \div 16.5 = 0.9869$$

It will be noted that steps *a* (2) and *b* (1) could have been combined. However, for the purpose of illustration, the procedure for correction to the base conditions was followed. Also, this is the procedure which is used to correct the meter registration to volume at base conditions in normal operation. As an example, assume that the same meter is operated at 500 psig and 100 F on the same liquid used in proving and that the meter registration is 10,000 bbl. To obtain the volumes at 60 F and 92 psig, the following steps should be taken:

*a.* Obtain the actual volume at metered conditions (500 psig and 100 F):

(Meter registration) (meter factor) = actual volume

$$(10{,}000)\ (0.9869) = 9{,}869 \text{ bbl}$$

*b.* Correct volume from 100 F and 500 psig ($V_h$) to 100 F and 172 psig ($V_e$):

$$9{,}869 \div [1-(500-172)\ 0.0000517] = 10{,}039 \text{ bbl}$$

*c.* Correct volume from 100 F and 172 psig to 60 F and 92 psig:

$$(10{,}039)\ (0.9308) = 9{,}344 \text{ bbl}$$

Assume the same conditions as the foregoing, except that the meter is operating at 20 F; thus:

*a.* The actual volume at metered conditions (500 psig and 20 F) is obtained as in the foregoing and is 9,869 bbl.

*b.* Volume corrected from 20 F and 500 psig ($V_h$) to 20 F and 41 psig ($V_e$) is as follows:

$$9{,}869 \div [1-(500-41)\ 0.0000328] = 10{,}020 \text{ bbl}$$

*c.* Volume corrected from 20 F and 41 psig to 60 F and 92 psig is as follows:

$$(10{,}020)\ (1.0618) = 10{,}639 \text{ bbl}$$

### METER PERFORMANCE UNDER CONDITIONS OF VARYING FLOW FATE

**4012** There may be variation in meter performance when the operating flow rate varies appreciably from the proving flow rate. Maximum accuracy will be obtained by performing a meter proof at each flow rate encountered. However, where there is appreciable variation in the operating flow rate, a meter accuracy curve may be determined over the range of flow rates and an appropriate meter performance factor selected from the accuracy curve.

## SECTION V—OPERATION AND MAINTENANCE OF METERING SYSTEMS

### SCOPE

**5001** This section covers recommended meter operating and maintenance practices for all installations regardless of type of liquid or type of service.

### GENERAL CONSIDERATIONS

**5002** The accuracy of liquid measurement by meter will depend upon the condition of the meter; the proving system; the frequency of meter proving; the corrections made in proving; and the variations between operating and proving conditions, if any. The proving equipment should be selected, operated, and maintained, and the meter installation operated and maintained, in such a manner as to achieve the desired approach to accuracy which may be established by policy, mutual agreement, or regulation.

**5003** Meter installations should be checked periodically by operating personnel to assure that the following equipment has been properly installed, operated, and maintained as prescribed in this standard:

*a.* Meters, valves, and piping, note being taken of size, working pressure, and other physical characteristics.

*b.* Proving facilities.

*c.* Air elimination equipment, strainers, filters, and water removal equipment.

*d.* Protective devices such as relief valves, flow-limiting valves, back-pressure valves, and alarms.

*e.* Pressure gages, thermometers, samplers, and gravitometers.

*f.* Auxiliary equipment such as meter registers, ticket printers, registration combining devices, gravity selectors, temperature compensators, and remote telemetering devices.

**5004** Definite operating procedures should be furnished operating personnel. These operating procedures might include:

*a.* Step-by-step method for meter provings at a particular location.

*b.* Provision for periodic checking of the prover accuracy.

*c.* Specific frequency of meter provings to meet operational changes in flow rate, pressure, temperature, and liquid characteristics.

*d.* Witnessing of meter-proving operations and repairs.

*e.* Specific use of applicable temperature and pressure correction factors.

*f.* Accounting and reporting of metered volumes and other observed data.

*g.* Valve lubrication, if required.



**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | API Gravity 60F/60F | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| 75 | 039 | 040 | 041 | 041 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 | 051 | 051 | 052 | 053 | 054 | 055 |
| 76 | 039 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 054 | 055 |
| 77 | 040 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 046 | 047 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 055 |
| 78 | 040 | 041 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 047 | 048 | 049 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 |
| 79 | 040 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 049 | 050 | 050 | 051 | 052 | 053 | 054 | 055 | 056 |
| 80 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 052 | 053 | 054 | 055 | 056 |
| 81 | 040 | 041 | 042 | 042 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 055 | 056 |
| 82 | 041 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 047 | 048 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 |
| 83 | 041 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 049 | 050 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 |
| 84 | 041 | 042 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 054 | 055 | 056 | 057 |
| 85 | 041 | 042 | 043 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 |
| 86 | 041 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 |
| 87 | 042 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 049 | 050 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 058 | 059 |
| 88 | 042 | 042 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 |
| 89 | 042 | 043 | 043 | 044 | 045 | 046 | 047 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 |
| 90 | 042 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 058 | 059 | 060 |
| 91 | 042 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 |
| 92 | 043 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 060 | 061 |
| 93 | 043 | 044 | 044 | 045 | 046 | 047 | 048 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 058 | 059 | 060 | 061 |
| 94 | 043 | 044 | 045 | 045 | 046 | 047 | 048 | 049 | 050 | 050 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 |
| 95 | 043 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 060 | 061 | 062 |
| 96 | 044 | 044 | 045 | 046 | 047 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 058 | 059 | 060 | 061 | 062 |
| 97 | 044 | 045 | 046 | 046 | 047 | 048 | 049 | 049 | 050 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 062 | 063 |
| 98 | 044 | 045 | 046 | 047 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 060 | 061 | 062 | 063 |
| 99 | 045 | 045 | 046 | 047 | 048 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 057 | 058 | 059 | 060 | 061 | 062 | 063 |
| 100 | 045 | 046 | 046 | 047 | 048 | 049 | 049 | 050 | 051 | 052 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 063 | 064 |
| 101 | 045 | 046 | 047 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 061 | 062 | 063 | 064 |
| 102 | 045 | 046 | 047 | 048 | 048 | 049 | 050 | 051 | 052 | 053 | 055 | 056 | 056 | 058 | 059 | 060 | 061 | 062 | 064 | 065 |
| 103 | 046 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 062 | 063 | 064 | 065 |
| 104 | 046 | 047 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 060 | 061 | 062 | 063 | 064 | 065 |
| 105 | 046 | 047 | 048 | 049 | 049 | 050 | 051 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 |
| 106 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 062 | 063 | 064 | 065 | 066 |
| 107 | 047 | 048 | 048 | 049 | 050 | 051 | 052 | 053 | 055 | 056 | 057 | 057 | 058 | 060 | 061 | 062 | 063 | 065 | 066 | 067 |
| 108 | 047 | 048 | 049 | 050 | 050 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 063 | 064 | 065 | 066 | 067 |
| 109 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 061 | 062 | 063 | 064 | 065 | 066 | 068 |
| 110 | 048 | 049 | 049 | 050 | 051 | 052 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 068 |
| 111 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 062 | 063 | 064 | 065 | 066 | 068 | 069 |
| 112 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 056 | 057 | 057 | 058 | 060 | 061 | 062 | 063 | 064 | 066 | 067 | 068 | 069 |
| 113 | 049 | 049 | 050 | 051 | 052 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 067 | 069 | 070 |
| 114 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 061 | 062 | 063 | 064 | 065 | 067 | 068 | 069 | 071 |
| 115 | 049 | 050 | 051 | 052 | 053 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 068 | 070 | 071 |
| 116 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 062 | 063 | 064 | 065 | 066 | 068 | 069 | 070 | 072 |
| 117 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 058 | 059 | 060 | 061 | 062 | 063 | 064 | 066 | 067 | 068 | 070 | 071 | 072 |
| 118 | 050 | 051 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 068 | 069 | 070 | 072 | 073 |
| 119 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 060 | 061 | 062 | 063 | 064 | 065 | 067 | 068 | 070 | 071 | 072 | 074 |
| 120 | 051 | 052 | 053 | 054 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 |
| 121 | 051 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 062 | 063 | 064 | 065 | 067 | 068 | 069 | 071 | 072 | 073 | 075 |
| 122 | 052 | 053 | 054 | 055 | 056 | 057 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 075 |
| 123 | 052 | 053 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 063 | 064 | 065 | 066 | 068 | 069 | 071 | 072 | 073 | 074 | 076 |
| 124 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 061 | 062 | 063 | 064 | 066 | 067 | 068 | 070 | 071 | 073 | 074 | 075 | 077 |
| 125 | 053 | 054 | 055 | 056 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 067 | 069 | 070 | 072 | 073 | 074 | 076 | 077 |
| 126 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 063 | 064 | 065 | 067 | 068 | 069 | 071 | 072 | 074 | 075 | 077 | 078 |
| 127 | 054 | 055 | 056 | 057 | 058 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 068 | 070 | 071 | 073 | 074 | 076 | 077 | 079 |
| 128 | 054 | 055 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 068 | 069 | 070 | 072 | 074 | 075 | 077 | 078 | 080 |

**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | API Gravity 60F/60F 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 046 | 047 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 053 | 054 | 055 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 064 |
| 21 | 046 | 047 | 048 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 064 |
| 22 | 046 | 047 | 048 | 049 | 050 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 |
| 23 | 046 | 047 | 048 | 049 | 050 | 051 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 062 | 063 | 064 | 065 |
| 24 | 046 | 047 | 048 | 049 | 050 | 051 | 052 | 052 | 053 | 054 | 055 | 056 | 057 | 059 | 060 | 061 | 062 | 063 | 064 | 066 |
| 25 | 047 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 054 | 055 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 064 | 066 |
| 26 | 047 | 048 | 049 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 |
| 27 | 047 | 048 | 049 | 050 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 |
| 28 | 047 | 048 | 049 | 050 | 051 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 061 | 062 | 063 | 064 | 065 | 067 |
| 29 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 053 | 054 | 055 | 056 | 058 | 059 | 060 | 061 | 062 | 063 | 064 | 066 | 067 |
| 30 | 047 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 064 | 066 | 067 |
| 31 | 048 | 049 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 |
| 32 | 048 | 049 | 050 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 063 | 064 | 065 | 066 | 068 |
| 33 | 048 | 049 | 050 | 051 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 060 | 061 | 062 | 063 | 064 | 065 | 067 | 068 |
| 34 | 048 | 049 | 050 | 051 | 052 | 053 | 053 | 054 | 055 | 056 | 058 | 059 | 060 | 061 | 062 | 063 | 064 | 066 | 067 | 068 |
| 35 | 048 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 069 |
| 36 | 049 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 068 | 069 |
| 37 | 049 | 050 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 063 | 064 | 065 | 066 | 068 | 069 |
| 38 | 049 | 050 | 051 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 060 | 061 | 062 | 063 | 064 | 065 | 067 | 068 | 069 |
| 39 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 064 | 066 | 067 | 068 | 070 |
| 40 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 069 | 070 |
| 41 | 049 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 068 | 069 | 070 |
| 42 | 050 | 051 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 062 | 063 | 064 | 065 | 067 | 068 | 069 | 070 |
| 43 | 050 | 051 | 052 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 060 | 061 | 062 | 063 | 064 | 066 | 067 | 068 | 069 | 071 |
| 44 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 068 | 070 | 071 |
| 45 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 067 | 069 | 070 | 071 |
| 46 | 050 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 063 | 064 | 065 | 066 | 068 | 069 | 070 | 072 |
| 47 | 051 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 062 | 063 | 064 | 065 | 067 | 068 | 069 | 071 | 072 |
| 48 | 051 | 052 | 053 | 053 | 054 | 055 | 056 | 058 | 059 | 060 | 061 | 062 | 063 | 064 | 066 | 067 | 068 | 070 | 071 | 072 |
| 49 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 069 | 070 | 071 | 073 |
| 50 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 068 | 069 | 070 | 071 | 073 |
| 51 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 063 | 064 | 065 | 066 | 068 | 069 | 070 | 072 | 073 |
| 52 | 051 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 061 | 062 | 063 | 064 | 065 | 067 | 068 | 069 | 071 | 072 | 073 |
| 53 | 052 | 053 | 053 | 054 | 055 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 064 | 066 | 067 | 068 | 070 | 071 | 072 | 074 |
| 54 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 |
| 55 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 068 | 069 | 070 | 072 | 073 | 074 |
| 56 | 052 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 063 | 064 | 065 | 067 | 068 | 069 | 070 | 072 | 073 | 075 |
| 57 | 053 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 061 | 062 | 063 | 064 | 066 | 067 | 068 | 069 | 071 | 072 | 074 | 075 |
| 58 | 053 | 053 | 054 | 055 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 068 | 070 | 071 | 072 | 074 | 075 |
| 59 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 076 |
| 60 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 063 | 064 | 065 | 066 | 068 | 069 | 070 | 072 | 073 | 075 | 076 |
| 61 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 062 | 063 | 064 | 065 | 067 | 068 | 069 | 071 | 072 | 073 | 075 | 076 |
| 62 | 053 | 054 | 055 | 056 | 057 | 058 | 059 | 061 | 062 | 063 | 064 | 066 | 067 | 068 | 070 | 071 | 072 | 074 | 075 | 077 |
| 63 | 053 | 054 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 076 | 077 |
| 64 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 076 | 077 |
| 65 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 063 | 064 | 065 | 066 | 068 | 069 | 070 | 072 | 073 | 075 | 076 | 078 |
| 66 | 054 | 055 | 056 | 057 | 058 | 059 | 060 | 062 | 063 | 064 | 065 | 067 | 068 | 069 | 071 | 072 | 073 | 075 | 077 | 078 |
| 67 | 054 | 055 | 056 | 057 | 058 | 060 | 061 | 062 | 063 | 064 | 066 | 067 | 068 | 070 | 071 | 072 | 074 | 075 | 077 | 078 |
| 68 | 055 | 055 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 076 | 077 | 079 |
| 69 | 055 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 068 | 069 | 070 | 072 | 073 | 074 | 076 | 077 | 079 |
| 70 | 055 | 056 | 057 | 058 | 059 | 060 | 062 | 063 | 064 | 065 | 066 | 068 | 069 | 071 | 072 | 073 | 075 | 076 | 078 | 079 |
| 71 | 055 | 056 | 057 | 058 | 059 | 061 | 062 | 063 | 064 | 065 | 067 | 068 | 070 | 071 | 072 | 074 | 075 | 077 | 078 | 079 |
| 72 | 055 | 056 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 068 | 070 | 071 | 073 | 074 | 075 | 077 | 078 | 080 |
| 73 | 056 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 076 | 077 | 079 | 080 |
| 74 | 056 | 057 | 058 | 059 | 060 | 061 | 063 | 064 | 065 | 066 | 068 | 069 | 070 | 072 | 073 | 075 | 076 | 078 | 079 | 080 |



EXAMPLE:

Assume that a meter is proved at 80 F on 65 deg API at 60 F gasoline and 1,000 psi meter case pressure and has a meter factor of 1.0062. The vapor pressure is 10 psia, which is less than atmospheric. At some subsequent time the operating pressure within the meter is reduced to 750 psi, but other conditions remain the same. It is desired to continue measurement by meter without further provings. The meter is made of cast steel and is assumed to have negligible strain as a result of pressure. $F$ is determined directly from Fig. 33 or Table II, Appendix B. Then the meter factor at the lower pressure equals the meter factor at the higher pressure times the volume at the higher pressure over the volume at the lower pressure:

$$\text{MF at } P_l = (\text{MF at } P_h)\frac{V_e\,[1-(P_h-P_e)\,F]}{V_e\,[1-(P_l-P_e)\,F]}$$

$$= \text{MF at } P_h \frac{1-(P_h-P_e)\,F}{1-(P_l-P_e)\,F}$$

$$= 1.0062\ \frac{1-(1{,}000-0)\ 0.0000091}{1-(750-0)\ 0.0000091}$$

$$= 1.0062\ \frac{1-0.0091}{1-0.0068}$$

$$= 1.0062\ \frac{0.9909}{0.9932} = 1.0039$$

When liquids are being measured which have a vapor pressure above atmospheric, the volumes measured during proving (both prover and metered volumes) must be corrected for pressure to the vapor pressure of the liquid at the observed temperature.

**4011** Corrections for pressure effects on liquids with a vapor pressure above atmospheric are somewhat more involved than for liquids with lower vapor pressures because the volume corrections for temperature for products as given by the ASTM D 1250 tables also include the correction for pressure at equilibrium. Thus a meter factor cannot be applied to the reading of a meter measuring a liquid with a vapor pressure above atmospheric, and operating at various temperatures and a constant pressure, to correct the meter registration to a base temperature and pressure. It is usually most convenient, in proving meters used in measuring high-vapor-pressure liquids, to determine a meter factor which will correct the meter registration to the actual volume at operating temperature and pressure. If the measured volume is desired at a base temperature and equilibrium pressure, corrections for pressure are applied to correct the measured liquid volume from the measured pressure to the equilibrium pressure at the measured temperature, in accordance with Table II, Appendix B. Adjustments are then made by use of the ASTM D 1250 tables to correct the volume from the observed temperature to the desired base temperature. The following is an example based on the use of a non-temperature-compensated meter. Appropriate steps may be omitted where a temperature-compensated meter is used.

*a.* A meter is used to measure a liquid with specific gravity of 0.508 at 60 F.

*b.* The meter is operated at 500 psig and 85 F during proving and registers 16.5 bbl.

*c.* The observed volume in a volumetric prover is 16.6 bbl, at a temperature of 90 F and a pressure of 300 psig.

*d.* The liquid vapor pressure is:

11 psig at 20 F
92 psig at 60 F
138 psig at 85 F
149 psig at 90 F
172 psig at 100 F

To find the meter factor, the following steps should be taken:

*a.* Correct the observed volume in the prover to standard conditions.

1. Correct the observed volume in the prover from 90 F and 300 psig to 90 F and 149 psig:

$$\text{Volume at 90 F and 149 psig } (V_e) = \frac{\text{Volume at 90 F and 300 psig } (V_h)}{1-(P_h-P_e)\,F} \quad \text{(See Par. 3046.)}$$

The compressibility factor from Table II, Appendix B, for a liquid of 0.508 specific gravity at 90 F is 0.0000486; thus:

Volume at 90 F and 149 psig

$$= 16.6 \div [1-(300-149)\ 0.0000486]$$
$$= 16.7227 \text{ bbl}$$

2. Correct from 90 F and 149 psig to 60 F and 92 psig:

(Volume at 90 F) (correction factor) = volume at 60 F

The correction factor from ASTM D 1250 Table 24 for correcting the volume of a liquid of 0.508 specific gravity from 90 F to 60 F is 0.9486; thus:

$$(16.7227)(0.9486) = 15.8632 \text{ bbl}$$

which is the observed volume in the prover corrected to 60 F and 92 psig.

*b.* Correct the prover volume at standard conditions to the volume at metered conditions.

1. Correct volume from 60 F and 92 psig to 85 F and 138 psig. From ASTM D 1250 Table 24, the factor is 0.9576; thus:

$$15.8632 \div 0.9576 = 16.5656 \text{ bbl}$$

2. Correct volume from 85 F and 138 psig ($V_e$) to 85 F and 500 psig ($V_h$). The compressibility factor from Table II, Appendix B, is 0.0000470. From Par. 3046,

$$V_h = V_e\,[1-(P_h-P_e)\,F]$$
$$= 16.5656\,[1-(500-138)\ 0.0000470]$$
$$= 16.5656\,[1-(362)\ 0.0000470]$$
$$= 16.2838 \text{ bbl}$$

Alternately, a slightly less accurate determination of air density may be computed from the foregoing formula by substituting information obtainable from *Local Climatological Data* published monthly by the United States Department of Commerce, Weather Bureau.

Upon agreement by all parties involved (and for practical purposes), an average density of standard air, namely, 0.001217 g per cu cm, may be as used by ASTM D 1250 tables. This average density, when converted to avoirdupois units, becomes 0.0759752 lb per cubic foot at 60 F, or 0.4265 lb per barrel at 60 F.

## SECTION IV—METER PERFORMANCE

### SCOPE

**4001** This section describes the various computations in the proving of a meter and shows basically how the resulting expressions of meter performance may be applied to the meter's normal measurement operations.

### GENERAL

**4002** Meter performance (see definition No. 49) must be obtained by proving the meter. It is variously termed "meter factor," "meter accuracy," "over-or-under delivery," or "over-or-under registration" (see definitions No. 48, 42, 18, and 76), depending upon preference or custom. It is always an expression of the relative throughputs for any one given set of operating conditions; for example, some particular pressure, rate of flow, viscosity, gravity, mechanical condition of the meter, and temperature. The performance of a meter will change whenever any of the significant conditions under which it operates is changed. For this reason, a meter must be proved under conditions simulating those existing in its normal operation. The proper meter performance for the existing operating conditions applied mathematically to the indicated meter quantity will give the true quantity.

**4003** A meter characteristic is determined from a series of meter provings and is normally presented in graph form. It is common practice within the industry to speak of an "accuracy curve" for a meter. This may be a plot of the meter performance versus rate of flow, pressure, temperature, viscosity, or mechanical condition.

**4004** Meter performance is affected by meter slippage and by change in volume of the metered liquid with change in operating temperature, pressure, or both.

**4005** Conditions which may affect meter slippage are:

*a.* The viscosity of the metered liquid.

*b.* The clearances in the measuring element through which liquid can pass.

*c.* The hydraulic head loss (pressure loss within the meter).

*d.* Lubricating qualities of the liquid.

*e.* Flow rate of the liquid through the meter.

*f.* Temperature of the liquid flowing through the meter.

*g.* Pressure of the liquid flowing through the meter.

### TEMPERATURE EFFECTS ON METER PERFORMANCE

**4006** Consideration of temperature effects is important in actual proving operations and in expression of meter performance. Temperature change of the metered stream may affect meter slippage and the actual metered volume, and may cause vaporization of the liquid. An automatic temperature compensator or temperature correction factors may be used to correct the indicated throughput to 60 F or to some desired base temperature (see Par. 4011).

**4007** When a meter is being proved, the temperature of the liquid in the meter and in the prover must be the same or be corrected to a common temperature to secure the correct expression of meter performance.

### PRESSURE EFFECTS ON METER PERFORMANCE

**4008** The pressure which is held in a volumetric prover at the time the volume is observed, or the pressure at which the gravity is determined for a gravimetric prover, is the pressure at which the meter being proved will measure the liquid passing through it. This volume observed in the prover must be corrected to its equivalent volume at the reference pressure and temperature to obtain the correct meter factor. Unless the pressure inside the meter case is essentially the same at all times during a meter's continuous operation as it was when the meter was proved, a pressure correction should be applied (see Par. 3046 and Par. 4010). This is true, regardless of the pressure in the meter during proving, for both volumetric and gravimetric provers.

**4009** The pressure maintained in a volumetric prover should be as near the desired reference pressure as possible. Where this cannot be done, it is necessary to adjust the volume observed in the prover at the observed pressure to the volume which it would occupy at the desired reference pressure. This may be done by means of the compressibility chart shown in Fig. 33 and the formula given in Par. 3046, or by means of the compressibility factors given in Table II, Appendix B.

**4010** The meter factor is obtained for the existing operating pressure. If, after proving, the operating pressure is changed and it is impractical to prove the meter at the new pressure, the meter factor may be adjusted for the new operating pressure in accordance with Par. 3046.



**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | API Gravity 60F/60F | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| 75 | 056 | 057 | 058 | 059 | 061 | 062 | 063 | 064 | 065 | 067 | 068 | 069 | 071 | 072 | 073 | 075 | 076 | 078 | 079 | 081 |
| 76 | 056 | 057 | 058 | 060 | 061 | 062 | 063 | 064 | 066 | 067 | 068 | 070 | 071 | 072 | 074 | 075 | 077 | 078 | 080 | 081 |
| 77 | 057 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 076 | 077 | 079 | 080 | 082 |
| 78 | 057 | 058 | 059 | 060 | 061 | 062 | 064 | 065 | 066 | 068 | 069 | 070 | 072 | 073 | 074 | 076 | 077 | 079 | 080 | 082 |
| 79 | 057 | 058 | 059 | 061 | 062 | 063 | 064 | 065 | 067 | 068 | 069 | 071 | 072 | 073 | 075 | 076 | 078 | 079 | 081 | 082 |
| 80 | 057 | 058 | 060 | 061 | 062 | 063 | 064 | 066 | 067 | 068 | 070 | 071 | 072 | 074 | 075 | 077 | 078 | 080 | 081 | 083 |
| 81 | 058 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 |
| 82 | 058 | 059 | 060 | 062 | 063 | 064 | 065 | 066 | 068 | 069 | 070 | 072 | 073 | 074 | 076 | 078 | 079 | 080 | 082 | 084 |
| 83 | 058 | 059 | 061 | 062 | 063 | 064 | 065 | 067 | 068 | 069 | 071 | 072 | 074 | 075 | 076 | 078 | 079 | 081 | 082 | 084 |
| 84 | 059 | 060 | 061 | 062 | 063 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 085 |
| 85 | 059 | 060 | 061 | 063 | 064 | 065 | 066 | 068 | 069 | 070 | 072 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 085 |
| 86 | 059 | 061 | 062 | 063 | 064 | 065 | 067 | 068 | 069 | 071 | 072 | 073 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 |
| 87 | 060 | 061 | 062 | 063 | 064 | 066 | 067 | 068 | 070 | 071 | 072 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 |
| 88 | 060 | 061 | 063 | 064 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 086 |
| 89 | 061 | 062 | 063 | 064 | 065 | 066 | 068 | 069 | 070 | 072 | 073 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 |
| 90 | 061 | 062 | 063 | 064 | 066 | 067 | 068 | 070 | 071 | 072 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 087 |
| 91 | 061 | 063 | 064 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 |
| 92 | 062 | 063 | 064 | 065 | 066 | 068 | 069 | 070 | 072 | 073 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 088 |
| 93 | 062 | 063 | 065 | 066 | 067 | 068 | 070 | 071 | 072 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 087 | 089 |
| 94 | 063 | 064 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 |
| 95 | 063 | 064 | 065 | 066 | 068 | 069 | 071 | 072 | 073 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 088 | 090 |
| 96 | 063 | 065 | 066 | 067 | 069 | 069 | 071 | 072 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 087 | 089 | 091 |
| 97 | 064 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 |
| 98 | 064 | 065 | 066 | 068 | 069 | 070 | 072 | 073 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 088 | 090 | 092 |
| 99 | 065 | 066 | 067 | 068 | 070 | 071 | 072 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 087 | 089 | 091 | 093 |
| 100 | 065 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 087 | 088 | 090 | 092 | 094 |
| 101 | 065 | 066 | 068 | 069 | 070 | 072 | 073 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 092 | 094 |
| 102 | 066 | 067 | 068 | 070 | 071 | 072 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 088 | 089 | 091 | 093 | 095 |
| 103 | 066 | 067 | 069 | 070 | 071 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 096 |
| 104 | 066 | 068 | 069 | 071 | 072 | 073 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 093 | 094 | 096 |
| 105 | 067 | 068 | 070 | 071 | 073 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 088 | 090 | 092 | 093 | 095 | 097 |
| 106 | 068 | 069 | 070 | 072 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 096 | 098 |
| 107 | 068 | 069 | 071 | 072 | 074 | 075 | 077 | 078 | 079 | 081 | 083 | 084 | 086 | 087 | 089 | 091 | 093 | 095 | 097 | 098 |
| 108 | 069 | 070 | 071 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 095 | 097 | 099 |
| 109 | 069 | 071 | 072 | 073 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 092 | 094 | 096 | 098 | 100 |
| 110 | 070 | 071 | 072 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 087 | 089 | 091 | 093 | 095 | 097 | 099 | 100 |
| 111 | 070 | 072 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 096 | 098 | 099 | 101 |
| 112 | 071 | 072 | 074 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 086 | 087 | 089 | 091 | 093 | 094 | 096 | 098 | 100 | 102 |
| 113 | 071 | 073 | 074 | 075 | 077 | 078 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 095 | 097 | 099 | 101 | 103 |
| 114 | 072 | 073 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 092 | 094 | 096 | 098 | 100 | 102 | 103 |
| 115 | 073 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 088 | 090 | 091 | 093 | 095 | 096 | 099 | 101 | 102 | 104 |
| 116 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 087 | 088 | 090 | 092 | 094 | 096 | 097 | 099 | 101 | 103 | 105 |
| 117 | 074 | 075 | 076 | 078 | 079 | 081 | 083 | 084 | 086 | 087 | 089 | 091 | 093 | 095 | 096 | 098 | 100 | 102 | 104 | 106 |
| 118 | 074 | 075 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 095 | 097 | 099 | 101 | 103 | 105 | 107 |
| 119 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 086 | 087 | 089 | 091 | 093 | 094 | 096 | 098 | 100 | 102 | 104 | 106 | 108 |
| 120 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 093 | 095 | 097 | 099 | 101 | 103 | 105 | 107 | 109 |
| 121 | 076 | 078 | 079 | 081 | 082 | 084 | 086 | 087 | 089 | 091 | 093 | 094 | 096 | 098 | 100 | 102 | 104 | 106 | 108 | 110 |
| 122 | 077 | 078 | 080 | 081 | 083 | 085 | 087 | 088 | 090 | 092 | 093 | 095 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 111 |
| 123 | 077 | 079 | 081 | 082 | 084 | 086 | 087 | 089 | 091 | 093 | 094 | 095 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 112 |
| 124 | 078 | 080 | 081 | 083 | 085 | 086 | 088 | 090 | 092 | 093 | 095 | 096 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 |
| 125 | 079 | 081 | 082 | 084 | 086 | 087 | 089 | 091 | 093 | 094 | 096 | 097 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 |
| 126 | 080 | 081 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 095 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 114 | 116 |
| 127 | 081 | 082 | 084 | 086 | 087 | 089 | 091 | 093 | 094 | 096 | 098 | 099 | 102 | 104 | 106 | 108 | 110 | 112 | 115 | 117 |
| 128 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 095 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 114 | 116 | 118 |

**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | API Gravity 60F/60F 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 066 | 067 | 068 | 070 | 071 | 072 | 073 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 088 | 090 | 092 | 094 |
| 21 | 066 | 067 | 069 | 070 | 071 | 072 | 074 | 075 | 077 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 092 | 094 |
| 22 | 066 | 068 | 069 | 070 | 071 | 073 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 087 | 089 | 091 | 093 | 094 |
| 23 | 066 | 068 | 069 | 070 | 072 | 073 | 074 | 076 | 077 | 079 | 080 | 081 | 083 | 084 | 086 | 088 | 090 | 091 | 093 | 095 |
| 24 | 067 | 068 | 069 | 071 | 072 | 073 | 075 | 076 | 078 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 095 |
| 25 | 067 | 068 | 070 | 071 | 072 | 074 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 090 | 092 | 094 | 096 |
| 26 | 067 | 069 | 070 | 071 | 073 | 074 | 075 | 077 | 078 | 080 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 093 | 094 | 096 |
| 27 | 068 | 069 | 070 | 072 | 073 | 074 | 076 | 077 | 079 | 080 | 081 | 083 | 084 | 086 | 088 | 090 | 091 | 093 | 095 | 096 |
| 28 | 068 | 069 | 070 | 072 | 073 | 075 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 093 | 095 | 097 |
| 29 | 068 | 069 | 071 | 072 | 073 | 075 | 076 | 078 | 079 | 081 | 082 | 083 | 085 | 087 | 088 | 090 | 092 | 094 | 096 | 097 |
| 30 | 068 | 070 | 071 | 072 | 074 | 075 | 077 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 092 | 094 | 096 | 098 |
| 31 | 069 | 070 | 071 | 073 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 087 | 089 | 091 | 093 | 095 | 096 | 098 |
| 32 | 069 | 070 | 072 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 084 | 086 | 088 | 090 | 091 | 093 | 095 | 097 | 099 |
| 33 | 069 | 071 | 072 | 073 | 075 | 076 | 078 | 079 | 080 | 082 | 083 | 085 | 087 | 088 | 090 | 092 | 094 | 095 | 097 | 099 |
| 34 | 070 | 071 | 072 | 074 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 092 | 094 | 096 | 098 | 099 |
| 35 | 070 | 071 | 072 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 087 | 089 | 091 | 093 | 094 | 096 | 098 | 100 |
| 36 | 070 | 071 | 073 | 074 | 076 | 077 | 079 | 080 | 081 | 083 | 084 | 086 | 088 | 090 | 091 | 093 | 095 | 097 | 099 | 100 |
| 37 | 070 | 072 | 073 | 075 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 095 | 097 | 099 | 101 |
| 38 | 071 | 072 | 073 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 090 | 092 | 094 | 096 | 098 | 099 | 101 |
| 39 | 071 | 072 | 074 | 075 | 077 | 078 | 080 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 093 | 094 | 096 | 098 | 100 | 102 |
| 40 | 071 | 073 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 088 | 089 | 091 | 093 | 095 | 096 | 098 | 100 | 102 |
| 41 | 072 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 093 | 095 | 097 | 099 | 101 | 102 |
| 42 | 072 | 073 | 075 | 076 | 078 | 079 | 080 | 082 | 083 | 085 | 087 | 088 | 090 | 092 | 094 | 096 | 097 | 099 | 101 | 103 |
| 43 | 072 | 073 | 075 | 077 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 093 | 094 | 096 | 098 | 100 | 101 | 103 |
| 44 | 072 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 087 | 089 | 091 | 093 | 095 | 097 | 098 | 100 | 102 | 104 |
| 45 | 073 | 074 | 076 | 077 | 079 | 080 | 081 | 083 | 084 | 086 | 088 | 090 | 092 | 093 | 095 | 097 | 099 | 100 | 102 | 104 |
| 46 | 073 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 096 | 097 | 099 | 101 | 103 | 105 |
| 47 | 073 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 092 | 094 | 096 | 098 | 099 | 101 | 103 | 105 |
| 48 | 074 | 075 | 077 | 078 | 080 | 081 | 082 | 084 | 086 | 087 | 089 | 091 | 093 | 095 | 096 | 098 | 100 | 102 | 104 | 106 |
| 49 | 074 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 088 | 090 | 091 | 093 | 095 | 097 | 099 | 100 | 102 | 104 | 106 |
| 50 | 074 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 095 | 097 | 099 | 101 | 102 | 104 | 106 |
| 51 | 075 | 076 | 078 | 079 | 080 | 082 | 083 | 085 | 087 | 089 | 090 | 092 | 094 | 096 | 098 | 099 | 101 | 103 | 105 | 107 |
| 52 | 075 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 093 | 094 | 096 | 098 | 100 | 101 | 103 | 105 | 107 |
| 53 | 075 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 088 | 089 | 091 | 093 | 095 | 097 | 098 | 100 | 102 | 104 | 106 | 108 |
| 54 | 076 | 077 | 079 | 080 | 081 | 083 | 084 | 086 | 088 | 090 | 092 | 094 | 095 | 097 | 099 | 100 | 102 | 104 | 106 | 108 |
| 55 | 076 | 077 | 079 | 080 | 082 | 083 | 085 | 087 | 089 | 090 | 092 | 094 | 096 | 098 | 099 | 101 | 103 | 105 | 107 | 109 |
| 56 | 076 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 093 | 094 | 096 | 098 | 100 | 101 | 103 | 105 | 107 | 109 |
| 57 | 077 | 078 | 079 | 081 | 082 | 084 | 086 | 087 | 089 | 091 | 093 | 095 | 097 | 098 | 100 | 102 | 104 | 106 | 108 | 110 |
| 58 | 077 | 078 | 080 | 081 | 083 | 084 | 086 | 088 | 090 | 092 | 093 | 095 | 097 | 099 | 100 | 102 | 104 | 106 | 108 | 110 |
| 59 | 077 | 079 | 080 | 082 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 096 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 110 |
| 60 | 077 | 079 | 080 | 082 | 084 | 085 | 087 | 089 | 090 | 092 | 094 | 096 | 098 | 099 | 101 | 103 | 105 | 107 | 109 | 111 |
| 61 | 078 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 093 | 095 | 097 | 098 | 100 | 101 | 104 | 106 | 107 | 109 | 111 |
| 62 | 078 | 080 | 081 | 083 | 084 | 086 | 088 | 090 | 091 | 093 | 095 | 097 | 099 | 100 | 102 | 104 | 106 | 108 | 110 | 112 |
| 63 | 078 | 080 | 081 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 096 | 097 | 099 | 101 | 102 | 104 | 106 | 108 | 110 | 112 |
| 64 | 079 | 080 | 082 | 083 | 085 | 087 | 089 | 090 | 092 | 094 | 096 | 098 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 |
| 65 | 079 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 093 | 095 | 096 | 098 | 100 | 101 | 103 | 105 | 107 | 109 | 111 | 113 |
| 66 | 079 | 081 | 082 | 084 | 086 | 088 | 089 | 091 | 093 | 095 | 097 | 099 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 |
| 67 | 080 | 081 | 083 | 084 | 086 | 088 | 090 | 092 | 094 | 095 | 097 | 099 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 |
| 68 | 080 | 082 | 083 | 085 | 087 | 088 | 090 | 092 | 094 | 096 | 098 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 |
| 69 | 080 | 082 | 084 | 085 | 087 | 089 | 091 | 093 | 094 | 096 | 098 | 100 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 116 |
| 70 | 081 | 082 | 084 | 085 | 087 | 089 | 091 | 093 | 095 | 097 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 |
| 71 | 081 | 083 | 084 | 086 | 088 | 090 | 091 | 093 | 095 | 097 | 099 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 117 |
| 72 | 081 | 083 | 085 | 086 | 088 | 090 | 092 | 094 | 095 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 118 |
| 73 | 082 | 083 | 085 | 087 | 089 | 090 | 092 | 094 | 096 | 098 | 100 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 116 | 118 |
| 74 | 082 | 084 | 085 | 087 | 089 | 091 | 093 | 094 | 096 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 119 |



accurately determined. The net weight of the liquid sample is the gross weight minus the tare weight. The density of the sample, in pounds per gallon, is determined by dividing the net weight by the volume of the sample in the bottle. The results obtained by this method are "apparent" unless corrected for air buoyancy.

**3056** The Westphal balance is an instrument designed for the measurement of density or specific gravity by means of the hydrostatic weighing method. It consists of a sensitive analytical balance for determining the buoyant effect of the liquid being tested upon a totally immersed plummet of a predetermined volume. The result is "apparent" specific gravity unless corrected for the buoyancy of the air, or unless the instrument is calibrated to compensate for an average air density to give "true" specific gravity. The Westphal balance should be checked periodically against a laboratory standard to assure that no damage has occurred to the balance knife edges and mechanism.

## Calculation of Weight per Unit Volume

### Open Provers

**3057** In the case of proving into an *open* gravimetric tank, the "apparent" weight of the test draft is read from the scale since the quantity weighed is affected by air buoyancy. The ASTM D 1250 tables give the "apparent" weight of petroleum liquids corresponding to "true" API or specific gravity. The weight per unit volume ($W_{UV}$), as used in the calculation of the volume measured in the prover, is read directly from these tables.

### Closed Provers

**3058** In the case of proving into a *closed* gravimetric tank, the "true" weight of the test draft is the difference between the indicated gross and tare weights, inasmuch as the air buoyancy effects on the prover and liquid at the start and end of the proof run are equal. Because the ASTM D 1250 tables show the "apparent" weight of liquid, it is necessary to correct "apparent" weight to "true" weight by adding the effect of air buoyancy to the published "apparent" weight. The weight per unit volume ($W_{UV}$), to be used in the calculation of the volume measured in the prover, is obtained as follows:

$W_{UV}$ = apparent weight per unit volume, from ASTM D 1250 tables + air buoyancy per unit volume

The method of determining the "air buoyancy per unit volume" is discussed in Par. 3059 through Par. 3060.

## Air Buoyancy Determination

**3059** The air buoyancy correction applied to any "apparent" weight to convert it to "true" weight is calculated by multiplying the air density by the difference between the volume of the object weighed and the volume of the weights required to balance it on an even arm balance. The buoyancy correction is added to the "apparent" weight of the liquid to obtain the "true" weight of the liquid.

Exact formulas for this purpose are cumbersome to use, and it is not always convenient to find the volume of the scale weights. However, it can be shown that, for practical field purposes, the buoyancy correction may be simply expressed as follows:

$$B = (0.9)(d_a)(V)$$

*Where:*

B = air buoyancy, in pounds per cubic foot.
$d_a$ = air density, in pounds per cubic foot.
V = volume of liquid at "apparent" weight, in cubic feet.

Therefore, the buoyancy correction per gallon becomes

$$B\ (\text{gallon}) = \frac{(0.9)\ (d_a)}{7.4805} = (0.12030)\,(d_a)$$

and the correction per barrel becomes

$$B\ (\text{barrel}) = (0.9)\,(d_a)\,(5.6146) = (5.05314)\,(d_a)$$

In computing meter performance, the maximum expected error arising through the use of this formula will not exceed plus or minus 0.005 per cent.

In using the gravimetric method of proving into a closed prover, a table of "true" weights of the liquid being metered may be useful if an average or constant air buoyancy correction is acceptable in the measurement procedure.

**3060** To determine the buoyant effect of air, it is necessary to know the air density. For the most precise possible determination of air density at the time and place of the test, a sling psychrometer shall be used in the determination of dry- and wet-bulb temperatures of the air; and an acceptable barometer, corrected for local elevation, shall be used for measurement of atmospheric pressure at the time of the test. The air density may then be determined by the following equation:

$$d_a = \frac{p_a - 0.38p_v}{0.754T_a}$$

*Where:*

$d_a$ = density of atmospheric air, in pounds per cubic foot.
$T_a$ = absolute temperature of atmospheric air, in degrees fahrenheit + 460.
$p_a$ = barometric pressure, in inches of mercury at 32 F.
$p_v$ = partial vapor pressure of water in atmosphere, in inches of mercury

$$= p_g - \frac{p_a\,(t_a - t_w)}{2{,}800 - 1.3t_w}.$$

$p_g$ = saturated water vapor pressure at wet-bulb temperature, in inches of mercury (from steam tables corresponding to $t_w$).
$t_a$ = dry-bulb temperature, in degrees fahrenheit.
$t_w$ = wet-bulb temperature, in degrees fahrenheit.

Compressibility factors are shown in Fig. 33 and Table II, Appendix B.

### Change in Volume of Test Liquid with Change in Temperature

**3047** The correction factor ($C_{tl}$) for the change in volume of test liquid with change in temperature is determined from *ASTM-IP Petroleum Measurement Tables* (ASTM designation: D 1250; IP designation: 200). These volume correction factors for liquids having a vapor pressure above atmospheric include a pressure correction factor for the change in vapor pressure which occurs with a change in temperature. This must be considered when calculating true volume at reference conditions.

## DETERMINATION OF TRUE VOLUME MEASURED BY GRAVIMETRIC PROVER

**3048** In the gravimetric methods of proving, the API or specific gravity of the test liquid must be accurately determined in order to calculate the volume corresponding to the net weight of the liquid metered into the prover. The volume determined by the gravimetric method will be for the reference pressure and temperature at which the API or specific gravity is determined. In this method of proving, the effect of the buoyancy of air is also an important consideration.

**3049** The true volume measured in an open or closed gravimetric prover may be expressed in a formula as follows:

$$V_T\,60\,F = \frac{W_G + W_V - W_T}{W_{UV}\,60\,F}$$

*Where:*

$V_T\,60\,F$ = volume measured in prover at 60 F.
$W_G$ = gross weight of the prover and test liquid, in pounds.
$W_V$ = weight of air, gas, or vapor displaced from the prover, in pounds.
$W_T$ = tare weight of the prover and residual test liquid, in pounds.
$W_{UV}\,60\,F$ = weight per unit volume of the test liquid at 60 F, corrected for buoyancy of air if necessary, in pounds.

The volume measured in the prover may be calculated at any temperature, providing the weight per unit volume is at the same reference temperature.

### Weight of Vapor

**3050** In gravimetric proving, it may be necessary to account for the weight of any air or vapor ($W_V$) displaced from the prover during filling. Proper accounting for such air or vapor transfer requires accurate analysis of the vapor to determine its physical properties.

### Weight per Unit Volume

**3051** The weight per unit volume ($W_{UV}$) is determined from applicable ASTM or NGAA tables by using the API or specific gravity of a representative sample of the test liquid.

### Sampling Procedure

**3052** A sample which is representative of the metered liquid flowing to the weigh tank must be obtained ahead of the meter during each test run. This sample is to be used to determine the API or specific gravity of the liquid being metered. Details of the sampling procedure are outlined in API Standard 2500. The sampling procedure for liquefied petroleum gas shall be in accordance with *NGAA Publication 2140-57: Liquefied Petroleum Gas Specifications and Test Methods* or some other suitable method which is acceptable to the interested parties.

### API or Specific Gravity Determination

**3053** The hydrometer is the most frequently used instrument for the determination of API or specific gravity. The procedure for using the hydrometer should be in accordance with *ASTM Designation D 287-55: Standard Method of Test for API Gravity of Petroleum and Its Products* (*Hydrometer Method*). When the hydrometer is used to test LPG, the procedure should be in accordance with NGAA Publication 2140-57. Hydrometers manufactured in the United States are calibrated to indicate gravities corrected for the buoyant effect of air or true gravity.

**3054** The pycnometer or specific gravity bottle method of gravity determination may be used. Several common types of pycnometers are shown and described in *Instruments and Apparatus, Part 16: Density Determinations,* supplement to *ASME Power Test Codes.* In this method, care must be exercised in cleaning the pycnometer, avoiding air bubbles in the sample, and weighing. A pycnometer that eliminates the trouble with the air bubbles, and in which the volume of the sample is more easily and accurately determined, is shown and described in *ASTM Designation D 941-55: Standard Method of Test for Density and Specific Gravity of Liquids by Lipkin Bicapillary Pycnometer.* This method does not correct for the buoyant effect of air, and the results obtained are "apparent" values. In the case of high-vapor-pressure petroleum liquids, the pycnometer method of specific gravity determination shall be in accordance with NGAA Publication 2140-57 or some other suitable method which gives accuracy of measurement acceptable to the interested parties.

**3055** The "gallon bottle" method is a variation of the pycnometer. The tare weight of a closed bottle of any exact known capacity is accurately determined. The bottle is filled hydrostatically full with the known volume of the liquid sample, and the gross weight is



**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | API Gravity 60F/60F | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
| 75 | 082 | 084 | 086 | 088 | 089 | 091 | 093 | 095 | 097 | 099 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 115 | 117 | 120 |
| 76 | 083 | 084 | 086 | 088 | 090 | 092 | 093 | 095 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 118 | 120 |
| 77 | 083 | 085 | 087 | 088 | 090 | 092 | 094 | 096 | 098 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 114 | 116 | 118 | 121 |
| 78 | 084 | 085 | 087 | 089 | 091 | 092 | 094 | 096 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 119 | 121 |
| 79 | 084 | 086 | 087 | 089 | 091 | 093 | 095 | 097 | 099 | 100 | 102 | 104 | 106 | 108 | 111 | 113 | 115 | 117 | 120 | 122 |
| 80 | 085 | 086 | 088 | 090 | 091 | 093 | 095 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 118 | 120 | 123 |
| 81 | 085 | 087 | 088 | 090 | 092 | 094 | 096 | 097 | 099 | 101 | 103 | 105 | 107 | 110 | 112 | 114 | 116 | 119 | 121 | 123 |
| 82 | 085 | 087 | 089 | 091 | 092 | 094 | 096 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 117 | 119 | 121 | 124 |
| 83 | 086 | 088 | 089 | 091 | 093 | 095 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 120 | 122 | 124 |
| 84 | 086 | 088 | 090 | 092 | 093 | 095 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 118 | 120 | 123 | 125 |
| 85 | 087 | 089 | 090 | 092 | 094 | 096 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 119 | 121 | 123 | 126 |
| 86 | 087 | 089 | 091 | 093 | 095 | 097 | 098 | 100 | 102 | 104 | 106 | 108 | 111 | 113 | 114 | 117 | 119 | 122 | 124 | 127 |
| 87 | 088 | 090 | 091 | 093 | 095 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 118 | 120 | 122 | 125 | 127 |
| 88 | 088 | 090 | 092 | 094 | 096 | 098 | 099 | 101 | 103 | 105 | 107 | 110 | 112 | 114 | 116 | 118 | 120 | 123 | 125 | 128 |
| 89 | 089 | 091 | 092 | 094 | 096 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 119 | 121 | 124 | 126 | 129 |
| 90 | 089 | 091 | 093 | 095 | 097 | 099 | 101 | 103 | 105 | 106 | 109 | 111 | 113 | 115 | 117 | 120 | 122 | 124 | 127 | 130 |
| 91 | 090 | 092 | 094 | 096 | 098 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 114 | 115 | 118 | 120 | 123 | 125 | 128 | 131 |
| 92 | 090 | 092 | 094 | 096 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 121 | 123 | 126 | 129 | 131 |
| 93 | 091 | 093 | 095 | 097 | 099 | 100 | 102 | 104 | 106 | 109 | 111 | 113 | 115 | 117 | 119 | 122 | 124 | 127 | 130 | 132 |
| 94 | 092 | 094 | 096 | 098 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 120 | 122 | 125 | 128 | 130 | 133 |
| 95 | 092 | 094 | 096 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 121 | 123 | 126 | 128 | 131 | 134 |
| 96 | 093 | 095 | 097 | 099 | 100 | 102 | 104 | 106 | 108 | 110 | 113 | 114 | 117 | 119 | 121 | 124 | 126 | 129 | 132 | 134 |
| 97 | 094 | 096 | 098 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 122 | 125 | 127 | 130 | 133 | 135 |
| 98 | 094 | 096 | 098 | 100 | 102 | 103 | 105 | 108 | 110 | 112 | 114 | 116 | 118 | 120 | 123 | 126 | 128 | 131 | 133 | 136 |
| 99 | 095 | 097 | 099 | 100 | 102 | 104 | 106 | 108 | 110 | 113 | 114 | 116 | 119 | 121 | 124 | 126 | 129 | 132 | 134 | 137 |
| 100 | 095 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 120 | 122 | 125 | 127 | 130 | 132 | 135 | 138 |
| 101 | 096 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 120 | 123 | 126 | 128 | 131 | 133 | 136 | 139 |
| 102 | 097 | 099 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 121 | 124 | 126 | 129 | 132 | 134 | 137 | 140 |
| 103 | 098 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 122 | 125 | 127 | 130 | 133 | 135 | 138 | 141 |
| 104 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 120 | 123 | 126 | 128 | 131 | 133 | 136 | 139 | 142 |
| 105 | 099 | 101 | 102 | 104 | 106 | 108 | 111 | 113 | 115 | 117 | 119 | 121 | 124 | 127 | 129 | 132 | 134 | 137 | 140 | 143 |
| 106 | 099 | 101 | 103 | 105 | 107 | 109 | 112 | 114 | 116 | 117 | 120 | 122 | 125 | 128 | 130 | 133 | 135 | 138 | 141 | 144 |
| 107 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 121 | 123 | 126 | 129 | 131 | 134 | 136 | 139 | 142 | 145 |
| 108 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 122 | 124 | 127 | 130 | 132 | 135 | 137 | 140 | 143 | 146 |
| 109 | 101 | 103 | 105 | 107 | 110 | 112 | 114 | 116 | 118 | 120 | 123 | 125 | 128 | 131 | 133 | 136 | 138 | 141 | 144 | 147 |
| 110 | 102 | 104 | 106 | 108 | 111 | 113 | 115 | 117 | 119 | 121 | 124 | 126 | 129 | 132 | 134 | 137 | 139 | 142 | 145 | 148 |
| 111 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 122 | 125 | 127 | 130 | 133 | 135 | 138 | 140 | 143 | 146 | 149 |
| 112 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 121 | 123 | 126 | 128 | 131 | 134 | 136 | 139 | 142 | 144 | 147 | 150 |
| 113 | 104 | 106 | 109 | 111 | 113 | 115 | 117 | 119 | 122 | 124 | 127 | 130 | 132 | 135 | 137 | 140 | 143 | 146 | 149 | 151 |
| 114 | 105 | 107 | 110 | 112 | 114 | 116 | 118 | 120 | 123 | 125 | 128 | 131 | 133 | 136 | 138 | 141 | 144 | 147 | 150 | 152 |
| 115 | 106 | 108 | 111 | 112 | 115 | 117 | 119 | 121 | 124 | 126 | 129 | 132 | 134 | 137 | 139 | 142 | 145 | 148 | 151 | 153 |
| 116 | 107 | 109 | 112 | 114 | 115 | 118 | 120 | 123 | 125 | 128 | 130 | 133 | 135 | 138 | 140 | 143 | 146 | 149 | 152 | 154 |
| 117 | 108 | 110 | 112 | 114 | 116 | 119 | 121 | 124 | 126 | 129 | 131 | 134 | 137 | 139 | 142 | 144 | 147 | 150 | 153 | 156 |
| 118 | 109 | 111 | 113 | 115 | 117 | 120 | 122 | 125 | 127 | 130 | 133 | 135 | 138 | 140 | 143 | 145 | 148 | 151 | 154 | 157 |
| 119 | 110 | 112 | 114 | 116 | 118 | 121 | 123 | 126 | 129 | 131 | 134 | 136 | 139 | 141 | 144 | 147 | 150 | 153 | 156 | 158 |
| 120 | 111 | 113 | 115 | 118 | 120 | 122 | 125 | 127 | 130 | 132 | 135 | 137 | 140 | 142 | 145 | 148 | 151 | 154 | 157 | 160 |
| 121 | 112 | 114 | 116 | 119 | 121 | 123 | 126 | 129 | 131 | 134 | 136 | 138 | 141 | 144 | 146 | 150 | 153 | 156 | 158 | 161 |
| 122 | 113 | 115 | 117 | 120 | 122 | 125 | 127 | 130 | 133 | 135 | 138 | 139 | 143 | 145 | 148 | 151 | 154 | 157 | 159 | 162 |
| 123 | 114 | 116 | 119 | 121 | 124 | 126 | 129 | 131 | 134 | 137 | 139 | 141 | 144 | 146 | 149 | 152 | 155 | 158 | 161 | 164 |
| 124 | 115 | 117 | 120 | 122 | 125 | 128 | 130 | 133 | 136 | 138 | 141 | 143 | 145 | 148 | 151 | 154 | 157 | 159 | 162 | 165 |
| 125 | 116 | 119 | 121 | 124 | 127 | 129 | 132 | 134 | 137 | 140 | 142 | 145 | 147 | 150 | 153 | 156 | 159 | 161 | 164 | 168 |
| 126 | 118 | 120 | 123 | 125 | 128 | 131 | 133 | 136 | 139 | 141 | 144 | 146 | 149 | 152 | 155 | 158 | 161 | 163 | 166 | 170 |
| 127 | 119 | 122 | 124 | 127 | 130 | 132 | 135 | 138 | 140 | 143 | 145 | 148 | 151 | 154 | 157 | 160 | 163 | 165 | 168 | 172 |
| 128 | 120 | 123 | 126 | 128 | 131 | 134 | 137 | 140 | 142 | 145 | 147 | 150 | 153 | 156 | 159 | 162 | 164 | 167 | 170 | 174 |

**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | API Gravity 60F/60F | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
| 20 | 095 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 121 | 123 | 125 | 127 | 129 | 131 | 133 |
| 21 | 096 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 121 | 123 | 126 | 128 | 130 | 132 | 134 |
| 22 | 096 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 120 | 122 | 124 | 126 | 128 | 130 | 132 | 134 |
| 23 | 097 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 120 | 122 | 125 | 127 | 129 | 131 | 133 | 135 |
| 24 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 121 | 123 | 125 | 127 | 129 | 131 | 133 | 135 |
| 25 | 097 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 121 | 124 | 126 | 128 | 130 | 132 | 134 | 136 |
| 26 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 111 | 114 | 116 | 118 | 120 | 122 | 124 | 126 | 128 | 130 | 132 | 135 | 137 |
| 27 | 098 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 120 | 123 | 125 | 127 | 129 | 131 | 133 | 135 | 137 |
| 28 | 099 | 101 | 102 | 105 | 107 | 108 | 110 | 112 | 115 | 117 | 119 | 121 | 123 | 125 | 127 | 129 | 131 | 134 | 136 | 138 |
| 29 | 099 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 121 | 124 | 126 | 128 | 130 | 132 | 134 | 136 | 139 |
| 30 | 100 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 120 | 122 | 124 | 126 | 129 | 131 | 133 | 135 | 137 | 140 |
| 31 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 120 | 123 | 125 | 127 | 129 | 131 | 133 | 135 | 138 | 140 |
| 32 | 100 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 121 | 123 | 126 | 128 | 130 | 132 | 134 | 136 | 138 | 141 |
| 33 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 121 | 124 | 126 | 128 | 130 | 132 | 135 | 137 | 139 | 141 |
| 34 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 122 | 124 | 127 | 129 | 131 | 133 | 135 | 137 | 140 | 142 |
| 35 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 120 | 123 | 125 | 127 | 129 | 131 | 134 | 136 | 138 | 140 | 143 |
| 36 | 102 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 121 | 123 | 126 | 128 | 130 | 132 | 134 | 136 | 139 | 141 | 143 |
| 37 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 121 | 124 | 126 | 128 | 130 | 133 | 135 | 137 | 139 | 141 | 144 |
| 38 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 122 | 124 | 127 | 129 | 131 | 133 | 135 | 138 | 140 | 142 | 144 |
| 39 | 104 | 106 | 108 | 109 | 111 | 113 | 116 | 118 | 120 | 122 | 125 | 127 | 129 | 132 | 134 | 136 | 138 | 141 | 143 | 145 |
| 40 | 104 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 121 | 123 | 125 | 128 | 130 | 132 | 135 | 137 | 139 | 141 | 144 | 146 |
| 41 | 104 | 106 | 108 | 110 | 112 | 114 | 117 | 119 | 121 | 124 | 126 | 129 | 131 | 133 | 135 | 137 | 140 | 142 | 144 | 146 |
| 42 | 105 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 122 | 124 | 127 | 129 | 131 | 134 | 136 | 138 | 140 | 143 | 145 | 147 |
| 43 | 105 | 107 | 109 | 111 | 113 | 115 | 118 | 120 | 122 | 125 | 127 | 130 | 132 | 134 | 136 | 139 | 141 | 143 | 145 | 148 |
| 44 | 106 | 108 | 110 | 112 | 114 | 116 | 118 | 120 | 123 | 125 | 128 | 131 | 133 | 135 | 137 | 139 | 142 | 144 | 146 | 148 |
| 45 | 106 | 108 | 110 | 112 | 114 | 116 | 119 | 121 | 123 | 126 | 129 | 132 | 133 | 136 | 138 | 140 | 142 | 144 | 146 | 149 |
| 46 | 107 | 109 | 111 | 113 | 115 | 117 | 119 | 122 | 124 | 127 | 129 | 132 | 134 | 136 | 138 | 141 | 143 | 145 | 147 | 150 |
| 47 | 107 | 109 | 111 | 113 | 115 | 118 | 120 | 122 | 125 | 127 | 130 | 132 | 135 | 137 | 139 | 141 | 143 | 145 | 148 | 151 |
| 48 | 108 | 109 | 111 | 113 | 116 | 118 | 120 | 123 | 125 | 128 | 131 | 132 | 135 | 137 | 139 | 142 | 144 | 146 | 148 | 152 |
| 49 | 108 | 110 | 112 | 114 | 116 | 119 | 121 | 123 | 126 | 128 | 131 | 134 | 136 | 138 | 140 | 143 | 145 | 147 | 149 | 152 |
| 50 | 108 | 110 | 112 | 114 | 117 | 119 | 122 | 124 | 126 | 129 | 132 | 134 | 136 | 138 | 141 | 143 | 145 | 147 | 150 | 153 |
| 51 | 109 | 111 | 113 | 115 | 117 | 120 | 122 | 124 | 127 | 130 | 132 | 135 | 137 | 139 | 142 | 144 | 146 | 148 | 151 | 154 |
| 52 | 109 | 111 | 113 | 115 | 118 | 120 | 123 | 125 | 127 | 130 | 133 | 136 | 138 | 140 | 142 | 144 | 146 | 149 | 152 | 155 |
| 53 | 110 | 112 | 114 | 116 | 118 | 121 | 123 | 126 | 128 | 131 | 134 | 136 | 138 | 140 | 143 | 145 | 147 | 149 | 152 | 156 |
| 54 | 110 | 112 | 114 | 117 | 119 | 121 | 124 | 126 | 129 | 131 | 134 | 137 | 139 | 141 | 143 | 145 | 147 | 150 | 153 | 156 |
| 55 | 111 | 113 | 115 | 117 | 120 | 122 | 124 | 127 | 130 | 132 | 135 | 138 | 139 | 142 | 144 | 146 | 148 | 151 | 154 | 157 |
| 56 | 111 | 113 | 115 | 118 | 120 | 123 | 125 | 127 | 130 | 133 | 135 | 138 | 140 | 142 | 144 | 146 | 149 | 152 | 155 | 158 |
| 57 | 112 | 113 | 116 | 118 | 121 | 123 | 125 | 128 | 131 | 133 | 136 | 139 | 141 | 143 | 145 | 147 | 149 | 153 | 156 | 159 |
| 58 | 112 | 114 | 116 | 119 | 121 | 124 | 126 | 129 | 131 | 134 | 136 | 139 | 141 | 143 | 145 | 147 | 150 | 154 | 157 | 160 |
| 59 | 112 | 115 | 117 | 119 | 122 | 124 | 127 | 129 | 132 | 134 | 137 | 140 | 142 | 144 | 146 | 148 | 151 | 155 | 158 | 161 |
| 60 | 113 | 115 | 118 | 120 | 123 | 125 | 127 | 130 | 132 | 135 | 138 | 141 | 143 | 145 | 147 | 149 | 152 | 155 | 158 | 162 |
| 61 | 113 | 116 | 118 | 121 | 123 | 125 | 128 | 130 | 133 | 136 | 138 | 141 | 143 | 145 | 147 | 150 | 153 | 156 | 159 | 163 |
| 62 | 114 | 116 | 119 | 121 | 123 | 126 | 128 | 131 | 134 | 136 | 139 | 142 | 144 | 146 | 148 | 151 | 154 | 157 | 160 | 164 |
| 63 | 114 | 117 | 119 | 122 | 124 | 126 | 129 | 132 | 134 | 137 | 139 | 142 | 144 | 146 | 149 | 152 | 155 | 158 | 161 | 165 |
| 64 | 115 | 117 | 120 | 122 | 125 | 127 | 130 | 132 | 135 | 137 | 140 | 142 | 144 | 147 | 149 | 153 | 156 | 159 | 162 | 165 |
| 65 | 116 | 118 | 120 | 123 | 125 | 128 | 130 | 133 | 135 | 138 | 141 | 143 | 145 | 147 | 150 | 154 | 157 | 160 | 163 | 167 |
| 66 | 116 | 119 | 121 | 123 | 126 | 128 | 131 | 133 | 136 | 139 | 142 | 144 | 146 | 148 | 151 | 155 | 158 | 161 | 164 | 168 |
| 67 | 117 | 119 | 122 | 124 | 126 | 129 | 132 | 134 | 137 | 139 | 142 | 144 | 146 | 149 | 152 | 156 | 158 | 161 | 165 | 169 |
| 68 | 118 | 120 | 122 | 124 | 127 | 130 | 132 | 135 | 137 | 140 | 143 | 145 | 147 | 150 | 153 | 156 | 159 | 162 | 166 | 170 |
| 69 | 118 | 121 | 123 | 125 | 127 | 130 | 133 | 135 | 138 | 141 | 144 | 146 | 148 | 151 | 154 | 157 | 160 | 163 | 167 | 170 |
| 70 | 119 | 121 | 123 | 126 | 128 | 131 | 133 | 136 | 139 | 142 | 145 | 147 | 149 | 152 | 155 | 158 | 161 | 164 | 168 | 171 |
| 71 | 119 | 122 | 124 | 126 | 129 | 131 | 134 | 137 | 139 | 142 | 145 | 147 | 149 | 153 | 156 | 159 | 162 | 165 | 169 | 172 |
| 72 | 120 | 122 | 124 | 127 | 130 | 132 | 135 | 137 | 140 | 143 | 146 | 148 | 150 | 153 | 157 | 159 | 162 | 166 | 169 | 173 |
| 73 | 121 | 123 | 125 | 127 | 130 | 133 | 135 | 138 | 141 | 144 | 146 | 149 | 151 | 154 | 157 | 160 | 163 | 167 | 170 | 174 |
| 74 | 121 | 123 | 125 | 128 | 131 | 133 | 136 | 139 | 142 | 144 | 147 | 150 | 152 | 155 | 158 | 161 | 164 | 168 | 171 | 175 |



*Where:*

$V_t60$ = net prover tank volume at 60 F and equilibrium pressure.

$V_e$ = volume at equilibrium pressure for observed temperature $T$ (see Par. 3046).

$C_{ps}$ = correction factor for change in prover tank shell dimensions with change in pressure (see Par. 2116 through Par. 2122).

$C_{ts}$ = correction factor for change in prover tank shell dimensions with change in temperature (see Par. 3045).

$C_{tl}$ = correction factor for change in volume of test liquid for change in temperature (see Par. 3047).

## Change in Prover Tank Shell Dimensions with Change in Temperature

**3045** The correction factor ($C_{ts}$) for the change in tank shell dimensions with change in temperature is determined as follows:

$$C_{ts} = 1 + (T_p - 60)(E_m)$$

*Where:*

$T_p$ = temperature of the tank shell, usually assumed to be the same as the average liquid temperature in the prover tank, in degrees fahrenheit.

$E_m$ = coefficient of cubical expansion per degree fahrenheit of the material of which the tank is made.

Thus $C_{ts}$ will be greater than 1.0000 when $T_p$ is greater than 60 F and less than 1.0000 when $T_p$ is less than 60 F.

The coefficient of cubical expansion of a mild steel tank, as recommended in *ASA Standard B31.3-1959: Petroleum Refinery Piping,* is 0.0000182 per degree fahrenheit. Based on this coefficient, the following table of $C_{ts}$ values shall be used for various temperatures of liquid in mild steel prover tanks:

## Change in Volume of Test Liquid with Change in Pressure

**3046** The formula for the liquid volume at a pressure higher than equilibrium pressure and at any temperature $T$ is as follows:

$$V_h = V_e[1 - (P_h - P_e)F]$$

*Where:*

$V_e$ = volume at equilibrium pressure and $T$.

$P_e$ = equilibrium pressure at $T$ if above atmospheric pressure, in pounds per square inch gage. (If equilibrium pressure is atmospheric pressure or below, use zero gage pressure.)

$V_h$ = volume at any specific pressure above equilibrium pressure and at $T$. (May be prover pressure, meter pressure, or any other desired pressure.)

$P_h$ = pressure at $V_h$ and $T$, in pounds per square inch gage.

$F$ = compressibility factor per pound per square inch gage for the liquid involved at temperature $T$ (from Fig. 33 or Table II).

For converting a known volume at a higher pressure to the volume at equilibrium pressure, the following form of the formula will be more convenient:

$$V_e = \frac{V_h}{1 - (P_h - P_e)F}$$

To convert a volume from one known pressure $P_h$ to the volume at a lower pressure $P_l$, when both volumes are above equilibrium pressure, the following formula is used:

$$V_l = V_h \frac{1 - (P_l - P_e)F}{1 - (P_h - P_e)F}$$

*Where:*

$P_l$ = pressure at which the new volume is desired.

$V_l$ = volume at the lower pressure $P_l$.

| Temperature (Degrees Fahrenheit) | 0 | 2 | 4 | 6 | 8 |
|---|---|---|---|---|---|
| 20 | 0.999272 | 0.999308 | 0.999345 | 0.999381 | 0.999418 |
| 30 | 0.999454 | 0.999490 | 0.999527 | 0.999563 | 0.999600 |
| 40 | 0.999636 | 0.999672 | 0.999709 | 0.999745 | 0.999782 |
| 50 | 0.999818 | 0.999854 | 0.999891 | 0.999927 | 0.999964 |
| 60 | 1.000000 | 1.000036 | 1.000073 | 1.000109 | 1.000146 |
| 70 | 1.000182 | 1.000218 | 1.000255 | 1.000291 | 1.000328 |
| 80 | 1.000364 | 1.000400 | 1.000437 | 1.000473 | 1.000510 |
| 90 | 1.000546 | 1.000582 | 1.000619 | 1.000655 | 1.000692 |
| 100 | 1.000728 | 1.000764 | 1.000801 | 1.000837 | 1.000874 |
| 110 | 1.000910 | 1.000946 | 1.000983 | 1.001019 | 1.001056 |
| 120 | 1.001092 | 1.001128 | 1.001165 | 1.001201 | 1.001238 |

When provers made of materials other than mild steel are used, the proper coefficients of expansion of the material shall be agreed upon by all parties involved and these coefficients shall be used.

Or, solving for $V_h$,

$$V_h = V_l \frac{1 - (P_h - P_e)F}{1 - (P_l - P_e)F}$$

**3037** The master meter is connected in series with the meter to be proved, and the two meters are operated at the desired flow rate for a sufficient period of time to purge the system and equalize pressure and temperature. Either the standing start-and-stop or the running start-and-stop method may be employed. Flow through the meters is stopped, and the opening readings are recorded. To start the proof run, flow is started through the two meters simultaneously by opening a valve on the downstream side of the meters to give the desired flow rate. When sufficient time has elapsed to provide a satisfactory meter proof, the two meters are stopped by closing the same valve. A minimum test run of 5 min is recommended. Closing meter readings and necessary pressures and temperatures should be observed and recorded.

## OPEN GRAVIMETRIC PROVERS (See Fig. 19)

**3038** A preliminary run is made, and the prover is filled with the test liquid from the meter to be proved in order to purge the system of air or vapor and to equalize temperatures. When the prover is full, all valves and connections should be checked for leakage. The scale and allied equipment should be checked to assure proper operation. The prover is then pumped out or drained, leaving sufficient liquid to fill the inlet line.

To start the proof run, the initial meter reading is recorded; then the scale is read to the nearest one-half increment of scale division, which is recorded as the tare weight. Flow is then started through the meter into the prover at the desired flow rate. Necessary pressures and temperatures at the meter are recorded while the prover is filling, and a representative sample of the metered liquid is obtained ahead of the meter as described in Par. 3052. When the liquid level in the prover approaches capacity, the flow is stopped and the final meter reading and the weight (gross) on the scale are noted and recorded. The net weight of the liquid in the prover is then obtained by subtracting the tare weight from the gross weight. The volume corresponding to this net weight is calculated from the density of the metered liquid and compared with the metered volume to determine meter performance. The net weight of the liquid in the prover can also be compared with the calculated net weight corresponding to the volume registered on the meter.

## CLOSED GRAVIMETRIC PROVERS (See Fig. 20)

**3039** The basic procedures outlined for the open gravimetric prover in Par. 3038 will apply. Actual operation of the prover will depend upon the method used for controlling the vaporization of the test liquid. The gas displacement, vapor displacement, and vapor-condensing methods outlined for closed volumetric provers are acceptable methods for controlling vaporization in closed gravimetric provers.

### Gas Displacement Method

**3040** The pressure in a closed gas displacement prover shall be maintained sufficiently above the vapor pressure of the test liquid to prevent vaporization; it shall be not less than the vapor pressure of the test liquid and preferably about 10 per cent higher.

**3041** The gas displacement method of proving into a closed gravimetric prover consists of applying vapor or gas pressure to the prover, raising the pressure to a desired point. A back-pressure gas regulator should be used to maintain the desired pressure in the prover during the proof run. When liquid is withdrawn from the prover, the tank should be filled with gas under pressure. Proper accounting must be made for the weight of any vapor displaced from the prover during filling.

### Vapor Displacement Method

**3042** The vapor displacement method of proving into a closed gravimetric prover is used on meters delivering from a supply vessel; it utilizes a pressure-equalizing line between the prover and the supply vessel. This line allows free passage of the vapors of the test liquid between the prover and the supply vessel, equalizing pressures at all times. Proper accounting must be made for the weight of the vapors displaced from the prover during filling.

### Vapor-Condensing Method

**3043** The vapor-condensing method of proving into a closed gravimetric prover consists of filling the prover without the use of a vapor return line, condensing the vapor to liquid as the tank fills. No vapor is vented in proving with this method.

## DETERMINATION OF TRUE VOLUME MEASURED IN VOLUMETRIC PROVERS

**3044** The volumetric methods of proving meters require that certain corrections be applied to the liquid volume measured in the prover in order to determine the true volume. These corrections include allowances for the following:

*a.* Change in tank shell dimensions with change in pressure.

*b.* Change in tank shell dimensions with change in temperature.

*c.* Change in volume of test liquid with change in pressure.

*d.* Change in volume of test liquid with change in temperature.

These factors may be expressed as follows:

$$V_t60 = (V_e)(C_{ps})(C_{ts})(C_{tl})$$



**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | API Gravity 60F/60F | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
| 75 | 122 | 124 | 126 | 129 | 132 | 134 | 137 | 140 | 142 | 145 | 148 | 151 | 153 | 156 | 159 | 162 | 165 | 169 | 172 | 176 |
| 76 | 122 | 124 | 127 | 130 | 132 | 135 | 137 | 140 | 143 | 146 | 149 | 151 | 154 | 157 | 160 | 163 | 166 | 170 | 173 | 177 |
| 77 | 123 | 125 | 127 | 130 | 133 | 135 | 138 | 141 | 144 | 146 | 149 | 152 | 155 | 158 | 161 | 164 | 167 | 171 | 174 | 178 |
| 78 | 123 | 126 | 128 | 131 | 134 | 136 | 139 | 142 | 145 | 147 | 150 | 153 | 156 | 159 | 162 | 165 | 168 | 172 | 175 | 179 |
| 79 | 124 | 126 | 129 | 132 | 134 | 137 | 140 | 143 | 145 | 148 | 151 | 154 | 157 | 160 | 163 | 166 | 169 | 173 | 176 | 180 |
| 80 | 125 | 127 | 130 | 133 | 135 | 138 | 141 | 143 | 146 | 149 | 152 | 155 | 158 | 161 | 164 | 167 | 170 | 174 | 177 | 181 |
| 81 | 125 | 128 | 131 | 133 | 136 | 138 | 141 | 144 | 147 | 150 | 153 | 156 | 159 | 162 | 165 | 168 | 171 | 175 | 178 | 182 |
| 82 | 126 | 129 | 131 | 134 | 136 | 139 | 142 | 145 | 148 | 151 | 154 | 157 | 160 | 163 | 166 | 169 | 172 | 176 | 179 | 183 |
| 83 | 127 | 130 | 132 | 135 | 137 | 140 | 143 | 146 | 149 | 151 | 155 | 158 | 160 | 164 | 167 | 170 | 173 | 177 | 180 | 185 |
| 84 | 128 | 130 | 133 | 135 | 138 | 141 | 144 | 146 | 149 | 152 | 156 | 159 | 161 | 165 | 168 | 171 | 174 | 178 | 182 | 186 |
| 85 | 128 | 131 | 133 | 136 | 139 | 142 | 145 | 147 | 150 | 153 | 157 | 159 | 162 | 166 | 169 | 172 | 175 | 179 | 183 | 187 |
| 86 | 129 | 132 | 134 | 137 | 140 | 143 | 145 | 148 | 151 | 154 | 158 | 160 | 163 | 167 | 170 | 173 | 176 | 180 | 184 | 188 |
| 87 | 130 | 132 | 135 | 138 | 141 | 144 | 146 | 149 | 152 | 155 | 159 | 161 | 164 | 168 | 171 | 174 | 177 | 181 | 185 | 189 |
| 88 | 131 | 133 | 136 | 138 | 141 | 144 | 147 | 150 | 153 | 156 | 160 | 162 | 165 | 168 | 172 | 175 | 178 | 182 | 185 | 190 |
| 89 | 131 | 134 | 137 | 139 | 142 | 145 | 148 | 151 | 154 | 157 | 160 | 163 | 166 | 169 | 173 | 176 | 179 | 183 | 187 | 191 |
| 90 | 132 | 135 | 137 | 140 | 143 | 146 | 149 | 152 | 155 | 158 | 161 | 164 | 167 | 170 | 173 | 177 | 181 | 184 | 188 | 193 |
| 91 | 133 | 135 | 138 | 141 | 144 | 147 | 150 | 153 | 156 | 159 | 162 | 165 | 168 | 172 | 174 | 178 | 182 | 185 | 189 | 194 |
| 92 | 134 | 136 | 139 | 142 | 145 | 148 | 151 | 154 | 157 | 160 | 163 | 166 | 169 | 172 | 175 | 179 | 183 | 187 | 190 | 195 |
| 93 | 134 | 137 | 140 | 143 | 146 | 149 | 152 | 155 | 158 | 161 | 164 | 167 | 170 | 173 | 177 | 180 | 184 | 188 | 192 | 197 |
| 94 | 135 | 138 | 141 | 144 | 147 | 150 | 153 | 156 | 159 | 162 | 165 | 168 | 171 | 174 | 178 | 181 | 185 | 189 | 193 | 198 |
| 95 | 136 | 139 | 142 | 145 | 148 | 151 | 154 | 157 | 160 | 163 | 166 | 169 | 172 | 175 | 179 | 183 | 186 | 190 | 195 | 199 |
| 96 | 137 | 140 | 143 | 146 | 149 | 152 | 155 | 158 | 161 | 164 | 167 | 170 | 173 | 177 | 180 | 184 | 187 | 191 | 196 | 201 |
| 97 | 138 | 141 | 144 | 147 | 150 | 153 | 156 | 159 | 162 | 165 | 168 | 171 | 174 | 178 | 181 | 185 | 188 | 192 | 197 | 202 |
| 98 | 139 | 141 | 145 | 148 | 151 | 154 | 157 | 160 | 163 | 166 | 169 | 172 | 175 | 179 | 182 | 186 | 189 | 194 | 198 | 203 |
| 99 | 140 | 142 | 146 | 149 | 152 | 155 | 158 | 161 | 164 | 167 | 170 | 173 | 177 | 180 | 184 | 187 | 190 | 195 | 200 | 205 |
| 100 | 141 | 144 | 147 | 150 | 153 | 156 | 159 | 162 | 165 | 168 | 171 | 174 | 178 | 181 | 185 | 188 | 192 | 197 | 201 | 206 |
| 101 | 142 | 145 | 148 | 151 | 154 | 157 | 160 | 163 | 166 | 169 | 172 | 175 | 179 | 183 | 186 | 189 | 193 | 198 | 203 | 207 |
| 102 | 143 | 146 | 149 | 152 | 155 | 158 | 161 | 164 | 167 | 170 | 173 | 176 | 180 | 184 | 187 | 190 | 195 | 199 | 204 | 208 |
| 103 | 144 | 147 | 150 | 153 | 156 | 159 | 162 | 165 | 168 | 171 | 175 | 178 | 181 | 185 | 188 | 191 | 196 | 201 | 205 | 210 |
| 104 | 145 | 148 | 151 | 154 | 157 | 160 | 163 | 166 | 169 | 172 | 176 | 179 | 183 | 186 | 189 | 193 | 198 | 202 | 207 | 212 |
| 105 | 146 | 149 | 152 | 155 | 158 | 161 | 164 | 167 | 170 | 173 | 177 | 180 | 184 | 187 | 190 | 194 | 199 | 204 | 208 | 213 |
| 106 | 147 | 150 | 153 | 156 | 159 | 162 | 165 | 168 | 171 | 175 | 178 | 181 | 185 | 188 | 191 | 196 | 201 | 205 | 210 | 214 |
| 107 | 148 | 151 | 154 | 157 | 160 | 163 | 166 | 169 | 172 | 176 | 179 | 182 | 186 | 189 | 193 | 198 | 202 | 207 | 211 | 216 |
| 108 | 149 | 152 | 155 | 158 | 161 | 164 | 167 | 170 | 174 | 177 | 180 | 183 | 187 | 190 | 195 | 199 | 204 | 208 | 213 | 217 |
| 109 | 150 | 153 | 156 | 159 | 162 | 165 | 168 | 172 | 175 | 178 | 181 | 184 | 188 | 192 | 196 | 201 | 205 | 210 | 214 | 219 |
| 110 | 151 | 154 | 157 | 160 | 163 | 166 | 170 | 173 | 176 | 180 | 183 | 186 | 189 | 193 | 198 | 202 | 207 | 211 | 216 | 221 |
| 111 | 152 | 155 | 158 | 161 | 164 | 168 | 171 | 174 | 177 | 181 | 184 | 187 | 190 | 195 | 200 | 204 | 209 | 213 | 217 | 223 |
| 112 | 153 | 156 | 159 | 162 | 165 | 169 | 172 | 175 | 179 | 182 | 185 | 188 | 192 | 197 | 201 | 206 | 210 | 215 | 219 | 225 |
| 113 | 154 | 157 | 160 | 164 | 167 | 170 | 173 | 177 | 180 | 183 | 186 | 189 | 193 | 198 | 203 | 207 | 212 | 216 | 221 | 227 |
| 114 | 155 | 159 | 162 | 165 | 168 | 171 | 175 | 178 | 181 | 184 | 187 | 191 | 195 | 200 | 204 | 209 | 213 | 218 | 223 | 229 |
| 115 | 157 | 160 | 163 | 166 | 170 | 173 | 176 | 179 | 183 | 186 | 189 | 193 | 197 | 202 | 206 | 211 | 215 | 220 | 225 | 232 |
| 116 | 158 | 161 | 164 | 168 | 171 | 174 | 178 | 181 | 184 | 187 | 190 | 194 | 198 | 203 | 208 | 212 | 217 | 222 | 227 | 232 |
| 117 | 159 | 163 | 166 | 169 | 172 | 176 | 179 | 182 | 185 | 188 | 192 | 196 | 200 | 205 | 210 | 214 | 218 | 224 | 228 | 233 |
| 118 | 161 | 164 | 167 | 171 | 174 | 177 | 180 | 184 | 187 | 190 | 194 | 198 | 202 | 207 | 211 | 216 | 221 | 226 | 231 | 235 |
| 119 | 162 | 165 | 169 | 172 | 175 | 179 | 182 | 185 | 188 | 192 | 196 | 199 | 204 | 209 | 213 | 218 | 222 | 227 | 232 | 237 |
| 120 | 164 | 167 | 170 | 174 | 177 | 180 | 183 | 187 | 190 | 194 | 198 | 202 | 206 | 210 | 215 | 219 | 224 | 229 | 234 | 241 |
| 121 | 165 | 169 | 172 | 175 | 178 | 182 | 185 | 188 | 192 | 196 | 200 | 204 | 208 | 212 | 217 | 221 | 226 | 231 | 234 | 241 |
| 122 | 167 | 170 | 173 | 177 | 180 | 183 | 187 | 190 | 194 | 198 | 202 | 206 | 210 | 214 | 219 | 223 | 228 | 232 | 237 | 243 |
| 123 | 168 | 172 | 175 | 178 | 182 | 185 | 188 | 192 | 196 | 200 | 204 | 208 | 212 | 216 | 220 | 225 | 229 | 234 | 239 | 246 |
| 124 | 170 | 173 | 177 | 180 | 183 | 186 | 190 | 194 | 198 | 202 | 206 | 210 | 214 | 218 | 222 | 226 | 231 | 236 | 242 | 249 |
| 125 | 172 | 175 | 178 | 182 | 185 | 188 | 192 | 196 | 200 | 204 | 208 | 212 | 216 | 220 | 224 | 228 | 233 | 238 | 244 | 251 |
| 126 | 174 | 177 | 180 | 183 | 187 | 190 | 194 | 198 | 202 | 207 | 210 | 214 | 218 | 222 | 226 | 230 | 235 | 240 | 247 | 255 |
| 127 | 176 | 179 | 182 | 185 | 189 | 193 | 196 | 200 | 204 | 209 | 212 | 216 | 220 | 224 | 228 | 231 | 237 | 242 | 250 | 258 |
| 128 | 178 | 181 | 184 | 187 | 191 | 195 | 198 | 204 | 207 | 211 | 214 | 218 | 221 | 225 | 229 | 233 | 238 | 244 | 252 | 261 |

**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | Specific Gravity 60F/60F 0.500 | 0.501 | 0.502 | 0.503 | 0.504 | 0.505 | 0.506 | 0.507 | 0.508 | 0.509 | 0.510 | 0.511 | 0.512 | 0.513 | 0.514 | 0.515 | 0.516 | 0.517 | 0.518 | 0.519 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 356 | 353 | 350 | 346 | 342 | 339 | 335 | 332 | 328 | 325 | 322 | 319 | 316 | 313 | 310 | 306 | 303 | 300 | 296 | 293 |
| 21 | 358 | 355 | 351 | 348 | 344 | 340 | 337 | 334 | 330 | 326 | 323 | 320 | 317 | 314 | 311 | 308 | 304 | 301 | 298 | 295 |
| 22 | 360 | 356 | 352 | 349 | 345 | 342 | 338 | 335 | 331 | 328 | 325 | 322 | 318 | 316 | 312 | 309 | 306 | 302 | 299 | 296 |
| 23 | 362 | 358 | 354 | 350 | 347 | 344 | 340 | 337 | 333 | 330 | 326 | 323 | 320 | 317 | 314 | 311 | 308 | 304 | 301 | 298 |
| 24 | 364 | 360 | 356 | 352 | 349 | 345 | 342 | 338 | 335 | 331 | 328 | 325 | 321 | 318 | 315 | 312 | 309 | 306 | 302 | 300 |
| 25 | 366 | 362 | 358 | 354 | 350 | 347 | 343 | 340 | 336 | 333 | 330 | 326 | 323 | 320 | 317 | 314 | 311 | 308 | 304 | 301 |
| 26 | 367 | 364 | 360 | 356 | 352 | 349 | 345 | 342 | 338 | 335 | 332 | 328 | 325 | 321 | 318 | 315 | 312 | 309 | 306 | 302 |
| 27 | 369 | 366 | 362 | 358 | 354 | 350 | 347 | 343 | 340 | 336 | 333 | 330 | 326 | 323 | 320 | 317 | 313 | 311 | 307 | 304 |
| 28 | 371 | 367 | 363 | 360 | 356 | 352 | 349 | 345 | 342 | 338 | 335 | 332 | 328 | 324 | 321 | 318 | 315 | 312 | 309 | 306 |
| 29 | 373 | 368 | 365 | 362 | 358 | 354 | 350 | 347 | 343 | 340 | 336 | 333 | 330 | 326 | 323 | 320 | 317 | 314 | 311 | 308 |
| 30 | 375 | 371 | 367 | 363 | 360 | 356 | 352 | 349 | 345 | 342 | 338 | 335 | 332 | 328 | 324 | 322 | 318 | 315 | 312 | 309 |
| 31 | 377 | 373 | 369 | 365 | 362 | 358 | 354 | 350 | 347 | 343 | 340 | 336 | 333 | 330 | 326 | 323 | 320 | 316 | 313 | 311 |
| 32 | 380 | 375 | 371 | 367 | 363 | 360 | 356 | 352 | 349 | 345 | 342 | 338 | 335 | 332 | 328 | 325 | 322 | 318 | 315 | 312 |
| 33 | 382 | 377 | 373 | 369 | 365 | 362 | 358 | 354 | 350 | 347 | 344 | 340 | 336 | 333 | 330 | 326 | 323 | 320 | 317 | 313 |
| 34 | 384 | 379 | 375 | 371 | 367 | 363 | 360 | 356 | 352 | 349 | 345 | 342 | 338 | 335 | 332 | 328 | 324 | 322 | 318 | 315 |
| 35 | 386 | 381 | 377 | 373 | 369 | 365 | 362 | 358 | 354 | 350 | 347 | 344 | 340 | 336 | 333 | 330 | 326 | 323 | 320 | 316 |
| 36 | 387 | 383 | 379 | 375 | 371 | 367 | 364 | 360 | 356 | 352 | 349 | 346 | 342 | 338 | 335 | 332 | 328 | 325 | 322 | 318 |
| 37 | 389 | 385 | 381 | 377 | 373 | 369 | 365 | 362 | 358 | 354 | 350 | 347 | 344 | 340 | 336 | 333 | 330 | 326 | 323 | 320 |
| 38 | 391 | 387 | 383 | 379 | 375 | 371 | 367 | 364 | 360 | 356 | 352 | 349 | 346 | 342 | 338 | 335 | 331 | 328 | 325 | 322 |
| 39 | 393 | 389 | 385 | 381 | 377 | 373 | 369 | 366 | 362 | 358 | 354 | 351 | 348 | 344 | 340 | 336 | 333 | 330 | 326 | 323 |
| 40 | 396 | 391 | 387 | 383 | 379 | 375 | 371 | 367 | 364 | 360 | 356 | 352 | 349 | 346 | 342 | 338 | 335 | 331 | 328 | 325 |
| 41 | 398 | 393 | 389 | 385 | 381 | 377 | 373 | 369 | 366 | 362 | 358 | 354 | 351 | 347 | 344 | 340 | 336 | 333 | 330 | 326 |
| 42 | 400 | 395 | 391 | 387 | 383 | 379 | 375 | 371 | 368 | 364 | 360 | 356 | 353 | 349 | 346 | 342 | 338 | 335 | 332 | 328 |
| 43 | 402 | 397 | 393 | 389 | 385 | 381 | 377 | 373 | 370 | 366 | 362 | 358 | 354 | 351 | 348 | 344 | 340 | 337 | 333 | 330 |
| 44 | 404 | 400 | 395 | 391 | 387 | 383 | 379 | 375 | 372 | 368 | 364 | 360 | 356 | 352 | 349 | 346 | 342 | 338 | 335 | 332 |
| 45 | 406 | 402 | 397 | 393 | 389 | 385 | 381 | 377 | 374 | 370 | 366 | 362 | 358 | 355 | 351 | 348 | 344 | 340 | 337 | 334 |
| 46 | 408 | 404 | 399 | 395 | 391 | 387 | 383 | 379 | 376 | 372 | 368 | 364 | 360 | 357 | 353 | 350 | 346 | 342 | 339 | 335 |
| 47 | 410 | 406 | 402 | 397 | 393 | 389 | 385 | 381 | 377 | 374 | 370 | 366 | 362 | 359 | 355 | 351 | 348 | 344 | 340 | 337 |
| 48 | 413 | 409 | 405 | 400 | 395 | 391 | 387 | 383 | 379 | 376 | 372 | 368 | 364 | 360 | 357 | 353 | 350 | 346 | 342 | 339 |
| 49 | 415 | 411 | 407 | 402 | 397 | 393 | 389 | 385 | 381 | 377 | 374 | 370 | 366 | 362 | 359 | 355 | 351 | 348 | 344 | 340 |
| 50 | 418 | 413 | 409 | 404 | 400 | 395 | 391 | 387 | 383 | 379 | 376 | 372 | 368 | 365 | 361 | 357 | 353 | 350 | 346 | 342 |
| 51 | 420 | 417 | 411 | 407 | 402 | 397 | 393 | 389 | 385 | 381 | 378 | 374 | 370 | 367 | 363 | 359 | 355 | 351 | 348 | 344 |
| 52 | 423 | 419 | 414 | 409 | 404 | 400 | 395 | 391 | 387 | 383 | 379 | 376 | 372 | 369 | 365 | 361 | 357 | 353 | 350 | 346 |
| 53 | 425 | 421 | 416 | 411 | 407 | 402 | 397 | 393 | 389 | 385 | 381 | 378 | 374 | 370 | 367 | 363 | 359 | 355 | 352 | 348 |
| 54 | 428 | 424 | 419 | 414 | 409 | 405 | 400 | 396 | 391 | 387 | 383 | 380 | 376 | 372 | 369 | 365 | 361 | 357 | 354 | 350 |
| 55 | 430 | 426 | 421 | 416 | 412 | 407 | 403 | 398 | 393 | 389 | 385 | 382 | 378 | 374 | 371 | 367 | 363 | 359 | 356 | 352 |
| 56 | 432 | 428 | 423 | 419 | 414 | 409 | 406 | 400 | 396 | 392 | 388 | 384 | 380 | 376 | 373 | 369 | 365 | 362 | 358 | 354 |
| 57 | 435 | 431 | 426 | 422 | 416 | 412 | 408 | 403 | 398 | 394 | 390 | 386 | 382 | 378 | 375 | 371 | 367 | 364 | 360 | 356 |
| 58 | 438 | 433 | 428 | 424 | 419 | 414 | 410 | 406 | 401 | 396 | 392 | 388 | 384 | 380 | 377 | 373 | 369 | 366 | 362 | 358 |
| 59 | 440 | 435 | 430 | 426 | 421 | 417 | 412 | 408 | 404 | 399 | 394 | 390 | 386 | 382 | 379 | 375 | 371 | 368 | 364 | 360 |
| 60 | 442 | 437 | 432 | 428 | 424 | 420 | 415 | 410 | 406 | 401 | 396 | 392 | 388 | 384 | 381 | 377 | 373 | 370 | 366 | 362 |
| 61 | 445 | 439 | 434 | 430 | 426 | 422 | 417 | 412 | 408 | 404 | 400 | 394 | 390 | 386 | 383 | 379 | 375 | 372 | 368 | 364 |
| 62 | 448 | 442 | 437 | 432 | 428 | 424 | 420 | 416 | 411 | 406 | 402 | 397 | 393 | 388 | 385 | 381 | 378 | 374 | 370 | 366 |
| 63 | 451 | 445 | 439 | 435 | 430 | 426 | 422 | 418 | 414 | 409 | 405 | 400 | 396 | 390 | 387 | 383 | 380 | 376 | 372 | 368 |
| 64 | 454 | 448 | 442 | 437 | 432 | 428 | 424 | 420 | 416 | 412 | 408 | 402 | 398 | 393 | 389 | 385 | 382 | 378 | 374 | 370 |
| 65 | 456 | 450 | 444 | 440 | 434 | 431 | 426 | 422 | 418 | 414 | 410 | 405 | 400 | 396 | 392 | 387 | 384 | 380 | 376 | 372 |
| 66 | 458 | 452 | 447 | 442 | 437 | 432 | 428 | 424 | 420 | 416 | 412 | 408 | 403 | 398 | 394 | 390 | 386 | 382 | 378 | 374 |
| 67 | 460 | 455 | 450 | 445 | 440 | 435 | 431 | 427 | 423 | 418 | 414 | 410 | 406 | 401 | 396 | 392 | 388 | 384 | 380 | 376 |
| 68 | 463 | 458 | 453 | 448 | 443 | 438 | 433 | 429 | 425 | 420 | 417 | 412 | 408 | 404 | 400 | 395 | 390 | 386 | 382 | 378 |
| 69 | 466 | 461 | 456 | 450 | 446 | 441 | 435 | 431 | 427 | 423 | 419 | 415 | 410 | 406 | 402 | 396 | 392 | 388 | 384 | 381 |
| 70 | 468 | 464 | 459 | 452 | 448 | 444 | 438 | 433 | 429 | 426 | 422 | 417 | 413 | 408 | 404 | 399 | 395 | 390 | 386 | 383 |
| 71 | 471 | 466 | 461 | 456 | 450 | 446 | 441 | 436 | 432 | 428 | 424 | 419 | 416 | 411 | 406 | 402 | 398 | 393 | 388 | 385 |
| 72 | 474 | 469 | 464 | 458 | 453 | 449 | 444 | 438 | 434 | 430 | 426 | 422 | 418 | 414 | 409 | 405 | 400 | 396 | 391 | 387 |
| 73 | 477 | 472 | 467 | 462 | 456 | 451 | 447 | 442 | 436 | 432 | 428 | 424 | 420 | 416 | 412 | 407 | 403 | 398 | 394 | 390 |
| 74 | 480 | 475 | 470 | 465 | 459 | 454 | 449 | 444 | 439 | 434 | 430 | 426 | 422 | 418 | 414 | 410 | 406 | 401 | 396 | 392 |



The flow into the prover should be continued until the meter stops. When the meter stops, the inlet valve to the prover should be closed, and final meter reading, temperature, and pressure of the prover should be noted and recorded. The top bleed valve is used to determine if the prover is completely full. If the prover is not liquid-full, the run should be disregarded. The actual volume delivered into the prover will be the volume of the prover less the volume of the condensed vapor corrected for the difference in temperature of the metered stream and the temperature of the liquid in the prover at the end of the test run. Proving of meters by this method can be facilitated by the use of special tables from which corrections may be read directly.

## Mechanical Displacement Provers (See Fig. 21, 22, and 23)

**3032** The procedure for proving meters into piston displacement provers is dependent upon the type of prover which is used. These procedures are described in the following paragraphs for the bidirectional piston displacement prover and the unidirectional piston displacement prover.

## Bidirectional Piston Method (See Fig. 21 and Fig. 22)

**3033** The bidirectional piston prover involves the use of a honed cylinder with a sealed piston, as illustrated in Fig. 21 and Fig. 22. The prover must be displaced with liquid a sufficient number of times to assure that it is full of liquid and free of vapor, as well as to equalize temperatures in the prover. These displacements are accomplished by alternately changing the two-position, four-way, four-port valve from one position to the other. Vapors, if present, can be released from the cylinder through the vapor vent valves at the top ends of the cylinder. The pressure differential valve, where required, should be adjusted to insure that the liquid entering and leaving the prover is not flashing to vapor. The proof run is started by moving the piston to its stop at either end of the cylinder, noting the initial meter reading, and then changing the four-way valve to its alternate position to start flow into the prover. When the piston stroke is completed, the liquid flow through the meter will automatically stop when the known and precalibrated volume of liquid has been displaced from the cylinder. The final meter reading is recorded along with necessary pressures and temperatures observed during the proof run.

## Unidirectional Piston Method (See Fig. 23)

**3034** The unidirectional piston method of proving involves using as a prover a section of the line in which a meter, or meters, is installed, with a piston employed to displace liquid between two reference points at the extremities of the section. This piston may consist of a steel shaft equipped with conventional rubber scraper discs or cups mounted on each end, or other suitable devices.

**3035** A piston is inserted in the launching barrel, and the barrel is filled with liquid. The valves at the receiving barrel are arranged to permit receipt of a piston into the receiving barrel. The initial meter reading is made on the proving counter, or counters, and the piston is launched into the prover section. The proving counter will be engaged when the piston contacts the first mechanical tripper (indicator) and will be disengaged when it contacts the second tripper. Meter temperature must be recorded as the proof progresses unless a temperature-compensated meter is used. When the prover section is downstream from the meter, the temperature and pressure at each tripper should be observed and recorded when the piston strikes tripper No. 2. When the prover section is upstream from the meter, the temperature and pressure at each tripper should be observed and recorded when the piston strikes tripper No. 1. Such readings are averaged to find the representative temperature and pressure of the displaced volume of liquid. The piston will displace (or allow the replacement of) a known volume of liquid from the prover section which will be comparable to the indicated registration on the meter counters. After the piston has contacted tripper No. 2, the final meter reading is obtained from the proving register. The elapsed time between the tripping of No. 1 and No. 2 is necessary in determining the rate of flow. The true displaced volume of the prover section is obtained by application of the proper corrections to the base (calibrated) volume of the prover, as described in Par. 3044.

## Master Meter Method (See Fig. 25)

**3036** The master meter method of proving meters requires the use of a master meter of acceptable performance to check the meter to be proved. The master meter can be any one of a parallel battery of meters, a portable meter, or a meter at a test station used specifically for proving meters. The master meter should be reliable, consistent in its performance, and maintained in the best operating condition. If used in portable service, the master meter should be adequately protected against damage in transportation, mishandling, and installation. The meter must be frequently proved with an acceptable proving system at as many flow rates as required and under conditions which simulate those under which it will operate. Its accuracy is established and must be maintained within the desired tolerances, consistent with the quality of measurement accuracy desired. In proving the master meter, a complete record of all data should be kept in order that necessary corrections may be applied when using the master meter to prove meters under pressure and temperature conditions different from those existing during the proof of the master meter.

pressure gas regulator should be used to maintain the desired pressure (necessarily above the vapor pressure of the test liquid) in the prover when this method is followed.

**3029** In proving a meter with this method, vapor or gas pressure is applied to the prover; it is thus purged of air, then the pressure is raised to the desired point. The metered stream is then turned into the prover to equalize temperatures, purge vapors from proving lines, and assure wetted walls within the prover. During this filling, the back-pressure gas regulator should be adjusted to maintain the required pressure in the prover. After the prover has been filled, the liquid is withdrawn until the liquid level is at the bottom zero mark. As test liquid is withdrawn, the prover is filled with gas under pressure, preferably saturated. The prover may be equipped with a spray nozzle for spraying the interior thoroughly with the test liquid to saturate the vapor space. This spray system should be run during withdrawal of liquid from the prover. When the liquid level approaches the bottom zero mark, the spray should be shut off and the prover walls allowed to drain before starting the proof run. The proof run is started by directing liquid through the meter into the prover after recording the meter reading, lower liquid level reading, and necessary pressures and temperatures. When the liquid appears at the final liquid level, the flow into the prover is stopped and the required readings noted and recorded. Subsequent proof runs are made in the same basic manner.

### Vapor Displacement Method (See Fig. 18)

**3030** This method is used primarily on meters delivering high-vapor-pressure liquids, such as LPG, from a supply vessel and involves the use of a pressure-equalizing line between the vapor space of the prover and the supply vessel. This line allows vapors of the test liquid to pass freely between the prover and the supply vessel, causing pressures in the two vessels to be equal at all times. This method of proving is generally limited to the pressure-type provers with top and bottom graduated necks. The determination of the lower zero level of liquid and the final liquid level will be similar to that outlined for open volumetric provers.

In preparing this system for meter proving, vapor from the supply tank is permitted to fill the equalizing line up to the prover. Test liquid is then used to fill the prover, venting the air from the prover through the top vent. The vapor-equalizing line may then be opened to the prover, whereupon equilibrium conditions between the prover and the supply vessel are established. The test liquid is then pumped out until the liquid level appears in the bottom gage glass at the starting level. The pump is stopped, the pump line valve is closed, and the starting liquid level is observed and recorded. The delivery pump is then started, and the piping to the prover inlet valve is pressurized. The opening meter reading and necessary temperatures and pressures are observed and recorded, after which the start-stop valve is opened to start flow through the meter into the prover and the rate valve adjusted for the desired flow rate. As the prover is filled, the vapor above the liquid in the prover is displaced into the vapor space of the supply tank through the equalizing line. When the liquid in the prover appears at the final liquid level in the top neck, the flow is stopped and final liquid level readings, prover temperature and pressure, and the closing meter readings are observed and recorded. If a non-temperature-compensated meter is used, the temperature of the metered stream should be determined and recorded frequently enough during the filling of the prover to assure an accurate average temperature of the liquid as it passes through the meter. Subsequent runs are made in the same manner. Attention is drawn to the fact that any appreciable rise in the pressure in the vapor space in the prover while it is filling over that in the supply tank may cause some condensation of vapor in the prover and give rise to errors. Also, errors may be caused by the addition of heat from pumps, solar radiation, or outside heating mediums.

### Vapor-Condensing Method (See Fig. 24)

**3031** The vapor-condensing method is used for LPG meters and consists of completely filling a prover without the use of a vapor return line. This proving method is applicable only to the vapor-condensing prover which is illustrated in Fig. 24. With this method, the total enclosed volume of the prover must be known and is determined as outlined in Par. 2082 through Par. 2085. The prover must be equipped with a spray-filling device in the top of the prover, which will provide maximum contact between the liquid spray and vapors in the prover during filling to insure a liquid-full prover. A bottom and top bleed valve are used with this type of prover instead of gage glasses, inasmuch as the prover must be checked to determine whether it is empty or full.

Prior to the proof runs, the prover must be filled and emptied one or more times to equalize temperatures and purge lines of vapors. After the prover has been emptied of liquid, a portion of the vapors is bled to the atmosphere to reduce the pressure in the prover to a predetermined level. The bottom bleed valve should then be checked to insure that the prover is empty of liquid, and the inlet piping should be pressurized. The opening meter reading and the temperature and pressure of the vapor in the prover should be noted and recorded. The proof run is then started by turning liquid flow through the meter into the prover at the desired flow rate. If a non-temperature-compensated meter is used, the temperature of the metered stream should be determined and recorded frequently enough during the filling of the prover to assure an accurate average temperature of the liquid as it passes through the meter.



**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | Specific Gravity 60F/60F | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.500 | 0.501 | 0.502 | 0.503 | 0.504 | 0.505 | 0.506 | 0.507 | 0.508 | 0.509 | 0.510 | 0.511 | 0.512 | 0.513 | 0.514 | 0.515 | 0.516 | 0.517 | 0.518 | 0.519 |
| 75 | 483 | 478 | 473 | 468 | 462 | 457 | 452 | 447 | 442 | 437 | 432 | 429 | 424 | 420 | 416 | 412 | 408 | 404 | 399 | 394 |
| 76 | 486 | 480 | 476 | 470 | 465 | 460 | 455 | 450 | 445 | 440 | 435 | 431 | 426 | 422 | 419 | 414 | 410 | 406 | 402 | 397 |
| 77 | 489 | 483 | 478 | 472 | 468 | 463 | 458 | 452 | 448 | 443 | 438 | 433 | 429 | 425 | 420 | 416 | 412 | 408 | 404 | 400 |
| 78 | 492 | 486 | 480 | 475 | 470 | 466 | 461 | 455 | 450 | 446 | 440 | 436 | 432 | 428 | 423 | 419 | 415 | 411 | 406 | 402 |
| 79 | 494 | 488 | 484 | 478 | 473 | 468 | 464 | 458 | 453 | 449 | 443 | 438 | 434 | 430 | 425 | 421 | 417 | 414 | 408 | 405 |
| 80 | 497 | 492 | 486 | 481 | 476 | 471 | 466 | 461 | 456 | 452 | 446 | 441 | 436 | 432 | 428 | 423 | 420 | 416 | 411 | 408 |
| 81 | 500 | 495 | 491 | 484 | 479 | 474 | 469 | 464 | 459 | 454 | 449 | 444 | 439 | 434 | 430 | 426 | 422 | 418 | 414 | 410 |
| 82 | 504 | 498 | 493 | 487 | 482 | 477 | 471 | 467 | 462 | 457 | 452 | 447 | 442 | 437 | 433 | 428 | 424 | 420 | 417 | 412 |
| 83 | 508 | 501 | 496 | 490 | 485 | 480 | 474 | 469 | 465 | 460 | 455 | 450 | 444 | 440 | 436 | 431 | 426 | 422 | 419 | 415 |
| 84 | 512 | 505 | 499 | 493 | 488 | 483 | 477 | 472 | 467 | 463 | 458 | 452 | 447 | 442 | 438 | 433 | 429 | 424 | 420 | 417 |
| 85 | 516 | 509 | 502 | 496 | 491 | 486 | 480 | 475 | 470 | 466 | 460 | 455 | 450 | 445 | 440 | 436 | 432 | 427 | 423 | 419 |
| 86 | 519 | 512 | 506 | 499 | 494 | 489 | 484 | 478 | 472 | 468 | 463 | 458 | 453 | 448 | 443 | 438 | 434 | 430 | 426 | 421 |
| 87 | 522 | 516 | 510 | 502 | 497 | 492 | 487 | 481 | 475 | 470 | 466 | 461 | 456 | 451 | 446 | 440 | 437 | 432 | 428 | 423 |
| 88 | 525 | 519 | 514 | 506 | 500 | 495 | 490 | 484 | 478 | 473 | 468 | 464 | 459 | 454 | 449 | 442 | 439 | 435 | 431 | 425 |
| 89 | 528 | 522 | 517 | 510 | 504 | 498 | 493 | 487 | 482 | 476 | 471 | 467 | 462 | 457 | 451 | 445 | 442 | 438 | 434 | 427 |
| 90 | 531 | 526 | 520 | 514 | 508 | 502 | 496 | 490 | 486 | 479 | 474 | 470 | 465 | 460 | 454 | 448 | 445 | 440 | 436 | 430 |
| 91 | 534 | 529 | 524 | 518 | 512 | 506 | 499 | 493 | 489 | 482 | 477 | 473 | 468 | 463 | 457 | 451 | 448 | 442 | 439 | 432 |
| 92 | 537 | 531 | 526 | 521 | 515 | 509 | 502 | 496 | 492 | 486 | 480 | 476 | 471 | 466 | 460 | 454 | 451 | 445 | 441 | 435 |
| 93 | 540 | 534 | 529 | 524 | 518 | 512 | 506 | 500 | 495 | 489 | 483 | 479 | 474 | 469 | 463 | 457 | 454 | 448 | 444 | 438 |
| 94 | 543 | 537 | 532 | 527 | 521 | 516 | 510 | 504 | 498 | 492 | 486 | 482 | 477 | 471 | 466 | 460 | 457 | 451 | 447 | 441 |
| 95 | 546 | 540 | 535 | 530 | 524 | 519 | 513 | 507 | 501 | 496 | 490 | 485 | 480 | 474 | 469 | 463 | 460 | 454 | 450 | 444 |
| 96 | 549 | 543 | 538 | 533 | 527 | 522 | 516 | 510 | 504 | 499 | 493 | 488 | 483 | 477 | 472 | 466 | 463 | 457 | 453 | 447 |
| 97 | 553 | 546 | 541 | 536 | 530 | 525 | 519 | 513 | 508 | 502 | 496 | 491 | 486 | 480 | 475 | 469 | 466 | 460 | 456 | 450 |
| 98 | 556 | 550 | 544 | 539 | 533 | 528 | 522 | 516 | 511 | 506 | 500 | 494 | 489 | 483 | 478 | 472 | 469 | 463 | 458 | 453 |
| 99 | 560 | 554 | 547 | 542 | 536 | 531 | 525 | 519 | 514 | 509 | 504 | 498 | 492 | 486 | 481 | 475 | 472 | 466 | 461 | 456 |
| 100 | 564 | 558 | 551 | 545 | 539 | 534 | 528 | 523 | 517 | 512 | 507 | 501 | 495 | 490 | 484 | 478 | 475 | 469 | 463 | 459 |
| 101 | 568 | 562 | 554 | 548 | 542 | 537 | 531 | 526 | 520 | 515 | 510 | 504 | 498 | 493 | 487 | 482 | 478 | 472 | 466 | 462 |
| 102 | 572 | 566 | 558 | 552 | 546 | 540 | 534 | 529 | 523 | 518 | 513 | 508 | 502 | 496 | 490 | 485 | 481 | 475 | 469 | 465 |
| 103 | 576 | 570 | 562 | 556 | 549 | 544 | 538 | 532 | 526 | 521 | 516 | 511 | 506 | 500 | 494 | 488 | 484 | 478 | 472 | 468 |
| 104 | 580 | 574 | 566 | 560 | 553 | 548 | 541 | 535 | 529 | 524 | 519 | 514 | 509 | 503 | 497 | 492 | 487 | 481 | 475 | 471 |
| 105 | 584 | 578 | 570 | 564 | 557 | 551 | 544 | 538 | 532 | 528 | 522 | 517 | 512 | 506 | 501 | 495 | 490 | 484 | 478 | 474 |
| 106 | 588 | 582 | 574 | 568 | 561 | 554 | 548 | 542 | 536 | 531 | 525 | 520 | 515 | 509 | 504 | 498 | 493 | 488 | 482 | 477 |
| 107 | 592 | 586 | 578 | 572 | 565 | 558 | 552 | 546 | 539 | 534 | 528 | 523 | 518 | 512 | 507 | 502 | 496 | 491 | 486 | 480 |
| 108 | 596 | 590 | 582 | 576 | 569 | 562 | 556 | 549 | 543 | 537 | 531 | 526 | 521 | 515 | 510 | 506 | 500 | 494 | 489 | 484 |
| 109 | 599 | 594 | 586 | 580 | 573 | 566 | 560 | 553 | 547 | 540 | 534 | 529 | 524 | 518 | 513 | 509 | 504 | 498 | 492 | 487 |
| 110 | 603 | 597 | 590 | 584 | 577 | 570 | 563 | 557 | 551 | 544 | 538 | 532 | 527 | 521 | 516 | 512 | 507 | 502 | 496 | 490 |
| 111 | 606 | 600 | 594 | 588 | 581 | 574 | 567 | 561 | 555 | 548 | 542 | 536 | 530 | 524 | 519 | 515 | 510 | 505 | 500 | 494 |
| 112 | 610 | 604 | 598 | 592 | 585 | 578 | 571 | 565 | 558 | 552 | 546 | 539 | 534 | 528 | 522 | 518 | 513 | 508 | 503 | 497 |
| 113 | 614 | 608 | 602 | 596 | 589 | 582 | 575 | 569 | 562 | 556 | 550 | 543 | 538 | 531 | 526 | 521 | 516 | 511 | 506 | 500 |
| 114 | 618 | 612 | 605 | 599 | 593 | 586 | 581 | 573 | 566 | 560 | 554 | 547 | 541 | 534 | 529 | 524 | 519 | 514 | 509 | 504 |
| 115 | 621 | 615 | 608 | 602 | 596 | 590 | 584 | 577 | 570 | 564 | 558 | 551 | 544 | 538 | 532 | 528 | 522 | 517 | 512 | 507 |
| 116 | 625 | 618 | 612 | 606 | 600 | 594 | 588 | 581 | 574 | 568 | 562 | 555 | 548 | 542 | 536 | 531 | 526 | 520 | 515 | 510 |
| 117 | 628 | 622 | 616 | 610 | 604 | 598 | 592 | 585 | 578 | 572 | 566 | 559 | 552 | 546 | 540 | 534 | 529 | 524 | 518 | 514 |
| 118 | 631 | 626 | 620 | 614 | 608 | 601 | 596 | 589 | 582 | 576 | 570 | 563 | 556 | 550 | 544 | 538 | 532 | 527 | 522 | 517 |
| 119 | 635 | 629 | 623 | 617 | 611 | 605 | 598 | 593 | 586 | 580 | 574 | 567 | 560 | 554 | 548 | 542 | 536 | 530 | 526 | 520 |
| 120 | 639 | 632 | 626 | 621 | 614 | 608 | 602 | 596 | 590 | 584 | 578 | 571 | 564 | 558 | 552 | 546 | 539 | 534 | 529 | 524 |
| 121 | 642 | 636 | 630 | 623 | 618 | 612 | 606 | 600 | 593 | 588 | 582 | 575 | 568 | 562 | 556 | 550 | 543 | 538 | 532 | 527 |
| 122 | 646 | 639 | 633 | 626 | 621 | 615 | 609 | 603 | 596 | 590 | 585 | 581 | 572 | 566 | 560 | 554 | 547 | 542 | 536 | 530 |
| 123 | 650 | 643 | 636 | 630 | 624 | 618 | 612 | 606 | 600 | 594 | 588 | 584 | 576 | 570 | 564 | 558 | 551 | 546 | 540 | 534 |
| 124 | 653 | 646 | 640 | 634 | 627 | 622 | 612 | 610 | 604 | 598 | 592 | 587 | 580 | 574 | 568 | 562 | 555 | 550 | 544 | 538 |
| 125 | 656 | 650 | 643 | 637 | 630 | 625 | 619 | 613 | 607 | 602 | 596 | 590 | 584 | 578 | 572 | 566 | 559 | 554 | 548 | 542 |
| 126 | 660 | 653 | 646 | 640 | 634 | 628 | 622 | 617 | 611 | 605 | 600 | 593 | 588 | 582 | 576 | 570 | 563 | 558 | 552 | 546 |
| 127 | 664 | 656 | 650 | 644 | 637 | 632 | 625 | 620 | 614 | 608 | 603 | 596 | 591 | 586 | 580 | 574 | 567 | 562 | 556 | 550 |
| 128 | 667 | 660 | 654 | 647 | 640 | 635 | 628 | 623 | 617 | 612 | 606 | 600 | 594 | 589 | 584 | 578 | 571 | 566 | 560 | 554 |

**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | Specific Gravity 60F/60F | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.520 | 0.521 | 0.522 | 0.523 | 0.524 | 0.525 | 0.526 | 0.527 | 0.528 | 0.529 | 0.530 | 0.531 | 0.532 | 0.533 | 0.534 | 0.535 | 0.536 | 0.537 | 0.538 | 0.539 |
| 20 | 290 | 288 | 285 | 282 | 280 | 278 | 276 | 273 | 271 | 268 | 266 | 263 | 261 | 258 | 256 | 253 | 251 | 249 | 247 | 244 |
| 21 | 292 | 289 | 286 | 284 | 281 | 279 | 277 | 275 | 273 | 270 | 267 | 265 | 262 | 259 | 257 | 255 | 253 | 250 | 248 | 245 |
| 22 | 293 | 290 | 288 | 285 | 282 | 280 | 278 | 276 | 274 | 271 | 269 | 266 | 263 | 261 | 258 | 256 | 254 | 251 | 249 | 247 |
| 23 | 295 | 292 | 289 | 286 | 284 | 281 | 279 | 277 | 275 | 273 | 270 | 267 | 265 | 262 | 259 | 257 | 255 | 253 | 250 | 248 |
| 24 | 296 | 293 | 290 | 288 | 285 | 283 | 281 | 278 | 276 | 274 | 272 | 268 | 266 | 264 | 260 | 258 | 256 | 254 | 251 | 249 |
| 25 | 298 | 295 | 292 | 289 | 286 | 284 | 282 | 279 | 278 | 275 | 273 | 270 | 267 | 265 | 262 | 260 | 257 | 255 | 253 | 251 |
| 26 | 300 | 296 | 293 | 290 | 288 | 286 | 283 | 281 | 279 | 276 | 274 | 271 | 269 | 266 | 264 | 261 | 259 | 256 | 254 | 252 |
| 27 | 301 | 298 | 295 | 292 | 289 | 287 | 285 | 282 | 280 | 278 | 275 | 273 | 270 | 267 | 265 | 263 | 260 | 257 | 255 | 253 |
| 28 | 302 | 300 | 296 | 293 | 291 | 288 | 286 | 283 | 281 | 279 | 276 | 274 | 272 | 269 | 266 | 264 | 261 | 259 | 256 | 254 |
| 29 | 304 | 301 | 298 | 295 | 292 | 290 | 287 | 285 | 283 | 280 | 278 | 275 | 273 | 270 | 268 | 265 | 263 | 260 | 258 | 255 |
| 30 | 306 | 302 | 300 | 296 | 294 | 291 | 289 | 286 | 284 | 281 | 279 | 276 | 274 | 272 | 269 | 266 | 264 | 261 | 259 | 257 |
| 31 | 308 | 304 | 301 | 298 | 295 | 292 | 290 | 288 | 285 | 283 | 280 | 278 | 275 | 273 | 270 | 268 | 265 | 263 | 260 | 258 |
| 32 | 309 | 306 | 302 | 300 | 296 | 294 | 291 | 289 | 287 | 284 | 282 | 279 | 277 | 274 | 272 | 269 | 267 | 264 | 262 | 259 |
| 33 | 311 | 308 | 304 | 301 | 298 | 295 | 293 | 290 | 288 | 286 | 283 | 280 | 278 | 275 | 273 | 271 | 268 | 265 | 263 | 260 |
| 34 | 312 | 309 | 306 | 302 | 300 | 296 | 294 | 291 | 289 | 287 | 284 | 281 | 279 | 277 | 274 | 272 | 269 | 267 | 265 | 262 |
| 35 | 313 | 311 | 308 | 304 | 301 | 298 | 295 | 293 | 291 | 288 | 286 | 283 | 281 | 278 | 275 | 273 | 271 | 268 | 266 | 263 |
| 36 | 315 | 312 | 309 | 306 | 303 | 300 | 297 | 294 | 292 | 290 | 287 | 284 | 282 | 279 | 277 | 275 | 272 | 269 | 267 | 265 |
| 37 | 317 | 314 | 311 | 308 | 304 | 301 | 299 | 295 | 293 | 291 | 289 | 285 | 283 | 281 | 278 | 276 | 273 | 271 | 269 | 266 |
| 38 | 319 | 315 | 312 | 309 | 306 | 303 | 300 | 297 | 295 | 292 | 290 | 287 | 285 | 282 | 279 | 277 | 275 | 272 | 270 | 267 |
| 39 | 320 | 317 | 314 | 311 | 308 | 305 | 302 | 299 | 296 | 294 | 291 | 289 | 286 | 283 | 281 | 279 | 276 | 274 | 271 | 269 |
| 40 | 322 | 319 | 315 | 312 | 309 | 306 | 303 | 301 | 298 | 295 | 293 | 290 | 288 | 285 | 282 | 280 | 277 | 275 | 273 | 270 |
| 41 | 323 | 320 | 317 | 314 | 311 | 308 | 305 | 302 | 300 | 297 | 294 | 291 | 289 | 286 | 283 | 281 | 279 | 276 | 274 | 271 |
| 42 | 325 | 322 | 319 | 316 | 312 | 310 | 307 | 304 | 301 | 298 | 296 | 293 | 290 | 288 | 285 | 283 | 280 | 278 | 275 | 273 |
| 43 | 327 | 324 | 320 | 317 | 314 | 311 | 308 | 305 | 303 | 300 | 297 | 294 | 291 | 289 | 287 | 284 | 281 | 279 | 277 | 274 |
| 44 | 328 | 325 | 322 | 319 | 316 | 313 | 310 | 307 | 305 | 302 | 299 | 295 | 293 | 290 | 288 | 285 | 283 | 280 | 278 | 275 |
| 45 | 330 | 327 | 324 | 320 | 317 | 314 | 312 | 309 | 306 | 303 | 301 | 297 | 294 | 292 | 289 | 287 | 284 | 282 | 279 | 277 |
| 46 | 332 | 329 | 326 | 322 | 319 | 316 | 313 | 310 | 308 | 305 | 302 | 299 | 296 | 293 | 291 | 288 | 286 | 283 | 281 | 278 |
| 47 | 333 | 330 | 327 | 324 | 320 | 318 | 315 | 312 | 310 | 307 | 304 | 300 | 297 | 295 | 292 | 289 | 287 | 284 | 282 | 279 |
| 48 | 335 | 332 | 329 | 325 | 322 | 319 | 317 | 314 | 311 | 308 | 306 | 302 | 299 | 296 | 294 | 291 | 289 | 286 | 283 | 281 |
| 49 | 337 | 334 | 331 | 327 | 324 | 321 | 318 | 315 | 313 | 310 | 307 | 304 | 301 | 298 | 295 | 292 | 290 | 287 | 285 | 282 |
| 50 | 339 | 336 | 332 | 329 | 326 | 323 | 320 | 317 | 315 | 311 | 309 | 306 | 302 | 300 | 296 | 294 | 291 | 289 | 286 | 283 |
| 51 | 341 | 337 | 334 | 331 | 328 | 324 | 322 | 318 | 316 | 313 | 311 | 307 | 304 | 301 | 298 | 295 | 293 | 290 | 288 | 285 |
| 52 | 343 | 339 | 336 | 332 | 330 | 326 | 323 | 320 | 318 | 315 | 312 | 309 | 306 | 303 | 300 | 297 | 294 | 291 | 289 | 286 |
| 53 | 345 | 341 | 338 | 334 | 331 | 328 | 325 | 322 | 319 | 316 | 314 | 310 | 308 | 305 | 301 | 298 | 295 | 293 | 290 | 288 |
| 54 | 347 | 343 | 340 | 336 | 333 | 330 | 326 | 323 | 321 | 318 | 315 | 312 | 309 | 307 | 303 | 300 | 297 | 294 | 291 | 289 |
| 55 | 349 | 345 | 342 | 338 | 334 | 332 | 328 | 326 | 323 | 320 | 317 | 313 | 311 | 309 | 305 | 301 | 299 | 295 | 293 | 290 |
| 56 | 351 | 347 | 344 | 340 | 336 | 333 | 330 | 328 | 324 | 322 | 318 | 315 | 312 | 310 | 307 | 303 | 300 | 297 | 294 | 292 |
| 57 | 352 | 349 | 346 | 342 | 338 | 335 | 332 | 330 | 326 | 323 | 320 | 317 | 314 | 311 | 308 | 305 | 302 | 299 | 296 | 293 |
| 58 | 354 | 351 | 348 | 344 | 340 | 337 | 333 | 331 | 328 | 325 | 322 | 318 | 316 | 312 | 310 | 307 | 304 | 300 | 297 | 295 |
| 59 | 356 | 353 | 350 | 346 | 342 | 339 | 335 | 333 | 330 | 326 | 324 | 320 | 317 | 314 | 311 | 309 | 306 | 302 | 299 | 296 |
| 60 | 358 | 355 | 352 | 348 | 344 | 341 | 337 | 335 | 332 | 328 | 325 | 322 | 319 | 316 | 313 | 311 | 307 | 305 | 301 | 298 |
| 61 | 360 | 357 | 354 | 350 | 346 | 343 | 339 | 337 | 333 | 330 | 327 | 323 | 320 | 318 | 315 | 312 | 309 | 306 | 303 | 300 |
| 62 | 363 | 359 | 356 | 352 | 348 | 345 | 341 | 339 | 335 | 332 | 329 | 325 | 322 | 319 | 316 | 313 | 311 | 308 | 305 | 302 |
| 63 | 365 | 361 | 358 | 354 | 350 | 347 | 343 | 341 | 337 | 334 | 331 | 327 | 324 | 321 | 318 | 315 | 312 | 310 | 307 | 304 |
| 64 | 367 | 363 | 360 | 356 | 352 | 349 | 345 | 343 | 339 | 336 | 332 | 329 | 326 | 323 | 320 | 317 | 314 | 311 | 308 | 306 |
| 65 | 369 | 365 | 362 | 358 | 354 | 351 | 347 | 345 | 341 | 338 | 334 | 331 | 328 | 324 | 322 | 319 | 316 | 313 | 310 | 307 |
| 66 | 371 | 367 | 364 | 360 | 356 | 353 | 349 | 347 | 343 | 340 | 336 | 332 | 329 | 326 | 323 | 321 | 317 | 314 | 311 | 309 |
| 67 | 373 | 369 | 366 | 362 | 358 | 355 | 351 | 349 | 345 | 342 | 338 | 334 | 331 | 328 | 325 | 322 | 319 | 316 | 313 | 310 |
| 68 | 375 | 371 | 368 | 364 | 360 | 357 | 353 | 351 | 347 | 344 | 340 | 336 | 333 | 330 | 327 | 323 | 321 | 318 | 315 | 312 |
| 69 | 377 | 373 | 370 | 366 | 362 | 359 | 355 | 353 | 349 | 346 | 342 | 338 | 335 | 332 | 328 | 325 | 322 | 319 | 317 | 313 |
| 70 | 379 | 376 | 372 | 368 | 364 | 361 | 357 | 355 | 351 | 348 | 344 | 340 | 337 | 333 | 330 | 327 | 324 | 321 | 318 | 315 |
| 71 | 382 | 378 | 374 | 370 | 366 | 363 | 359 | 357 | 353 | 350 | 346 | 342 | 339 | 335 | 332 | 329 | 326 | 323 | 320 | 317 |
| 72 | 384 | 380 | 376 | 372 | 368 | 365 | 361 | 359 | 355 | 352 | 348 | 344 | 340 | 337 | 334 | 331 | 328 | 324 | 322 | 319 |
| 75 | 386 | 382 | 378 | 375 | 371 | 367 | 363 | 360 | 357 | 354 | 350 | 346 | 342 | 339 | 336 | 333 | 330 | 326 | 323 | 320 |
| 74 | 388 | 384 | 380 | 377 | 373 | 369 | 365 | 362 | 359 | 357 | 352 | 348 | 344 | 341 | 338 | 335 | 331 | 328 | 325 | 322 |



of the test liquid in order to reduce evaporation of the test liquid during the subsequent proof run. Where this is done, the spray should be turned on prior to each emptying of the prover and closed off prior to zeroing the liquid level.

**3022** There are certain variations inherent in the foregoing general procedure, arising primarily from design differences, with respect to the method of establishing the starting liquid level or zero level at the beginning of the proof run.

## CLOSED VOLUMETRIC PROVERS

### Water Displacement Method (See Fig. 15 and Fig. 16)

**3023** This method is applicable only to a closed prover with a top and bottom graduated neck and with immiscible liquids of different gravities. Variations of equipment and piping are recognized according to which of the following methods is used:

*a.* Dual-tank method.

*b.* Single-tank method, in which water is discharged to an auxiliary tank or to waste.

The basic procedures for proving meters with either of these methods are identical, the difference being in the method of re-using or disposing of the water. For simplification purposes, the dual-tank method is described in the following paragraphs.

**3024** The procedure for using the dual-tank water displacement method in proving meters begins with the complete filling of the second prover up to the vent valve, water thus displacing air through the vent at the top of the second prover. Before the vent valve is completely closed, test liquid from the meter is admitted to this second prover at the top, venting air and vapor from the line to the prover until the line is liquid-full. At this point, the valves on the interconnecting water line to the first prover are opened and test liquid from the meter is used to force the water from the second prover into the bottom of the first prover. Flow is continued until the water begins to pass through the top vent valve of the first prover, at which time flow is stopped. Test liquid from the meter is admitted to the top of the first prover, venting air and vapor through the top vent until the line is liquid-full. At this point, the first prover vent valve is closed and the system is completely liquid-full. Additional test liquid is now admitted to the first prover, displacing water to the second prover, until the liquid-water meniscus is lowered to coincide with the upper zero mark of the first prover and the water level of the second prover is made to fall near the center of the bottom neck. The provers are now in condition to start normal meter proving.

**3025** To make the first meter proof, all valves except the start-stop valve **G** and valve **C** are opened (see Fig. 16). The pressure and opening reading on the upper neck of the first prover are observed and recorded. The meter is stopped by closing valve **D**, and the opening meter reading is observed and recorded. Flow is started by opening the start-stop valve **G**, and the rate is established by rate valve **F**. As the water is displaced into the second prover, it, in turn, displaces test liquid above the water in the second prover back through valve **A** to a point downstream from valve **D**. Flow is continued at the properly adjusted rate until the water-liquid meniscus appears in the bottom gage glass of the first prover, at which time the start-stop valve **G** is closed. The reading on the lower gage glass of the first prover is then observed and recorded, along with the temperature and pressure of the test liquid in the first prover and the closing meter reading. During the filling of the first prover with test liquid, if the meter is non-temperature-compensated, the temperature of the metered stream should be determined and recorded frequently enough to assure an accurate average temperature of the liquid as it passes through the meter. The metered volume is then compared with the prover volume, as described in Sect. IV, to obtain the meter performance. This constitutes the first proof run.

**3026** To make the second meter proof, the necessary opening readings are made and the water-liquid meniscus in the top neck of the second prover is observed and recorded. The opening meter reading (which may be the closing reading of the first run) is observed and recorded. The flow of test liquid is started into the second prover by, first, closing valve **A**, opening valve **C**, closing valve **E**, and opening valve **D**; then opening the start-stop valve **G**. Proper rate is maintained by means of rate valve **F**, established from the previous run. Flow is continued until the water-liquid meniscus appears in the bottom neck of the second tank. The start-stop valve **G** is then closed; all readings are observed; and calculations, made as in the first proof, are repeated. If subsequent test runs are desired, the foregoing procedures are repeated.

**3027** The proving of meters by the single-tank water displacement method is identical in principle and is accomplished in a manner similar to the dual-tank method described in the foregoing paragraphs. The essential difference is that the water displaced from the prover must be pumped back into the prover from a supply source or from an auxiliary water-receiving vessel.

### Gas Displacement Method (See Fig. 17)

**3028** The gas displacement method of proving meters involves the application of gas pressure to the inside of the prover to minimize evaporation loss of the test liquid. This method of proving is applicable to the top and bottom graduated-neck, top graduated-neck, single-weir, and double-weir closed provers. The determination of the lower zero level of liquid and the final liquid level will be similar to that outlined for these provers when used as open volumetric provers. A back-indicate the quantity actually delivered. Second, it may be desired to prove a meter to determine its performance in terms of a meter factor or meter accuracy so that this ratio may be mathematically applied to the indicated registration to compute the actual quantity delivered through the meter. The latter is frequently the case in continuous or long-duration measurement, such as in pipeline operations where it is usually expedient to apply a meter factor to the indicated registration (see Par. 4002).

**3010** To obtain either end result described in Par. 3009, the proving technique is essentially identical. Every meter proof should be made with the same register equipment as is used in regular operation or with additional, satisfactorily synchronized auxiliary registers for the running start-and-stop procedure. Special auxiliary register equipment, such as the gravity selector, temperature compensator, and quantity-predetermining register, if employed, should be properly set and operative when making the proof runs. Time intervals between proof runs should be kept to a practical minimum.

**3011** When a meter is being proved, a preliminary unrecorded run should be made to equalize temperatures, displace vapors or gases, and wet the interior of the prover where necessary. Subsequent recorded proving test runs are made, and the meter registration is adjusted after each run to correct the error determined by that test run. Proving runs and required adjustment should be continued until two results are obtained which prove that the meter register is indicating the delivered quantity within the desired accuracy tolerances.

**3012** When a meter is being proved to determine the meter factor, the procedure is essentially as described in Par. 3011 except that no changes are made in the meter's registration adjusting device between runs. Proof runs are made and recorded until two results check each other within a pre-established allowable variation, at which point the average of these two runs is accepted as the established meter factor.

**3013** If it is indicated that a meter, during its proving, is not properly changing its accuracy in accordance with mechanical adjustments made to its register adjustment device, or if four individual unadjusted proving runs are made without any two successive runs checking within a pre-established allowable deviation, all phases of the proving operation should be examined for the cause of the discrepancy. If the cause is not found, the meter and its register mechanisms should be inspected. Lack of reproducibility of reasonably consistent meter factors may be indicative of mechanical defects. If inspection discloses mechanical defects, the meter shall be repaired and proved before being returned to service.

**3014** In all meter proofs, the observation error possible in determining the opening meter reading, the closing meter reading, and the test volume delivered to the prover should not exceed one ten-thousandth part of the test volume employed where possible. Observations of temperature, pressure, and other variable quantities which may influence the meter proof or operation must also be made compatible.

**3015** Liquid levels in gage glasses should be determined by reading the bottom of the meniscus with transparent liquids or the top of the meniscus with opaque liquids.

**3016** The meter accuracy or meter factor for each single proof and for the average of two or more proofs should be calculated to the nearest ten-thousandth part (0.01 per cent or 0.0001).

**3017** The observed and computed data for all test runs made in obtaining a meter factor or other expression of meter performance shall be reported on a suitable meter-proving report form, examples of which are illustrated in Appendix A. The completed form, when signed by all parties concerned, will constitute approval and acceptance of the meter proof.

## OPEN VOLUMETRIC PROVERS (See Fig. 5, 9, 10, 11, 12, 13, and 26)

**3018** The proving of meters into open volumetric provers consists of the measurement of the metered quantity of liquid in a container of known volume. The liquid is passed through the meter under simulated operating conditions of temperature, pressure, rate of flow, gravity, and viscosity, then into the prover where the delivered volume is determined.

**3019** After the preliminary filling and draining, the lower zero level of the test liquid is established and recorded. The meter to be proved is then stopped, and the opening or starting meter reading is recorded. The first proof run is then started by directing the liquid through the meter into the prover, maintaining the flow rate and meter pressure to simulate operating conditions. During the filling of the prover, if the meter is not temperature-compensated, the temperature of the metered stream near the meter should be determined and recorded frequently enough to assure an accurate average temperature of the liquid as it passes through the meter. Flow is continued into the prover until the liquid appears at a suitable reading level. Flow is stopped, and the quantity delivered to the prover is promptly observed on the top gage glass scale and recorded. The thermometers in the prover are then promptly read and the readings recorded. The closing meter reading should then be observed and recorded, after which the meter may be returned to service. Thermometer readings may now be averaged and the meter performance for the first proof run calculated.

**3020** Meter registration adjustments may be made as required, and subsequent proof runs may be made by repeating the proof run procedure just described.

**3021** In some types of open volumetric provers, a top spray is used during the emptying of the prover to saturate the air drawn into the prover with the vapor



**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | Specific Gravity 60F/60F | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.520 | 0.521 | 0.522 | 0.523 | 0.524 | 0.525 | 0.526 | 0.527 | 0.528 | 0.529 | 0.530 | 0.531 | 0.532 | 0.533 | 0.534 | 0.535 | 0.536 | 0.537 | 0.538 | 0.539 |
| 75 | 390 | 386 | 382 | 379 | 376 | 372 | 367 | 364 | 361 | 359 | 354 | 350 | 347 | 343 | 340 | 337 | 333 | 330 | 327 | 324 |
| 76 | 392 | 388 | 384 | 381 | 378 | 374 | 370 | 366 | 363 | 361 | 356 | 352 | 349 | 345 | 342 | 339 | 336 | 332 | 329 | 326 |
| 77 | 395 | 391 | 387 | 383 | 380 | 376 | 372 | 369 | 365 | 363 | 358 | 354 | 351 | 347 | 344 | 340 | 337 | 334 | 331 | 328 |
| 78 | 398 | 394 | 390 | 385 | 382 | 378 | 374 | 371 | 367 | 365 | 360 | 356 | 353 | 349 | 346 | 343 | 339 | 336 | 333 | 330 |
| 79 | 400 | 396 | 392 | 388 | 384 | 380 | 376 | 373 | 369 | 367 | 362 | 358 | 355 | 351 | 348 | 345 | 341 | 338 | 335 | 331 |
| 80 | 403 | 399 | 395 | 390 | 386 | 383 | 379 | 376 | 372 | 368 | 364 | 360 | 357 | 353 | 350 | 347 | 343 | 340 | 337 | 334 |
| 81 | 406 | 402 | 397 | 392 | 389 | 385 | 381 | 378 | 374 | 370 | 367 | 362 | 359 | 356 | 352 | 349 | 346 | 342 | 339 | 336 |
| 82 | 408 | 404 | 400 | 395 | 391 | 388 | 383 | 380 | 376 | 373 | 369 | 365 | 361 | 358 | 354 | 351 | 348 | 344 | 341 | 338 |
| 83 | 411 | 406 | 402 | 398 | 394 | 390 | 385 | 383 | 379 | 375 | 371 | 367 | 363 | 360 | 356 | 353 | 350 | 347 | 343 | 340 |
| 84 | 413 | 409 | 404 | 400 | 396 | 392 | 388 | 385 | 381 | 377 | 374 | 370 | 366 | 362 | 359 | 355 | 352 | 349 | 345 | 342 |
| 85 | 416 | 412 | 407 | 403 | 399 | 395 | 391 | 387 | 384 | 380 | 376 | 373 | 368 | 364 | 361 | 357 | 354 | 351 | 347 | 344 |
| 86 | 418 | 414 | 410 | 406 | 402 | 397 | 394 | 390 | 386 | 382 | 379 | 375 | 371 | 367 | 363 | 359 | 356 | 353 | 349 | 346 |
| 87 | 420 | 416 | 412 | 408 | 404 | 400 | 396 | 392 | 389 | 385 | 381 | 377 | 373 | 369 | 365 | 362 | 358 | 355 | 352 | 349 |
| 88 | 422 | 419 | 415 | 410 | 407 | 402 | 399 | 395 | 391 | 387 | 384 | 380 | 375 | 372 | 368 | 364 | 361 | 357 | 354 | 351 |
| 89 | 425 | 421 | 417 | 412 | 409 | 405 | 401 | 398 | 394 | 390 | 386 | 382 | 378 | 374 | 370 | 366 | 363 | 359 | 356 | 353 |
| 90 | 428 | 423 | 419 | 414 | 412 | 407 | 403 | 400 | 396 | 392 | 388 | 384 | 380 | 376 | 373 | 369 | 365 | 362 | 358 | 355 |
| 91 | 430 | 426 | 422 | 417 | 414 | 410 | 406 | 402 | 399 | 394 | 391 | 386 | 383 | 379 | 375 | 371 | 367 | 364 | 361 | 357 |
| 92 | 433 | 429 | 424 | 420 | 416 | 412 | 408 | 405 | 401 | 397 | 393 | 389 | 385 | 381 | 377 | 374 | 370 | 366 | 363 | 359 |
| 93 | 436 | 431 | 426 | 422 | 419 | 415 | 410 | 407 | 403 | 399 | 396 | 391 | 387 | 384 | 380 | 376 | 372 | 369 | 365 | 362 |
| 94 | 439 | 434 | 429 | 425 | 421 | 417 | 413 | 409 | 406 | 401 | 398 | 394 | 390 | 386 | 382 | 378 | 374 | 371 | 367 | 364 |
| 95 | 441 | 437 | 432 | 428 | 424 | 420 | 416 | 412 | 408 | 404 | 400 | 396 | 392 | 389 | 385 | 380 | 377 | 373 | 370 | 366 |
| 96 | 444 | 439 | 435 | 431 | 427 | 422 | 418 | 415 | 410 | 406 | 403 | 399 | 395 | 391 | 388 | 383 | 379 | 375 | 372 | 369 |
| 97 | 446 | 442 | 438 | 434 | 430 | 425 | 420 | 417 | 413 | 408 | 405 | 401 | 397 | 393 | 390 | 386 | 382 | 378 | 375 | 371 |
| 98 | 449 | 445 | 441 | 436 | 432 | 428 | 423 | 420 | 416 | 411 | 408 | 403 | 400 | 396 | 392 | 388 | 385 | 381 | 377 | 373 |
| 99 | 452 | 448 | 444 | 440 | 435 | 431 | 426 | 422 | 418 | 414 | 410 | 405 | 402 | 398 | 394 | 391 | 387 | 384 | 379 | 376 |
| 100 | 455 | 450 | 447 | 442 | 439 | 433 | 429 | 425 | 421 | 417 | 412 | 408 | 404 | 401 | 397 | 393 | 389 | 386 | 382 | 378 |
| 101 | 458 | 453 | 450 | 445 | 441 | 437 | 431 | 428 | 423 | 419 | 415 | 410 | 407 | 403 | 399 | 396 | 392 | 388 | 385 | 381 |
| 102 | 461 | 456 | 453 | 448 | 443 | 439 | 435 | 431 | 426 | 422 | 418 | 413 | 409 | 405 | 402 | 398 | 394 | 391 | 387 | 384 |
| 103 | 464 | 458 | 456 | 450 | 446 | 442 | 437 | 434 | 429 | 425 | 420 | 416 | 411 | 408 | 404 | 401 | 397 | 393 | 390 | 386 |
| 104 | 467 | 461 | 459 | 453 | 449 | 445 | 439 | 436 | 431 | 427 | 423 | 418 | 414 | 410 | 406 | 403 | 399 | 396 | 392 | 388 |
| 105 | 470 | 464 | 461 | 455 | 451 | 447 | 443 | 439 | 434 | 430 | 426 | 421 | 417 | 412 | 409 | 405 | 402 | 398 | 394 | 391 |
| 106 | 473 | 467 | 464 | 458 | 454 | 450 | 446 | 442 | 437 | 433 | 429 | 424 | 419 | 416 | 411 | 407 | 404 | 401 | 397 | 393 |
| 107 | 476 | 471 | 467 | 461 | 457 | 453 | 449 | 445 | 440 | 436 | 431 | 427 | 423 | 418 | 414 | 410 | 406 | 403 | 399 | 396 |
| 108 | 479 | 475 | 470 | 464 | 460 | 455 | 451 | 448 | 443 | 439 | 434 | 430 | 425 | 420 | 417 | 412 | 409 | 405 | 402 | 398 |
| 109 | 482 | 478 | 473 | 468 | 463 | 459 | 454 | 450 | 446 | 442 | 437 | 432 | 428 | 424 | 420 | 415 | 411 | 407 | 404 | 401 |
| 110 | 486 | 481 | 477 | 472 | 466 | 461 | 457 | 453 | 449 | 445 | 440 | 435 | 431 | 427 | 422 | 418 | 414 | 410 | 407 | 403 |
| 111 | 489 | 484 | 479 | 475 | 470 | 466 | 460 | 456 | 452 | 448 | 443 | 438 | 434 | 430 | 425 | 421 | 417 | 412 | 409 | 405 |
| 112 | 492 | 487 | 482 | 478 | 475 | 469 | 462 | 459 | 454 | 452 | 446 | 441 | 437 | 432 | 428 | 423 | 419 | 415 | 411 | 407 |
| 113 | 496 | 490 | 486 | 481 | 477 | 471 | 466 | 462 | 457 | 455 | 449 | 444 | 440 | 435 | 431 | 426 | 422 | 418 | 414 | 410 |
| 114 | 500 | 494 | 487 | 485 | 481 | 476 | 469 | 465 | 460 | 458 | 452 | 447 | 442 | 438 | 434 | 429 | 425 | 420 | 417 | 413 |
| 115 | 503 | 498 | 492 | 488 | 484 | 478 | 473 | 468 | 463 | 461 | 454 | 449 | 445 | 441 | 437 | 432 | 428 | 423 | 419 | 416 |
| 116 | 506 | 501 | 496 | 491 | 487 | 481 | 476 | 472 | 467 | 464 | 458 | 453 | 448 | 444 | 439 | 435 | 430 | 426 | 422 | 418 |
| 117 | 509 | 504 | 499 | 494 | 490 | 484 | 480 | 475 | 470 | 467 | 461 | 455 | 451 | 446 | 442 | 438 | 434 | 429 | 425 | 420 |
| 118 | 512 | 508 | 502 | 498 | 493 | 487 | 483 | 478 | 473 | 468 | 464 | 458 | 454 | 449 | 445 | 441 | 437 | 432 | 427 | 423 |
| 119 | 515 | 511 | 506 | 501 | 496 | 490 | 486 | 481 | 475 | 471 | 467 | 461 | 457 | 452 | 448 | 443 | 440 | 435 | 430 | 426 |
| 120 | 518 | 514 | 509 | 504 | 499 | 493 | 489 | 485 | 480 | 475 | 470 | 464 | 460 | 455 | 451 | 446 | 442 | 438 | 433 | 429 |
| 121 | 522 | 517 | 512 | 507 | 502 | 497 | 492 | 488 | 483 | 478 | 473 | 467 | 462 | 458 | 454 | 449 | 445 | 441 | 436 | 432 |
| 122 | 526 | 520 | 515 | 510 | 506 | 500 | 495 | 491 | 486 | 481 | 476 | 470 | 466 | 461 | 456 | 452 | 448 | 443 | 439 | 435 |
| 123 | 529 | 524 | 518 | 514 | 509 | 504 | 499 | 494 | 489 | 484 | 479 | 474 | 468 | 464 | 459 | 455 | 451 | 446 | 442 | 438 |
| 124 | 533 | 528 | 522 | 517 | 512 | 507 | 502 | 497 | 492 | 488 | 483 | 477 | 472 | 467 | 462 | 458 | 454 | 449 | 444 | 441 |
| 125 | 537 | 532 | 526 | 520 | 516 | 511 | 505 | 500 | 495 | 491 | 486 | 480 | 475 | 470 | 465 | 461 | 457 | 452 | 447 | 443 |
| 126 | 541 | 536 | 530 | 524 | 519 | 514 | 509 | 504 | 499 | 494 | 489 | 484 | 479 | 474 | 468 | 464 | 459 | 455 | 450 | 446 |
| 127 | 544 | 539 | 534 | 528 | 522 | 517 | 511 | 508 | 502 | 497 | 492 | 487 | 482 | 477 | 471 | 466 | 462 | 458 | 453 | 449 |
| 128 | 548 | 542 | 537 | 532 | 526 | 521 | 514 | 511 | 506 | 500 | 495 | 490 | 486 | 480 | 474 | 470 | 465 | 461 | 456 | 452 |

**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | Specific Gravity 60F/60F | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.540 | 0.541 | 0.542 | 0.543 | 0.544 | 0.545 | 0.546 | 0.547 | 0.548 | 0.549 | 0.550 | 0.551 | 0.552 | 0.553 | 0.554 | 0.555 | 0.556 | 0.557 | 0.558 | 0.559 |
| 20 | 242 | 239 | 237 | 235 | 233 | 231 | 229 | 227 | 225 | 223 | 221 | 219 | 217 | 215 | 213 | 211 | 209 | 207 | 205 | 203 |
| 21 | 243 | 240 | 238 | 236 | 234 | 232 | 230 | 228 | 226 | 224 | 222 | 220 | 218 | 216 | 213 | 211 | 209 | 207 | 206 | 203 |
| 22 | 244 | 242 | 239 | 237 | 235 | 233 | 231 | 229 | 227 | 225 | 223 | 221 | 219 | 217 | 214 | 212 | 210 | 208 | 206 | 204 |
| 23 | 246 | 243 | 241 | 238 | 236 | 234 | 232 | 230 | 228 | 226 | 224 | 222 | 220 | 218 | 215 | 213 | 211 | 209 | 207 | 205 |
| 24 | 247 | 245 | 242 | 240 | 237 | 235 | 233 | 231 | 229 | 227 | 225 | 223 | 221 | 219 | 216 | 214 | 212 | 210 | 208 | 206 |
| 25 | 248 | 246 | 244 | 241 | 239 | 236 | 234 | 233 | 231 | 228 | 226 | 224 | 222 | 220 | 217 | 215 | 213 | 211 | 209 | 207 |
| 26 | 249 | 247 | 245 | 242 | 240 | 237 | 236 | 234 | 232 | 230 | 227 | 225 | 223 | 221 | 218 | 216 | 214 | 212 | 210 | 208 |
| 27 | 251 | 248 | 246 | 244 | 241 | 239 | 237 | 235 | 233 | 231 | 229 | 227 | 224 | 222 | 220 | 217 | 215 | 213 | 211 | 209 |
| 28 | 252 | 249 | 247 | 245 | 243 | 240 | 238 | 236 | 234 | 232 | 230 | 228 | 225 | 223 | 221 | 218 | 216 | 214 | 212 | 210 |
| 29 | 253 | 251 | 249 | 246 | 244 | 242 | 239 | 237 | 235 | 233 | 231 | 229 | 227 | 225 | 222 | 220 | 217 | 215 | 213 | 211 |
| 30 | 255 | 252 | 250 | 247 | 245 | 243 | 240 | 238 | 236 | 234 | 232 | 230 | 228 | 226 | 223 | 221 | 218 | 216 | 214 | 212 |
| 31 | 256 | 253 | 251 | 249 | 247 | 244 | 242 | 239 | 237 | 235 | 233 | 231 | 229 | 227 | 225 | 222 | 220 | 217 | 215 | 213 |
| 32 | 257 | 255 | 252 | 250 | 248 | 245 | 243 | 241 | 238 | 236 | 234 | 232 | 230 | 228 | 226 | 223 | 221 | 218 | 216 | 214 |
| 33 | 258 | 256 | 253 | 251 | 249 | 247 | 244 | 242 | 239 | 237 | 235 | 233 | 231 | 229 | 227 | 225 | 222 | 220 | 217 | 215 |
| 34 | 259 | 257 | 255 | 253 | 250 | 248 | 246 | 243 | 241 | 239 | 236 | 234 | 232 | 230 | 228 | 226 | 223 | 221 | 218 | 216 |
| 35 | 261 | 258 | 256 | 254 | 251 | 249 | 247 | 245 | 242 | 240 | 237 | 235 | 233 | 231 | 229 | 227 | 225 | 222 | 220 | 217 |
| 36 | 262 | 259 | 257 | 255 | 253 | 250 | 248 | 246 | 244 | 241 | 239 | 237 | 235 | 233 | 231 | 228 | 226 | 223 | 221 | 218 |
| 37 | 263 | 261 | 259 | 256 | 254 | 252 | 249 | 247 | 245 | 243 | 240 | 238 | 236 | 234 | 232 | 230 | 227 | 225 | 222 | 220 |
| 38 | 265 | 262 | 260 | 258 | 255 | 253 | 251 | 248 | 246 | 244 | 241 | 239 | 237 | 235 | 233 | 231 | 229 | 226 | 224 | 221 |
| 39 | 266 | 264 | 261 | 259 | 256 | 254 | 252 | 249 | 248 | 245 | 243 | 240 | 238 | 236 | 234 | 232 | 230 | 228 | 225 | 222 |
| 40 | 267 | 265 | 262 | 260 | 258 | 255 | 253 | 251 | 249 | 246 | 244 | 242 | 240 | 237 | 235 | 233 | 231 | 229 | 226 | 224 |
| 41 | 269 | 266 | 264 | 261 | 259 | 257 | 254 | 252 | 250 | 247 | 245 | 243 | 241 | 238 | 236 | 234 | 232 | 230 | 227 | 225 |
| 42 | 270 | 268 | 265 | 263 | 260 | 258 | 255 | 253 | 251 | 249 | 247 | 244 | 242 | 240 | 237 | 235 | 233 | 231 | 229 | 226 |
| 43 | 271 | 269 | 266 | 264 | 262 | 259 | 257 | 255 | 252 | 250 | 248 | 246 | 243 | 241 | 239 | 237 | 235 | 233 | 230 | 228 |
| 44 | 273 | 270 | 268 | 265 | 263 | 260 | 258 | 256 | 253 | 251 | 249 | 247 | 244 | 242 | 240 | 238 | 236 | 234 | 231 | 229 |
| 45 | 274 | 272 | 269 | 267 | 264 | 262 | 259 | 257 | 255 | 252 | 250 | 248 | 246 | 243 | 241 | 239 | 237 | 235 | 232 | 230 |
| 46 | 275 | 273 | 270 | 268 | 265 | 263 | 260 | 258 | 256 | 254 | 252 | 249 | 247 | 245 | 243 | 240 | 238 | 236 | 233 | 231 |
| 47 | 277 | 274 | 272 | 269 | 267 | 264 | 262 | 259 | 257 | 255 | 253 | 251 | 248 | 246 | 244 | 241 | 239 | 237 | 235 | 233 |
| 48 | 278 | 275 | 273 | 271 | 268 | 265 | 263 | 261 | 258 | 256 | 254 | 252 | 249 | 247 | 245 | 243 | 240 | 238 | 236 | 234 |
| 49 | 279 | 277 | 274 | 272 | 269 | 267 | 264 | 262 | 260 | 257 | 255 | 253 | 251 | 248 | 246 | 244 | 242 | 239 | 237 | 235 |
| 50 | 281 | 278 | 276 | 273 | 271 | 268 | 266 | 263 | 261 | 259 | 256 | 254 | 252 | 250 | 247 | 245 | 243 | 240 | 238 | 236 |
| 51 | 282 | 280 | 277 | 275 | 272 | 269 | 267 | 265 | 262 | 260 | 258 | 255 | 253 | 251 | 249 | 246 | 244 | 242 | 239 | 237 |
| 52 | 283 | 281 | 279 | 276 | 274 | 271 | 268 | 266 | 264 | 261 | 259 | 257 | 254 | 252 | 250 | 248 | 245 | 243 | 240 | 238 |
| 53 | 285 | 282 | 280 | 277 | 275 | 272 | 270 | 267 | 265 | 263 | 260 | 258 | 255 | 253 | 251 | 249 | 246 | 244 | 242 | 240 |
| 54 | 287 | 284 | 281 | 279 | 276 | 274 | 271 | 268 | 266 | 264 | 261 | 259 | 257 | 254 | 252 | 250 | 248 | 245 | 243 | 242 |
| 55 | 288 | 285 | 283 | 280 | 277 | 275 | 272 | 270 | 268 | 265 | 262 | 260 | 258 | 256 | 253 | 251 | 249 | 247 | 245 | 243 |
| 56 | 289 | 287 | 284 | 281 | 279 | 277 | 274 | 271 | 269 | 266 | 264 | 261 | 259 | 257 | 255 | 252 | 250 | 248 | 246 | 244 |
| 57 | 290 | 288 | 285 | 283 | 280 | 278 | 275 | 273 | 270 | 268 | 265 | 263 | 260 | 258 | 256 | 254 | 251 | 249 | 248 | 245 |
| 58 | 292 | 289 | 287 | 284 | 282 | 279 | 277 | 274 | 272 | 269 | 267 | 264 | 262 | 259 | 257 | 255 | 253 | 250 | 249 | 246 |
| 59 | 293 | 291 | 288 | 286 | 283 | 281 | 278 | 276 | 273 | 271 | 268 | 265 | 263 | 261 | 258 | 256 | 254 | 251 | 250 | 248 |
| 60 | 295 | 292 | 290 | 287 | 285 | 282 | 279 | 277 | 275 | 272 | 269 | 267 | 264 | 262 | 260 | 257 | 255 | 253 | 251 | 249 |
| 61 | 296 | 294 | 291 | 289 | 286 | 284 | 281 | 279 | 276 | 274 | 271 | 269 | 266 | 263 | 261 | 259 | 257 | 255 | 252 | 250 |
| 62 | 298 | 295 | 293 | 290 | 288 | 285 | 283 | 280 | 278 | 275 | 273 | 270 | 268 | 265 | 262 | 260 | 258 | 256 | 254 | 251 |
| 63 | 300 | 297 | 294 | 292 | 289 | 287 | 284 | 282 | 279 | 277 | 274 | 271 | 269 | 266 | 264 | 261 | 259 | 257 | 255 | 253 |
| 64 | 302 | 299 | 296 | 294 | 291 | 288 | 286 | 283 | 281 | 278 | 275 | 273 | 271 | 268 | 266 | 263 | 261 | 258 | 256 | 254 |
| 65 | 304 | 301 | 298 | 295 | 292 | 290 | 287 | 285 | 282 | 280 | 277 | 275 | 272 | 270 | 267 | 265 | 262 | 259 | 258 | 255 |
| 66 | 306 | 302 | 300 | 296 | 294 | 291 | 289 | 286 | 284 | 281 | 279 | 276 | 274 | 271 | 269 | 266 | 264 | 261 | 259 | 257 |
| 67 | 307 | 305 | 301 | 298 | 295 | 293 | 290 | 288 | 285 | 283 | 280 | 278 | 275 | 273 | 270 | 269 | 265 | 263 | 260 | 258 |
| 68 | 309 | 306 | 303 | 300 | 297 | 294 | 292 | 289 | 287 | 285 | 282 | 279 | 277 | 275 | 272 | 270 | 267 | 264 | 262 | 259 |
| 69 | 311 | 308 | 305 | 302 | 299 | 296 | 293 | 291 | 288 | 286 | 284 | 281 | 278 | 276 | 274 | 271 | 269 | 266 | 264 | 261 |
| 70 | 312 | 310 | 307 | 304 | 301 | 298 | 295 | 292 | 290 | 287 | 285 | 283 | 280 | 278 | 275 | 273 | 270 | 268 | 265 | 262 |
| 71 | 314 | 311 | 308 | 306 | 302 | 299 | 297 | 294 | 291 | 289 | 287 | 284 | 282 | 280 | 277 | 275 | 272 | 269 | 267 | 264 |
| 72 | 316 | 313 | 310 | 307 | 304 | 301 | 299 | 295 | 293 | 291 | 288 | 286 | 283 | 281 | 279 | 276 | 274 | 271 | 269 | 266 |
| 73 | 318 | 314 | 312 | 308 | 306 | 303 | 300 | 297 | 295 | 292 | 289 | 287 | 285 | 282 | 280 | 277 | 275 | 273 | 270 | 268 |
| 74 | 319 | 316 | 313 | 310 | 308 | 305 | 302 | 299 | 296 | 293 | 291 | 289 | 286 | 284 | 281 | 279 | 277 | 274 | 272 | 270 |



2. *Gas displacement provers:* Those in which vaporization is retarded by displacement, by the test liquid, of a saturated gas atmosphere from the prover.

3. *Vapor displacement provers:* Those in which vaporization is retarded by displacement, by the test liquid, of the saturated vapor of the test liquid from the prover.

4. *Vapor-condensing provers:* Those which are completely filled so that all vapor in the prover is condensed.

5. *Piston provers:* Those in which a fixed quantity of the test liquid is displaced from the prover by means of a free piston.

6. *Master meter provers:* Those in which the test liquid used in a previously proved meter is measured so that comparison of the measurements can be made.

**3003** With the gravimetric method, any one of the following types of provers may be employed:

*a.* Open provers (see description in Par. 3002 and Fig. 19).

*b.* Closed provers (see description in Par. 3002 and Fig. 20), including:

1. Gas displacement provers.
2. Vapor displacement provers.
3. Vapor-condensing provers.

## GENERAL PROVISIONS

**3004** A positive displacement meter should be proved in its normal installation at the expected operating rates of flow, under the pressure and temperature at which it will normally operate, and on the liquid which it will measure in normal operation. Where it is not practical to prove the meter on the liquid being metered, the meter should be proved on a liquid having an API gravity and viscosity as close as possible to those of the liquid to be measured during normal operation. When a meter is measuring several different liquids, the meter should be proved on each liquid.

**3005** There are many petroleum liquids of different vapor pressures which are measured by meters. When the liquid loss through evaporation during proving significantly affects the liquid measurement, the proving method must take into consideration means to control the evaporation loss.

**3006** The proving of a meter is somewhat in the nature of a laboratory test and, when properly accomplished, can provide a high degree of measurement accuracy. There are many details of the meter, its piping, and proving system which can contribute to measurement inaccuracies; for example, physical properties of the measured liquid, temperature effects, corrosion, and trapped air. Thorough periodic inspection of all provers and their appurtenances should be made with sufficient frequency to assure accuracy. It is essential that meter performance data be observed and recorded carefully, and that subsequent calculations be correct.

**3007** Each of the proving methods and provers has advantages and disadvantages, depending upon the liquid being metered and the type of operation. The gravimetric method is advantageous where the metered liquid is viscous or has a tendency to deposit wax, sand, or other solids. These foreign materials have no effect on the accuracy of the gravimetric method, whereas they may cause serious inaccuracies in the volumetric method. The gravimetric method requires that the API or specific gravity of the metered liquid be accurately determined, as outlined in Par. 3053 through Par. 3056, in order to have a basis for converting weight to volume. The effect of the buoyancy of air, as outlined in Par. 3059 through Par. 3060, must be considered in gravimetric proving if the closest approach to accuracy is required. The volumetric method is advantageous where gravity determinations may be difficult or of dubious accuracy. The method is also more direct in that conversions from weight to volume are not required.

**3008** There are two procedures for conducting a meter proof run, as follows:

*a.* The standing start-and-stop procedure.

*b.* The running start-and-stop procedure.

The standing start-and-stop procedure utilizes standard registers, and the opening and closing readings are obtained at no-flow conditions. If flow is started too rapidly, the pressure in the piping may fall below the vapor pressure of the liquid, causing vapor to pass through the meter. Too rapid a change of velocity of the test liquid may also cause hydraulic shock.

The running start-and-stop procedure involves obtaining the opening and closing meter readings of the proof while the meter is in operation. Unless special registers are used, the length of the run in this procedure must be sufficient to make inaccuracies in reading at start and finish insignificant. Special register equipment may take readings photographically in synchronism with the movement of test controls, or the meter may be equipped with auxiliary or secondary registers which may be started or stopped in conjunction with test controls. In these procedures, any electrical or mechanical lag in actuation of meter registers should be compensated for in the calibration of the prover. It is important that no excessive drag be introduced on the meter's measuring element from auxiliary registers and equipment.

**3009** There are two general end results desired in meter proving, usually dependent upon the type of service in which a meter is to measure. First, it may be desired to prove a meter and establish its performance (by adjustment of its registration, if necessary) so that its register will indicate the quantity of liquid actually delivered within tolerances permitted by the operation or by law. This is the normal practice in the case of a meter operating on intermittent deliveries, such as a tank truck meter or a loading rack meter at a terminal or bulk plant. In such cases, the meter register is made to

*Where:*

$V_w$ = volume withdrawn from prover as pressure is decreased from $P_p$ to $P_a$.

$P_a$ = starting pressure (atmospheric) in prover tank, in pounds per square inch absolute.

$P_p$ = operating (test) pressure in prover tank, in pounds per square inch absolute.

EXAMPLE:

Assume a steel tank, rated capacity 1,250.00 gal, filled with water to the 1,250.00-gal mark at atmospheric pressure (27 in. of mercury barometer equals 13.26 psia), and then loaded with 150 psig air pressure is applied, the observed volume on the upper sure in order to find $C_{ps}$ at 150 psig. When this pressure scale is 1,248.50 gal. The quantity of water between the bottom zero mark and the stop valves is calculated as being 40.00 gal.

$$C_{ps} = 2 - (163.26 - 13.26)\ (0.0000032) - \frac{1{,}248.50 + 40.00}{1{,}250 + 40.00}$$

$$= 1.00068 \text{ at } 150 \text{ psig}$$

## DETERMINATION OF WATER VOLUME CORRECTIONS FOR TEMPERATURE CHANGES

**2123** Whenever the temperature of the liquid in a test measure varies from the average temperature measured in the full prover, volume corrections are necessary to insure correct volume determinations. The following procedure is for the withdrawal of water from a prover into test measures. If the prover is filled from test measures, appropriate changes in the procedure must be made.

The average temperature of the full prover shall be obtained immediately prior to commencement of withdrawals. The temperature of the contents of each test measure withdrawn shall be determined immediately after filling by using a certified etched-stem thermometer of the cup-case type designed for complete immersion. The temperature shall be determined near the midpoint of the liquid in the measure. The test measure temperature, and the volumetric reading for each withdrawal, shall be recorded in a carefully kept record. Care should be exercised to assure that each withdrawal is neither overlooked nor counted more than once.

**2124** Volume correction procedure for change in temperature of the water during the calibration of a prover is as follows:

*a.* Record starting prover temperature. If there is more than one thermometer in the prover, determine the average temperature from the several temperatures and record it as the starting prover temperature.

*b.* Record the volume, in gallons, of each test measure withdrawal.

*c.* Record the temperature of the water of each test measure withdrawn.

*d.* Record the difference between the water temperature in each withdrawal and the average starting temperature in the prover as a temperature rise, or a temperature drop, with respect to the average prover starting temperature.

*e.* After the calibration run (see Par. 2059) is completed, the test measure withdrawal volumes are totaled. This is the total recorded volume.

*f.* From Table I in Appendix B, determine the temperature correction factor for each test measure and multiply this factor by the test volume. The sum of these corrected volumes is the volume of the prover.

**2125** It must be emphasized that the volume of the prover determined by the foregoing method, wherein all volumes are corrected to the volumes at the starting prover temperature, is the true volume of the prover at 60 F. If the test measure and the prover are made of the same material, no correction of the volume of the prover to 60 F need be made. The volume of each measure certified by the National Bureau of Standards is adjusted to 60 F, so that correction of the test measure volume according to Table I, Appendix B, automatically makes the correction to 60 F.

# SECTION III—METER-PROVING PROCEDURES

## SCOPE

**3001** This section covers procedures to be used in proving positive displacement meters in liquid hydrocarbon service. The two basic types of provers, volumetric and gravimetric, described in Sect. II, are the basis of two general methods of meter proving—volumetric and gravimetric. It will be noted that the proving methods described do not parallel the descriptions of provers in Sect. II. The reason for this is that any one of several provers may be used with a given proving method. Conversely, a given prover may be used with any one of several proving methods.

**3002** With the volumetric method, any one of the following types of provers may be employed:

*a. Open provers:* Those which are open to the atmosphere through unrestricted openings.

*b. Closed provers:* Those in which a pressure greater than atmospheric is or may be maintained during the meter-proving operations. Closed provers may be classified as follows:

1. *Water displacement provers:* Those in which water is displaced by the test liquid from the prover to another vessel or to waste.



**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | Specific Gravity 60F/60F | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.540 | 0.541 | 0.542 | 0.543 | 0.544 | 0.545 | 0.546 | 0.547 | 0.548 | 0.549 | 0.550 | 0.551 | 0.552 | 0.553 | 0.554 | 0.555 | 0.556 | 0.557 | 0.558 | 0.559 |
| 75 | 321 | 318 | 315 | 312 | 309 | 307 | 304 | 301 | 298 | 295 | 293 | 290 | 288 | 285 | 283 | 281 | 278 | 276 | 274 | 271 |
| 76 | 323 | 320 | 317 | 314 | 312 | 308 | 306 | 303 | 300 | 297 | 294 | 291 | 289 | 287 | 284 | 282 | 280 | 277 | 275 | 273 |
| 77 | 325 | 322 | 319 | 316 | 313 | 310 | 307 | 305 | 302 | 299 | 296 | 293 | 291 | 288 | 286 | 283 | 281 | 279 | 277 | 274 |
| 78 | 327 | 323 | 321 | 318 | 315 | 312 | 309 | 306 | 303 | 300 | 298 | 295 | 292 | 290 | 287 | 285 | 283 | 281 | 278 | 276 |
| 79 | 328 | 325 | 323 | 320 | 317 | 314 | 311 | 308 | 305 | 302 | 300 | 296 | 294 | 291 | 289 | 287 | 285 | 282 | 280 | 278 |
| 80 | 330 | 327 | 324 | 321 | 319 | 316 | 313 | 310 | 307 | 304 | 301 | 298 | 296 | 293 | 290 | 288 | 286 | 283 | 281 | 279 |
| 81 | 332 | 329 | 326 | 323 | 320 | 318 | 315 | 312 | 309 | 306 | 303 | 300 | 297 | 294 | 292 | 289 | 287 | 285 | 283 | 281 |
| 82 | 335 | 331 | 328 | 325 | 322 | 319 | 317 | 314 | 311 | 308 | 305 | 302 | 299 | 296 | 293 | 291 | 289 | 287 | 285 | 283 |
| 83 | 337 | 334 | 330 | 327 | 324 | 321 | 319 | 316 | 313 | 310 | 307 | 304 | 301 | 298 | 295 | 293 | 291 | 289 | 286 | 284 |
| 84 | 339 | 336 | 332 | 329 | 326 | 323 | 320 | 318 | 315 | 312 | 309 | 306 | 303 | 300 | 297 | 295 | 292 | 290 | 288 | 286 |
| 85 | 341 | 338 | 334 | 331 | 328 | 325 | 322 | 319 | 317 | 313 | 311 | 308 | 305 | 302 | 299 | 297 | 294 | 291 | 289 | 287 |
| 86 | 343 | 340 | 336 | 333 | 330 | 327 | 324 | 321 | 318 | 315 | 313 | 310 | 307 | 304 | 301 | 299 | 296 | 293 | 291 | 289 |
| 87 | 345 | 342 | 338 | 335 | 332 | 329 | 326 | 323 | 320 | 317 | 315 | 312 | 309 | 306 | 303 | 301 | 298 | 295 | 293 | 290 |
| 88 | 347 | 344 | 340 | 337 | 334 | 331 | 328 | 325 | 322 | 319 | 317 | 314 | 311 | 308 | 305 | 303 | 300 | 297 | 294 | 292 |
| 89 | 349 | 346 | 342 | 339 | 336 | 333 | 331 | 327 | 324 | 321 | 319 | 316 | 313 | 310 | 307 | 305 | 302 | 299 | 296 | 294 |
| 90 | 352 | 348 | 345 | 341 | 338 | 335 | 333 | 329 | 326 | 323 | 321 | 318 | 315 | 312 | 309 | 307 | 304 | 301 | 298 | 296 |
| 91 | 345 | 350 | 347 | 344 | 340 | 337 | 334 | 332 | 328 | 325 | 323 | 320 | 317 | 314 | 311 | 309 | 306 | 303 | 300 | 298 |
| 92 | 356 | 353 | 349 | 346 | 342 | 339 | 336 | 333 | 330 | 327 | 325 | 322 | 319 | 316 | 313 | 311 | 308 | 305 | 302 | 300 |
| 93 | 358 | 355 | 352 | 348 | 345 | 341 | 338 | 335 | 333 | 330 | 327 | 324 | 321 | 318 | 315 | 313 | 310 | 307 | 305 | 302 |
| 94 | 360 | 357 | 354 | 350 | 347 | 343 | 340 | 337 | 335 | 332 | 329 | 326 | 323 | 320 | 317 | 315 | 312 | 309 | 307 | 304 |
| 95 | 363 | 359 | 356 | 353 | 349 | 346 | 343 | 339 | 337 | 334 | 331 | 328 | 325 | 323 | 319 | 317 | 314 | 311 | 307 | 306 |
| 96 | 365 | 362 | 358 | 355 | 352 | 348 | 345 | 342 | 339 | 336 | 333 | 330 | 327 | 325 | 322 | 319 | 316 | 313 | 311 | 308 |
| 97 | 368 | 364 | 360 | 357 | 354 | 350 | 347 | 344 | 341 | 338 | 335 | 333 | 330 | 327 | 324 | 322 | 318 | 315 | 313 | 310 |
| 98 | 370 | 366 | 362 | 359 | 356 | 353 | 350 | 347 | 343 | 340 | 337 | 335 | 332 | 329 | 326 | 324 | 321 | 317 | 315 | 312 |
| 99 | 372 | 369 | 365 | 361 | 358 | 355 | 352 | 349 | 346 | 342 | 339 | 337 | 334 | 331 | 328 | 326 | 323 | 320 | 318 | 315 |
| 100 | 375 | 372 | 368 | 364 | 361 | 357 | 355 | 352 | 348 | 345 | 342 | 339 | 335 | 333 | 330 | 328 | 325 | 323 | 320 | 317 |
| 101 | 377 | 374 | 370 | 366 | 363 | 360 | 357 | 354 | 350 | 347 | 345 | 341 | 338 | 336 | 333 | 330 | 327 | 325 | 322 | 319 |
| 102 | 379 | 376 | 373 | 369 | 365 | 362 | 359 | 356 | 353 | 349 | 347 | 344 | 340 | 338 | 335 | 332 | 329 | 327 | 325 | 321 |
| 103 | 382 | 378 | 375 | 372 | 368 | 364 | 361 | 358 | 355 | 352 | 349 | 346 | 343 | 340 | 337 | 335 | 332 | 329 | 327 | 324 |
| 104 | 385 | 381 | 377 | 374 | 371 | 367 | 363 | 360 | 357 | 354 | 351 | 348 | 345 | 342 | 339 | 337 | 334 | 331 | 329 | 326 |
| 105 | 387 | 383 | 380 | 376 | 373 | 370 | 366 | 363 | 359 | 357 | 354 | 351 | 347 | 345 | 341 | 339 | 336 | 334 | 331 | 328 |
| 106 | 390 | 386 | 382 | 378 | 375 | 372 | 369 | 366 | 362 | 359 | 356 | 353 | 350 | 347 | 344 | 341 | 338 | 336 | 334 | 330 |
| 107 | 392 | 388 | 385 | 381 | 378 | 375 | 371 | 368 | 365 | 361 | 358 | 355 | 353 | 349 | 347 | 343 | 340 | 338 | 336 | 333 |
| 108 | 395 | 391 | 387 | 383 | 380 | 377 | 373 | 370 | 367 | 364 | 360 | 357 | 355 | 352 | 349 | 346 | 343 | 340 | 338 | 335 |
| 109 | 397 | 394 | 390 | 386 | 382 | 379 | 376 | 373 | 369 | 366 | 363 | 360 | 357 | 354 | 351 | 348 | 346 | 342 | 340 | 337 |
| 110 | 400 | 396 | 392 | 388 | 385 | 381 | 378 | 375 | 372 | 369 | 366 | 362 | 359 | 356 | 353 | 351 | 348 | 345 | 342 | 339 |
| 111 | 402 | 398 | 395 | 391 | 387 | 384 | 380 | 377 | 374 | 371 | 368 | 365 | 362 | 358 | 356 | 353 | 350 | 347 | 344 | 341 |
| 112 | 404 | 400 | 397 | 393 | 390 | 386 | 382 | 379 | 377 | 373 | 370 | 367 | 365 | 361 | 358 | 355 | 352 | 350 | 347 | 344 |
| 113 | 407 | 403 | 399 | 396 | 392 | 389 | 385 | 381 | 379 | 376 | 372 | 369 | 367 | 364 | 360 | 357 | 355 | 352 | 349 | 347 |
| 114 | 409 | 406 | 402 | 398 | 395 | 392 | 387 | 384 | 381 | 377 | 375 | 371 | 369 | 366 | 362 | 359 | 357 | 354 | 352 | 349 |
| 115 | 411 | 408 | 404 | 400 | 397 | 394 | 390 | 386 | 383 | 379 | 377 | 374 | 371 | 368 | 365 | 362 | 359 | 356 | 354 | 351 |
| 116 | 414 | 410 | 407 | 403 | 399 | 396 | 392 | 389 | 385 | 381 | 379 | 376 | 373 | 370 | 367 | 365 | 361 | 358 | 356 | 353 |
| 117 | 416 | 413 | 409 | 405 | 402 | 399 | 395 | 391 | 388 | 384 | 381 | 378 | 375 | 372 | 369 | 367 | 364 | 360 | 358 | 356 |
| 118 | 419 | 415 | 412 | 408 | 404 | 401 | 398 | 394 | 390 | 386 | 383 | 380 | 377 | 374 | 371 | 369 | 366 | 363 | 360 | 358 |
| 119 | 422 | 418 | 414 | 410 | 407 | 404 | 400 | 396 | 393 | 389 | 385 | 382 | 379 | 377 | 373 | 371 | 368 | 365 | 363 | 360 |
| 120 | 424 | 420 | 416 | 413 | 409 | 406 | 402 | 398 | 395 | 392 | 388 | 384 | 381 | 378 | 375 | 373 | 370 | 367 | 365 | 362 |
| 121 | 427 | 422 | 418 | 415 | 412 | 409 | 404 | 401 | 397 | 394 | 390 | 386 | 383 | 380 | 377 | 375 | 372 | 369 | 366 | 364 |
| 122 | 430 | 425 | 421 | 417 | 414 | 411 | 407 | 403 | 399 | 396 | 392 | 389 | 385 | 382 | 379 | 377 | 374 | 371 | 369 | 367 |
| 123 | 433 | 428 | 424 | 419 | 416 | 413 | 410 | 406 | 402 | 398 | 395 | 392 | 388 | 384 | 381 | 379 | 376 | 373 | 371 | 368 |
| 124 | 436 | 431 | 427 | 422 | 418 | 415 | 412 | 408 | 404 | 401 | 397 | 394 | 390 | 386 | 383 | 380 | 378 | 375 | 373 | 371 |
| 125 | 439 | 434 | 430 | 425 | 420 | 417 | 414 | 411 | 407 | 403 | 400 | 396 | 393 | 389 | 385 | 382 | 379 | 377 | 375 | 373 |
| 126 | 442 | 437 | 433 | 428 | 423 | 419 | 416 | 413 | 410 | 406 | 402 | 399 | 395 | 392 | 388 | 385 | 381 | 379 | 377 | 374 |
| 127 | 444 | 440 | 435 | 431 | 426 | 422 | 419 | 415 | 412 | 408 | 405 | 401 | 398 | 394 | 391 | 387 | 384 | 381 | 378 | 376 |
| 128 | 447 | 443 | 439 | 434 | 430 | 425 | 421 | 418 | 415 | 411 | 408 | 404 | 401 | 397 | 393 | 390 | 386 | 383 | 380 | 378 |

**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | Specific Gravity 60F/60F 0.560 | 0.561 | 0.562 | 0.563 | 0.564 | 0.565 | 0.566 | 0.567 | 0.568 | 0.569 | 0.570 | 0.571 | 0.572 | 0.573 | 0.574 | 0.575 | 0.576 | 0.577 | 0.578 | 0.579 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 200 | 198 | 196 | 195 | 193 | 191 | 189 | 187 | 185 | 184 | 182 | 180 | 178 | 177 | 175 | 174 | 172 | 171 | 170 | 168 |
| 21 | 201 | 199 | 197 | 196 | 194 | 192 | 190 | 188 | 186 | 185 | 183 | 181 | 179 | 178 | 176 | 174 | 173 | 172 | 171 | 169 |
| 22 | 202 | 200 | 198 | 196 | 195 | 193 | 191 | 189 | 187 | 186 | 184 | 182 | 180 | 179 | 177 | 175 | 174 | 173 | 171 | 170 |
| 23 | 203 | 201 | 199 | 198 | 196 | 194 | 192 | 190 | 188 | 187 | 185 | 183 | 181 | 180 | 178 | 176 | 175 | 173 | 172 | 171 |
| 24 | 204 | 202 | 200 | 199 | 197 | 195 | 193 | 191 | 190 | 188 | 186 | 184 | 182 | 180 | 179 | 177 | 175 | 174 | 173 | 172 |
| 25 | 205 | 203 | 201 | 200 | 198 | 196 | 194 | 192 | 190 | 189 | 187 | 185 | 183 | 181 | 180 | 178 | 176 | 175 | 174 | 172 |
| 26 | 206 | 204 | 202 | 200 | 199 | 197 | 195 | 193 | 191 | 190 | 188 | 186 | 184 | 182 | 181 | 179 | 177 | 176 | 175 | 173 |
| 27 | 207 | 205 | 203 | 201 | 200 | 198 | 196 | 194 | 192 | 191 | 189 | 187 | 185 | 183 | 182 | 180 | 178 | 177 | 175 | 174 |
| 28 | 208 | 206 | 204 | 202 | 200 | 199 | 197 | 195 | 193 | 191 | 190 | 188 | 186 | 184 | 183 | 181 | 179 | 178 | 176 | 175 |
| 29 | 209 | 207 | 205 | 203 | 201 | 200 | 198 | 196 | 194 | 193 | 191 | 189 | 187 | 185 | 184 | 182 | 180 | 179 | 177 | 176 |
| 30 | 210 | 208 | 206 | 204 | 202 | 201 | 199 | 197 | 195 | 194 | 192 | 190 | 188 | 186 | 185 | 183 | 181 | 180 | 178 | 177 |
| 31 | 211 | 209 | 207 | 205 | 203 | 201 | 200 | 198 | 196 | 195 | 193 | 191 | 189 | 187 | 186 | 184 | 182 | 181 | 179 | 177 |
| 32 | 212 | 210 | 208 | 206 | 204 | 202 | 200 | 199 | 197 | 196 | 194 | 192 | 190 | 188 | 187 | 185 | 183 | 182 | 180 | 178 |
| 33 | 213 | 211 | 209 | 207 | 205 | 203 | 201 | 199 | 198 | 197 | 195 | 193 | 191 | 189 | 188 | 186 | 184 | 183 | 181 | 179 |
| 34 | 214 | 212 | 210 | 208 | 206 | 204 | 202 | 200 | 199 | 197 | 196 | 194 | 192 | 190 | 189 | 187 | 185 | 184 | 182 | 180 |
| 35 | 215 | 213 | 211 | 209 | 207 | 205 | 203 | 201 | 200 | 198 | 197 | 195 | 193 | 191 | 190 | 188 | 186 | 185 | 183 | 181 |
| 36 | 216 | 214 | 212 | 210 | 208 | 206 | 204 | 202 | 201 | 199 | 198 | 196 | 194 | 192 | 191 | 189 | 187 | 186 | 184 | 182 |
| 37 | 217 | 215 | 213 | 211 | 209 | 207 | 205 | 204 | 202 | 200 | 199 | 197 | 195 | 193 | 192 | 190 | 188 | 187 | 185 | 183 |
| 38 | 218 | 216 | 214 | 212 | 210 | 208 | 206 | 205 | 203 | 201 | 199 | 198 | 196 | 194 | 193 | 191 | 189 | 188 | 186 | 184 |
| 39 | 220 | 217 | 215 | 213 | 211 | 209 | 207 | 206 | 204 | 202 | 200 | 198 | 197 | 195 | 194 | 192 | 190 | 189 | 187 | 185 |
| 40 | 221 | 218 | 216 | 214 | 213 | 210 | 208 | 207 | 205 | 203 | 201 | 199 | 198 | 196 | 195 | 193 | 191 | 189 | 188 | 186 |
| 41 | 222 | 220 | 218 | 216 | 214 | 212 | 209 | 208 | 206 | 204 | 202 | 200 | 199 | 197 | 196 | 194 | 192 | 191 | 189 | 187 |
| 42 | 224 | 221 | 219 | 217 | 215 | 213 | 211 | 209 | 207 | 205 | 203 | 201 | 199 | 198 | 196 | 195 | 193 | 191 | 190 | 188 |
| 43 | 225 | 223 | 220 | 218 | 216 | 214 | 212 | 210 | 208 | 206 | 204 | 202 | 200 | 199 | 197 | 196 | 194 | 192 | 191 | 189 |
| 44 | 226 | 224 | 221 | 219 | 217 | 215 | 213 | 211 | 209 | 207 | 205 | 203 | 202 | 200 | 198 | 197 | 195 | 193 | 192 | 190 |
| 45 | 228 | 225 | 223 | 220 | 218 | 216 | 214 | 212 | 210 | 208 | 206 | 204 | 203 | 201 | 199 | 198 | 196 | 194 | 193 | 191 |
| 46 | 229 | 227 | 224 | 222 | 220 | 217 | 215 | 213 | 211 | 209 | 207 | 205 | 204 | 202 | 200 | 199 | 197 | 195 | 193 | 192 |
| 47 | 230 | 228 | 226 | 223 | 221 | 219 | 217 | 214 | 213 | 211 | 209 | 206 | 205 | 203 | 201 | 199 | 198 | 196 | 195 | 193 |
| 48 | 232 | 229 | 227 | 224 | 222 | 220 | 218 | 216 | 214 | 212 | 210 | 208 | 206 | 204 | 202 | 200 | 199 | 197 | 196 | 194 |
| 49 | 233 | 231 | 228 | 226 | 224 | 222 | 219 | 217 | 215 | 213 | 211 | 209 | 207 | 205 | 203 | 201 | 200 | 198 | 197 | 195 |
| 50 | 234 | 232 | 229 | 227 | 225 | 223 | 220 | 218 | 216 | 214 | 212 | 210 | 208 | 206 | 204 | 202 | 201 | 199 | 198 | 196 |
| 51 | 235 | 233 | 230 | 228 | 226 | 224 | 222 | 220 | 217 | 215 | 213 | 211 | 209 | 207 | 206 | 204 | 202 | 200 | 199 | 197 |
| 52 | 236 | 234 | 232 | 230 | 228 | 225 | 223 | 221 | 219 | 217 | 214 | 212 | 211 | 209 | 207 | 205 | 203 | 201 | 199 | 198 |
| 53 | 237 | 235 | 233 | 231 | 229 | 227 | 224 | 222 | 220 | 218 | 216 | 214 | 212 | 210 | 208 | 206 | 204 | 202 | 201 | 199 |
| 54 | 239 | 236 | 234 | 232 | 230 | 228 | 226 | 224 | 221 | 219 | 217 | 215 | 213 | 211 | 209 | 207 | 206 | 204 | 202 | 200 |
| 55 | 240 | 238 | 236 | 234 | 232 | 230 | 227 | 225 | 223 | 220 | 218 | 216 | 214 | 213 | 211 | 209 | 207 | 205 | 203 | 201 |
| 56 | 242 | 239 | 237 | 235 | 233 | 231 | 229 | 226 | 224 | 222 | 220 | 218 | 216 | 214 | 212 | 210 | 208 | 206 | 204 | 202 |
| 57 | 243 | 241 | 238 | 236 | 234 | 232 | 230 | 227 | 225 | 223 | 221 | 219 | 217 | 215 | 213 | 211 | 209 | 207 | 206 | 204 |
| 58 | 244 | 242 | 240 | 237 | 235 | 233 | 231 | 229 | 226 | 224 | 222 | 220 | 218 | 216 | 214 | 212 | 211 | 209 | 207 | 205 |
| 59 | 245 | 243 | 241 | 239 | 237 | 235 | 232 | 230 | 228 | 226 | 223 | 221 | 219 | 217 | 216 | 214 | 212 | 210 | 208 | 206 |
| 60 | 247 | 244 | 243 | 240 | 238 | 236 | 233 | 231 | 229 | 227 | 224 | 222 | 220 | 219 | 217 | 215 | 213 | 211 | 209 | 207 |
| 61 | 248 | 245 | 244 | 241 | 239 | 237 | 235 | 232 | 230 | 228 | 226 | 224 | 222 | 220 | 218 | 216 | 214 | 212 | 211 | 209 |
| 62 | 249 | 247 | 245 | 243 | 241 | 239 | 236 | 234 | 231 | 229 | 227 | 225 | 223 | 221 | 219 | 217 | 216 | 214 | 212 | 210 |
| 63 | 251 | 248 | 246 | 244 | 242 | 240 | 238 | 235 | 232 | 230 | 228 | 226 | 224 | 222 | 220 | 219 | 217 | 215 | 213 | 211 |
| 64 | 252 | 250 | 247 | 245 | 243 | 241 | 239 | 236 | 234 | 232 | 229 | 227 | 225 | 224 | 222 | 220 | 218 | 216 | 214 | 212 |
| 65 | 253 | 251 | 249 | 247 | 245 | 243 | 241 | 237 | 235 | 233 | 231 | 229 | 227 | 225 | 223 | 221 | 219 | 218 | 216 | 214 |
| 66 | 255 | 252 | 250 | 248 | 246 | 244 | 242 | 239 | 236 | 234 | 232 | 230 | 228 | 226 | 224 | 222 | 221 | 219 | 217 | 215 |
| 67 | 256 | 253 | 251 | 249 | 247 | 245 | 243 | 241 | 238 | 236 | 233 | 231 | 229 | 227 | 225 | 224 | 222 | 220 | 218 | 217 |
| 68 | 257 | 255 | 253 | 251 | 249 | 246 | 244 | 242 | 240 | 237 | 235 | 233 | 231 | 229 | 227 | 225 | 223 | 221 | 219 | 218 |
| 69 | 258 | 256 | 254 | 252 | 250 | 248 | 245 | 243 | 241 | 239 | 236 | 234 | 232 | 230 | 228 | 226 | 224 | 222 | 221 | 219 |
| 70 | 260 | 257 | 255 | 253 | 251 | 249 | 247 | 244 | 242 | 240 | 238 | 235 | 233 | 231 | 229 | 227 | 225 | 224 | 222 | 220 |
| 71 | 261 | 259 | 257 | 255 | 253 | 250 | 248 | 245 | 244 | 242 | 240 | 237 | 235 | 233 | 231 | 229 | 227 | 225 | 223 | 221 |
| 72 | 263 | 261 | 258 | 256 | 254 | 252 | 249 | 247 | 245 | 243 | 241 | 238 | 236 | 234 | 232 | 230 | 228 | 226 | 224 | 222 |
| 73 | 265 | 262 | 259 | 257 | 255 | 253 | 251 | 248 | 246 | 244 | 242 | 240 | 238 | 235 | 233 | 231 | 229 | 227 | 225 | 224 |
| 74 | 267 | 264 | 261 | 259 | 257 | 255 | 252 | 249 | 247 | 245 | 244 | 241 | 240 | 237 | 235 | 233 | 231 | 229 | 227 | 225 |



**2109** The calibration is repeated until two successive volume determinations agree within 0.02 per cent of the prover volume. The average of these two volumes shall be used.

**2110** The required graduations are marked on the gage glass scales, and these scales are securely attached and sealed as required.

## CALIBRATION OF A GRAVIMETRIC PROVER (See Fig. 19 and Fig. 20)

**2111** The following paragraphs describe the method of calibrating a gravimetric prover at 60 F and atmospheric pressure. The question of "to contain" or "to deliver" is not applicable.

**2112** The first operation is to assure that the weigh scale is on a firm foundation and that the platform is level (see Par. 2019).

**2113** The second operation is to install the tank, complete with piping and appurtenances, on the scale.

**2114** The third operation is to check the accuracy and sensitivity of the scale in accordance with NBS Handbook H 44. Tests shall be made with certified test weights applied in approximately equal increments and extending over the entire scale range. Two test runs should be made—one by adding weights from zero to full capacity, and the other by subtracting weights from full to zero capacity.

**2115** All instruments used in specific gravity determinations and air density determinations related to the use of the gravimetric prover shall be checked for accuracy.

## DETERMINATION OF PROVER VOLUME UNDER PRESSURE

**2116** If a volumetric prover is to be used at a pressure significantly above atmospheric pressure, a correction factor should be determined to correct for the resulting increase in prover volume over the volume determined in calibrating the prover at atmospheric pressure. This correction factor is referred to as $C_{ps}$ and will always be unity or greater. This factor should be determined experimentally for each prover.

**2117** For a prover that is to be used at a single working pressure, a correction factor should be determined at that pressure. If it is to be used at varying pressures, correction factors should be determined throughout the range of such operating pressures and a table, or curve, of pressure correction factors ($C_{ps}$) prepared. This should be done at the time the prover is calibrated.

**2118** Facilities should be provided for pressuring the prover to its maximum operating pressure.

**2119** For provers with top gage glasses, the first operation is to fill the prover with water to a mark near the top of the upper gage glass and record the gaged volume of the water in the tank at atmospheric pressure. Keeping the water temperature as nearly constant as possible, gas or air is introduced under pressure into the top of the prover, in reasonable pressure increments, until the maximum operating pressure has been reached. With each increment of pressure, the indicated volume of the water and the prover pressure are recorded.

**2120** The second operation is to reduce the pressure, in reasonable decrements, from the high pressure just obtained until atmospheric pressure has been reached. As before, the incremental volume of water for each pressure is recorded.

**2121** If the prover does not have a top gage glass, the volume change with pressure is determined by first pressuring the prover with water to the maximum expected operating pressure and then withdrawing water to reduce the pressure. The volume of water withdrawn between each increment of pressure is accurately measured and recorded.

**2122** A graph, or table, of pressure versus volume change is prepared, and the percentage change in the gaged volume from the actual atmospheric pressure volume may be calculated. A table, or curve, of volume correction factors is then prepared to cover the range of operating pressures. The formula for finding the factor $C_{ps}$ for a prover with neck or necks at any pressure $P_p$ is as follows:

$$C_{ps} = 1 + \frac{\begin{pmatrix}\text{observed increase}\\ \text{in tank volume}\\ \text{caused by increase}\\ \text{in pressure}\end{pmatrix} - \begin{pmatrix}\text{decrease in liquid}\\ \text{volume caused by}\\ \text{increase in pres-}\\ \text{sure}\end{pmatrix}}{\text{(original tank volume)}}$$

$$= 1 + \frac{(V_a+Q) - (V_p+Q) - (V_a+Q)(P_p-P_a)(F)}{(V_a+Q)}$$

$$= 2 - (P_p-P_a)(F) - \frac{(V_p+Q)}{(V_a+Q)}$$

*Where:*

$C_{ps}$ = pressure correction factor of prover tank.
$P_a$ = starting pressure (atmospheric) in prover tank, in pounds per square inch absolute.
$P_p$ = operating (test) pressure in prover tank, in pounds per square inch absolute.
$V_a$ = observed volume in prover tank at pressure $P_a$.
$V_p$ = observed volume in prover tank at pressure $P_p$.
Q = calculated or measured volume of liquid between the bottom reference mark of the prover tank and the stop valves.
F = compressibility factor for the liquid in the tank (0.0000032 per psi increase above atmospheric pressure for water from 1 psig to 1,000 psig).

For a vapor-condensing prover, the formula for finding the factor $C_{ps}$ at any pressure $P_p$ is as follows:

$$C_{ps} = 1 + \frac{\Delta V}{V_a}$$

*Where:*

$C_{ps}$ = pressure correction factor of prover tank.
$V_a$ = observed volume in prover tank at pressure $P_a$.
$\Delta V$ = volume change attributable to pressure
$= V_w - (V_a + V_w)(P_p - P_a)(F)$.

total flow rate capacity essentially equal to the flow rate in the prover section to be calibrated, is employed. Each meter in the calibration unit must be equipped with a continuously operating totalizer register and an auxiliary on-off proving register similar to the registers on the meters to be subsequently proved with the prover.

**2096** The first operation is to prove the individual meter or meters of this master meter calibration unit by an approved method, using the same liquid as is to be measured in the calibration of the prover section. Curves for meter accuracy versus rate of flow are plotted for each of the individual meters in the unit, and observations of the liquid temperatures and operating pressures are recorded.

**2097** The second operation is to connect these meters in parallel so that each meter measures its share of the total throughput expected through the master meter calibration unit. This master meter calibration unit is then connected in series with the prover section so that all of the liquid which passes through the master meter calibration unit must pass through the prover section. The operating mechanisms of the auxiliary proving registers are connected so that all will be actuated by the piston when it passes by the reference points.

**2098** The third operation is to direct the normal line flow through the master meter calibration unit and into the prover section, or vice versa, as follows: Make certain that the individual flow rates for each of the master meters lies within the range for which it was previously proved. Operate until the temperature of the meters and test liquid have equalized and all air and vapor have been eliminated, then launch the piston into the prover section. This piston moves through the prover section, actuating the mechanisms at the reference points and displacing the volume between them. It is stopped in the receiving barrel. Record the opening and closing meter readings and temperatures and the time required for the piston to travel between the reference points. Record the pressure and temperature of the liquid, either as displaced from the prover section if the meters are downstream or displaced into the prover section if the meters are upstream (see Fig. 41). Determine the rate of flow for each meter during the calibration of the meter prover section, and from their meter accuracy curves determine their respective performance factors. If necessary, make compressibility corrections when the meter operating pressures are not the same as when they were proved. Using these factors, determine the total observed throughput of the master meters. This is the observed volume of the prover section between reference points. The net prover volume at 60 F and at the required reference pressure is determined by application of the formula of Par. 3044, and as illustrated at the bottom of Fig. 41.

**2099** Repeat the calibration until two successive readings agree within 0.02 per cent of the volume of the prover section. The average of these two readings shall be used as the volume of the prover section.

### Calibration of a Volumetric Prover by Use of a Master Meter

**2100** In calibrating some provers, particularly large provers, it may be more expedient to use a master meter rather than test measures. A meter so used will calibrate the prover "to deliver" if the prover is first filled with liquid and the liquid metered out, or if the tank walls are first thoroughly wetted before liquid is metered into the prover. Conversely, if liquid is metered into the tank when its walls are dry, the resulting calibration of the prover will be "to contain."

**2101** The first operation is to prove the non-temperature-compensated master meter and obtain the meter factor at the intended flow rate, pressure, and temperature, using a calibrated prover or test measure and the same liquid with which it is intended to calibrate the uncalibrated prover. This test liquid may be water or some stable petroleum liquid.

**2102** The prover is then calibrated in accordance with the appropriate method, except that volumes are determined by the master meter rather than by test measures. If the prover being calibrated is equipped with a neck or necks, it is often more practical to calibrate the neck or necks by use of test measures and the body of the prover by use of the master meter.

**2103** Sufficient temperature readings must be taken at the meter to enable computation of the average temperature of the liquid metered. Volume correction necessitated by temperature differences between the metered liquid and the liquid in the filled prover must be made in accordance with Par. 2123 through Par. 2125.

**2104** The following paragraphs illustrate the use of a master meter to calibrate the body of a prover with elongated necks top and bottom with water, "to deliver" at 60 F and atmospheric pressure. Test measures are used for the calibration of the top and bottom necks.

**2105** The second operation is to connect the meter so that water may be removed from the prover through the meter at the required rate of flow. This may require a pump. The prover is then filled with water to near the top of the upper neck, and the meter is operated sufficiently during the filling operation to assure that the meter and piping are liquid-full.

**2106** The third operation is to calibrate the upper neck by withdrawing water through the meter into a suitably sized test measure, as described in Par. 2051.

**2107** The fourth operation is to calibrate the prover body by withdrawing water from the prover through the meter. The meter reading and water temperature are recorded and water withdrawn until the water level appears at the top of the lower gage glass scale. During this withdrawal the meter must be operated at the rate at which it was proved. The meter factor is applied to the observed volume, and any necessary temperature corrections are made.

**2108** The fifth operation is to calibrate the lower neck by withdrawing water through the meter into suitably sized test measures, in accordance with Par. 2053.



**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | Specific Gravity 60F/60F | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.560 | 0.561 | 0.562 | 0.563 | 0.564 | 0.565 | 0.566 | 0.567 | 0.568 | 0.569 | 0.570 | 0.571 | 0.572 | 0.573 | 0.574 | 0.575 | 0.576 | 0.577 | 0.578 | 0.579 |
| 75 | 269 | 266 | 263 | 260 | 258 | 256 | 254 | 251 | 248 | 247 | 245 | 243 | 241 | 238 | 236 | 234 | 232 | 230 | 228 | 226 |
| 76 | 270 | 268 | 265 | 262 | 259 | 257 | 255 | 252 | 250 | 248 | 246 | 244 | 242 | 240 | 238 | 235 | 233 | 231 | 229 | 228 |
| 77 | 272 | 269 | 267 | 264 | 261 | 259 | 257 | 254 | 252 | 250 | 248 | 245 | 244 | 241 | 239 | 237 | 235 | 233 | 231 | 229 |
| 78 | 273 | 271 | 269 | 266 | 263 | 260 | 258 | 255 | 253 | 251 | 249 | 247 | 245 | 243 | 241 | 239 | 236 | 234 | 232 | 230 |
| 79 | 275 | 273 | 270 | 268 | 265 | 262 | 259 | 257 | 255 | 253 | 251 | 248 | 246 | 244 | 242 | 240 | 238 | 236 | 234 | 232 |
| 80 | 277 | 274 | 272 | 270 | 266 | 264 | 261 | 258 | 256 | 254 | 252 | 250 | 248 | 246 | 244 | 241 | 239 | 237 | 235 | 233 |
| 81 | 279 | 276 | 273 | 271 | 268 | 266 | 263 | 260 | 258 | 255 | 253 | 251 | 249 | 247 | 245 | 243 | 241 | 239 | 237 | 235 |
| 82 | 281 | 278 | 275 | 272 | 270 | 268 | 265 | 261 | 259 | 257 | 255 | 253 | 251 | 249 | 247 | 244 | 242 | 240 | 238 | 236 |
| 83 | 282 | 279 | 276 | 274 | 271 | 269 | 266 | 263 | 260 | 258 | 256 | 254 | 252 | 250 | 248 | 246 | 244 | 242 | 240 | 237 |
| 84 | 283 | 280 | 278 | 275 | 273 | 270 | 268 | 265 | 262 | 260 | 258 | 256 | 253 | 251 | 250 | 248 | 245 | 243 | 241 | 239 |
| 85 | 285 | 282 | 280 | 277 | 275 | 272 | 270 | 267 | 264 | 261 | 259 | 257 | 255 | 253 | 251 | 249 | 247 | 245 | 243 | 240 |
| 86 | 287 | 284 | 282 | 279 | 277 | 274 | 271 | 268 | 266 | 263 | 261 | 258 | 257 | 254 | 252 | 251 | 248 | 246 | 244 | 242 |
| 87 | 288 | 286 | 283 | 281 | 278 | 276 | 273 | 270 | 267 | 265 | 262 | 260 | 258 | 256 | 254 | 252 | 250 | 248 | 246 | 243 |
| 88 | 290 | 287 | 285 | 283 | 280 | 278 | 275 | 272 | 269 | 267 | 264 | 261 | 259 | 257 | 255 | 253 | 251 | 249 | 247 | 245 |
| 89 | 291 | 289 | 287 | 284 | 282 | 280 | 277 | 274 | 271 | 269 | 266 | 263 | 261 | 259 | 257 | 255 | 253 | 251 | 249 | 247 |
| 90 | 293 | 291 | 288 | 286 | 284 | 281 | 279 | 275 | 273 | 271 | 268 | 265 | 262 | 260 | 258 | 257 | 254 | 252 | 250 | 248 |
| 91 | 295 | 292 | 290 | 288 | 286 | 283 | 281 | 278 | 275 | 272 | 270 | 267 | 265 | 262 | 260 | 258 | 256 | 254 | 252 | 250 |
| 92 | 297 | 294 | 292 | 289 | 287 | 285 | 282 | 280 | 277 | 274 | 272 | 269 | 267 | 264 | 261 | 259 | 257 | 255 | 253 | 251 |
| 93 | 299 | 296 | 294 | 291 | 289 | 287 | 284 | 281 | 279 | 276 | 273 | 271 | 268 | 266 | 263 | 261 | 259 | 257 | 255 | 253 |
| 94 | 301 | 298 | 295 | 293 | 291 | 288 | 286 | 283 | 281 | 278 | 275 | 273 | 270 | 268 | 265 | 263 | 260 | 258 | 257 | 254 |
| 95 | 303 | 300 | 298 | 295 | 293 | 290 | 287 | 285 | 283 | 280 | 277 | 275 | 272 | 270 | 267 | 265 | 262 | 260 | 258 | 256 |
| 96 | 306 | 303 | 300 | 297 | 295 | 292 | 289 | 287 | 284 | 282 | 279 | 277 | 274 | 272 | 269 | 267 | 264 | 262 | 260 | 257 |
| 97 | 308 | 305 | 302 | 299 | 296 | 294 | 291 | 289 | 286 | 284 | 281 | 279 | 276 | 274 | 271 | 269 | 266 | 264 | 261 | 259 |
| 98 | 310 | 307 | 305 | 302 | 299 | 296 | 293 | 290 | 288 | 286 | 283 | 281 | 278 | 276 | 273 | 271 | 268 | 266 | 263 | 261 |
| 99 | 312 | 309 | 307 | 304 | 301 | 298 | 295 | 292 | 290 | 287 | 285 | 283 | 280 | 278 | 275 | 273 | 270 | 268 | 265 | 263 |
| 100 | 314 | 311 | 309 | 306 | 304 | 300 | 298 | 294 | 292 | 289 | 287 | 284 | 282 | 279 | 277 | 275 | 272 | 270 | 267 | 265 |
| 101 | 316 | 313 | 311 | 308 | 306 | 303 | 300 | 297 | 294 | 291 | 289 | 286 | 284 | 281 | 279 | 276 | 274 | 272 | 269 | 267 |
| 102 | 318 | 316 | 313 | 310 | 308 | 305 | 302 | 299 | 296 | 294 | 291 | 288 | 286 | 283 | 281 | 278 | 276 | 274 | 271 | 269 |
| 103 | 321 | 318 | 315 | 312 | 310 | 307 | 305 | 302 | 299 | 296 | 293 | 290 | 287 | 285 | 283 | 280 | 278 | 276 | 273 | 271 |
| 104 | 324 | 320 | 317 | 315 | 312 | 310 | 307 | 304 | 301 | 297 | 295 | 292 | 290 | 287 | 285 | 282 | 280 | 278 | 275 | 273 |
| 105 | 326 | 323 | 320 | 317 | 314 | 312 | 309 | 306 | 304 | 300 | 297 | 295 | 292 | 289 | 287 | 284 | 282 | 280 | 277 | 275 |
| 106 | 328 | 325 | 323 | 319 | 317 | 314 | 311 | 309 | 306 | 303 | 300 | 297 | 294 | 291 | 288 | 287 | 284 | 282 | 280 | 277 |
| 107 | 330 | 327 | 325 | 322 | 319 | 317 | 314 | 311 | 308 | 306 | 303 | 300 | 297 | 294 | 291 | 288 | 286 | 284 | 282 | 280 |
| 108 | 332 | 329 | 327 | 325 | 322 | 319 | 316 | 313 | 311 | 308 | 306 | 303 | 299 | 296 | 294 | 291 | 288 | 286 | 284 | 282 |
| 109 | 334 | 332 | 329 | 327 | 324 | 321 | 319 | 316 | 313 | 310 | 308 | 305 | 302 | 298 | 296 | 293 | 290 | 288 | 286 | 284 |
| 110 | 336 | 334 | 331 | 329 | 327 | 324 | 321 | 318 | 315 | 312 | 310 | 307 | 304 | 301 | 298 | 295 | 293 | 290 | 288 | 286 |
| 111 | 339 | 336 | 334 | 331 | 328 | 326 | 323 | 320 | 318 | 315 | 312 | 310 | 307 | 304 | 300 | 297 | 295 | 293 | 290 | 288 |
| 112 | 341 | 338 | 336 | 333 | 331 | 328 | 326 | 323 | 320 | 317 | 315 | 312 | 309 | 307 | 304 | 300 | 298 | 295 | 292 | 290 |
| 113 | 344 | 341 | 338 | 335 | 333 | 330 | 328 | 325 | 322 | 320 | 317 | 314 | 311 | 309 | 306 | 304 | 300 | 297 | 295 | 292 |
| 114 | 346 | 343 | 340 | 337 | 335 | 332 | 330 | 327 | 325 | 322 | 319 | 316 | 314 | 311 | 309 | 306 | 303 | 300 | 297 | 295 |
| 115 | 348 | 346 | 343 | 340 | 337 | 335 | 332 | 330 | 327 | 324 | 322 | 319 | 316 | 314 | 311 | 308 | 306 | 303 | 300 | 297 |
| 116 | 351 | 348 | 345 | 342 | 339 | 337 | 335 | 332 | 329 | 327 | 324 | 321 | 318 | 316 | 313 | 310 | 308 | 305 | 303 | 300 |
| 117 | 353 | 350 | 348 | 345 | 342 | 339 | 337 | 334 | 331 | 329 | 326 | 324 | 320 | 318 | 315 | 312 | 310 | 308 | 305 | 302 |
| 118 | 355 | 352 | 350 | 347 | 344 | 341 | 339 | 336 | 334 | 331 | 329 | 326 | 323 | 320 | 318 | 315 | 312 | 310 | 307 | 305 |
| 119 | 357 | 354 | 352 | 349 | 347 | 344 | 341 | 338 | 336 | 333 | 331 | 328 | 325 | 322 | 320 | 317 | 315 | 312 | 310 | 307 |
| 120 | 359 | 356 | 354 | 352 | 349 | 346 | 344 | 341 | 338 | 336 | 333 | 330 | 328 | 325 | 322 | 320 | 317 | 314 | 312 | 309 |
| 121 | 362 | 359 | 356 | 353 | 351 | 348 | 346 | 344 | 340 | 338 | 336 | 332 | 330 | 327 | 324 | 322 | 319 | 317 | 314 | 312 |
| 122 | 364 | 361 | 358 | 356 | 353 | 350 | 348 | 346 | 342 | 340 | 338 | 335 | 332 | 330 | 327 | 324 | 322 | 319 | 316 | 314 |
| 123 | 366 | 364 | 361 | 358 | 355 | 352 | 350 | 348 | 345 | 342 | 340 | 337 | 334 | 332 | 329 | 326 | 324 | 321 | 319 | 316 |
| 124 | 368 | 366 | 363 | 360 | 358 | 355 | 352 | 350 | 347 | 345 | 342 | 339 | 337 | 334 | 332 | 329 | 326 | 324 | 321 | 318 |
| 125 | 370 | 368 | 366 | 363 | 360 | 358 | 355 | 352 | 350 | 347 | 345 | 342 | 339 | 337 | 334 | 331 | 329 | 326 | 323 | 320 |
| 126 | 372 | 370 | 368 | 365 | 363 | 360 | 357 | 354 | 352 | 349 | 347 | 344 | 342 | 339 | 336 | 333 | 331 | 329 | 326 | 323 |
| 127 | 374 | 372 | 370 | 368 | 365 | 363 | 360 | 357 | 354 | 351 | 349 | 347 | 344 | 341 | 339 | 336 | 334 | 331 | 329 | 326 |
| 128 | 376 | 374 | 372 | 369 | 367 | 365 | 362 | 359 | 356 | 353 | 351 | 349 | 346 | 343 | 341 | 338 | 336 | 333 | 331 | 328 |

**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | Specific Gravity 60F/60F | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.580 | 0.581 | 0.582 | 0.583 | 0.584 | 0.585 | 0.586 | 0.587 | 0.588 | 0.589 | 0.590 | 0.591 | 0.592 | 0.593 | 0.594 | 0.595 | 0.596 | 0.597 | 0.598 | 0.599 |
| 20 | 167 | 166 | 165 | 164 | 163 | 162 | 161 | 160 | 159 | 158 | 156 | 155 | 154 | 153 | 152 | 151 | 150 | 148 | 147 | 146 |
| 21 | 168 | 167 | 166 | 165 | 164 | 162 | 161 | 160 | 159 | 158 | 157 | 156 | 155 | 154 | 153 | 151 | 150 | 149 | 148 | 147 |
| 22 | 169 | 168 | 166 | 165 | 164 | 163 | 162 | 161 | 160 | 159 | 158 | 157 | 156 | 154 | 153 | 152 | 151 | 150 | 149 | 147 |
| 23 | 169 | 168 | 167 | 166 | 165 | 164 | 163 | 162 | 160 | 159 | 158 | 157 | 156 | 155 | 154 | 153 | 152 | 150 | 149 | 148 |
| 24 | 170 | 169 | 168 | 167 | 165 | 164 | 163 | 162 | 161 | 160 | 159 | 158 | 157 | 156 | 155 | 153 | 152 | 151 | 150 | 149 |
| 25 | 171 | 170 | 168 | 167 | 166 | 165 | 164 | 163 | 162 | 161 | 159 | 158 | 157 | 156 | 155 | 154 | 153 | 152 | 150 | 149 |
| 26 | 172 | 171 | 169 | 168 | 167 | 166 | 165 | 164 | 162 | 161 | 160 | 159 | 158 | 157 | 156 | 155 | 153 | 152 | 151 | 150 |
| 27 | 173 | 171 | 170 | 169 | 168 | 166 | 165 | 164 | 163 | 162 | 161 | 160 | 159 | 157 | 156 | 155 | 154 | 153 | 152 | 151 |
| 28 | 173 | 172 | 171 | 170 | 168 | 167 | 166 | 165 | 164 | 163 | 161 | 160 | 159 | 158 | 157 | 156 | 155 | 154 | 152 | 151 |
| 29 | 174 | 173 | 172 | 170 | 169 | 168 | 167 | 166 | 165 | 163 | 162 | 161 | 160 | 159 | 158 | 156 | 155 | 154 | 153 | 152 |
| 30 | 175 | 174 | 172 | 171 | 170 | 168 | 167 | 166 | 165 | 164 | 163 | 162 | 161 | 159 | 158 | 157 | 156 | 155 | 154 | 153 |
| 31 | 176 | 175 | 173 | 172 | 171 | 169 | 168 | 167 | 166 | 165 | 163 | 162 | 161 | 160 | 159 | 158 | 157 | 155 | 154 | 153 |
| 32 | 177 | 176 | 174 | 173 | 172 | 170 | 169 | 168 | 166 | 165 | 164 | 163 | 162 | 161 | 159 | 158 | 157 | 156 | 155 | 154 |
| 33 | 178 | 176 | 175 | 174 | 172 | 171 | 170 | 168 | 167 | 166 | 165 | 164 | 163 | 161 | 160 | 159 | 158 | 157 | 156 | 155 |
| 34 | 179 | 177 | 176 | 175 | 173 | 172 | 171 | 169 | 168 | 167 | 165 | 164 | 163 | 162 | 161 | 160 | 159 | 157 | 156 | 155 |
| 35 | 180 | 178 | 177 | 175 | 174 | 173 | 171 | 170 | 168 | 167 | 166 | 165 | 164 | 163 | 162 | 160 | 159 | 158 | 157 | 156 |
| 36 | 181 | 179 | 178 | 176 | 175 | 174 | 172 | 171 | 169 | 168 | 167 | 166 | 165 | 163 | 162 | 161 | 160 | 159 | 158 | 156 |
| 37 | 181 | 180 | 179 | 177 | 176 | 175 | 173 | 172 | 170 | 169 | 168 | 166 | 165 | 164 | 163 | 162 | 161 | 159 | 158 | 157 |
| 38 | 183 | 181 | 180 | 178 | 177 | 175 | 174 | 172 | 171 | 170 | 168 | 167 | 166 | 165 | 164 | 162 | 161 | 160 | 159 | 158 |
| 39 | 184 | 182 | 181 | 179 | 178 | 176 | 175 | 173 | 172 | 171 | 169 | 168 | 167 | 166 | 164 | 163 | 162 | 161 | 160 | 158 |
| 40 | 185 | 183 | 182 | 180 | 179 | 177 | 176 | 174 | 173 | 171 | 170 | 169 | 167 | 166 | 165 | 164 | 163 | 162 | 160 | 159 |
| 41 | 186 | 184 | 182 | 181 | 179 | 178 | 177 | 175 | 174 | 172 | 171 | 169 | 168 | 167 | 166 | 165 | 163 | 162 | 161 | 160 |
| 42 | 187 | 185 | 183 | 182 | 180 | 179 | 178 | 176 | 175 | 173 | 172 | 170 | 169 | 168 | 167 | 165 | 164 | 163 | 162 | 161 |
| 43 | 188 | 186 | 184 | 183 | 181 | 180 | 179 | 177 | 176 | 174 | 173 | 171 | 170 | 169 | 167 | 166 | 165 | 164 | 162 | 161 |
| 44 | 189 | 187 | 185 | 184 | 182 | 181 | 180 | 178 | 177 | 175 | 174 | 172 | 171 | 169 | 168 | 167 | 166 | 165 | 163 | 162 |
| 45 | 189 | 188 | 186 | 185 | 183 | 182 | 180 | 179 | 178 | 176 | 175 | 173 | 172 | 170 | 169 | 168 | 167 | 166 | 164 | 163 |
| 46 | 190 | 189 | 187 | 186 | 184 | 183 | 181 | 180 | 179 | 177 | 176 | 174 | 173 | 171 | 170 | 169 | 167 | 166 | 165 | 164 |
| 47 | 191 | 190 | 188 | 187 | 185 | 184 | 182 | 181 | 179 | 178 | 177 | 175 | 174 | 172 | 171 | 170 | 168 | 167 | 166 | 165 |
| 48 | 192 | 191 | 189 | 188 | 186 | 185 | 183 | 182 | 180 | 179 | 178 | 176 | 175 | 173 | 172 | 171 | 169 | 168 | 167 | 166 |
| 49 | 193 | 192 | 190 | 189 | 187 | 186 | 184 | 183 | 181 | 180 | 178 | 177 | 176 | 174 | 173 | 172 | 170 | 169 | 167 | 166 |
| 50 | 194 | 193 | 191 | 189 | 188 | 187 | 185 | 184 | 182 | 181 | 179 | 178 | 177 | 175 | 174 | 173 | 171 | 170 | 168 | 167 |
| 51 | 195 | 194 | 192 | 190 | 189 | 188 | 186 | 185 | 183 | 182 | 180 | 179 | 178 | 176 | 175 | 174 | 172 | 171 | 169 | 168 |
| 52 | 196 | 195 | 193 | 191 | 190 | 189 | 187 | 186 | 184 | 183 | 181 | 180 | 178 | 177 | 176 | 175 | 173 | 172 | 170 | 169 |
| 53 | 197 | 196 | 194 | 192 | 191 | 189 | 188 | 187 | 185 | 184 | 182 | 181 | 179 | 178 | 177 | 176 | 174 | 173 | 171 | 170 |
| 54 | 199 | 197 | 195 | 193 | 192 | 190 | 189 | 188 | 186 | 185 | 183 | 182 | 180 | 179 | 178 | 177 | 175 | 174 | 173 | 171 |
| 55 | 200 | 198 | 196 | 194 | 193 | 191 | 190 | 188 | 187 | 186 | 184 | 183 | 181 | 180 | 179 | 178 | 176 | 175 | 174 | 172 |
| 56 | 201 | 199 | 197 | 196 | 194 | 192 | 191 | 189 | 188 | 187 | 185 | 184 | 182 | 181 | 180 | 178 | 177 | 176 | 175 | 173 |
| 57 | 202 | 200 | 198 | 197 | 195 | 193 | 192 | 190 | 189 | 188 | 186 | 185 | 183 | 182 | 181 | 179 | 178 | 177 | 176 | 174 |
| 58 | 203 | 201 | 199 | 198 | 196 | 194 | 193 | 191 | 190 | 188 | 187 | 186 | 184 | 183 | 182 | 180 | 179 | 178 | 177 | 175 |
| 59 | 204 | 202 | 201 | 199 | 197 | 195 | 194 | 192 | 190 | 189 | 188 | 187 | 185 | 184 | 183 | 181 | 180 | 179 | 178 | 176 |
| 60 | 206 | 204 | 202 | 200 | 198 | 196 | 195 | 193 | 191 | 190 | 189 | 187 | 186 | 185 | 184 | 182 | 181 | 180 | 179 | 177 |
| 61 | 207 | 205 | 203 | 201 | 199 | 198 | 196 | 194 | 192 | 191 | 190 | 188 | 187 | 186 | 185 | 183 | 182 | 181 | 180 | 178 |
| 62 | 208 | 206 | 204 | 202 | 201 | 199 | 197 | 195 | 193 | 192 | 191 | 189 | 188 | 187 | 185 | 184 | 183 | 182 | 181 | 179 |
| 63 | 210 | 208 | 206 | 204 | 202 | 200 | 198 | 197 | 195 | 193 | 191 | 190 | 189 | 188 | 186 | 185 | 184 | 183 | 182 | 180 |
| 64 | 211 | 209 | 207 | 205 | 203 | 201 | 200 | 198 | 196 | 194 | 192 | 191 | 190 | 189 | 187 | 186 | 185 | 184 | 183 | 181 |
| 65 | 212 | 210 | 208 | 207 | 205 | 203 | 201 | 199 | 197 | 196 | 194 | 192 | 191 | 190 | 188 | 187 | 186 | 185 | 183 | 182 |
| 66 | 213 | 211 | 210 | 208 | 206 | 204 | 202 | 200 | 199 | 197 | 195 | 193 | 192 | 190 | 189 | 188 | 187 | 185 | 184 | 183 |
| 67 | 214 | 213 | 211 | 209 | 207 | 205 | 204 | 202 | 200 | 198 | 196 | 195 | 193 | 191 | 190 | 189 | 188 | 186 | 185 | 184 |
| 68 | 216 | 214 | 212 | 210 | 209 | 207 | 205 | 203 | 201 | 199 | 198 | 196 | 194 | 192 | 191 | 190 | 189 | 187 | 186 | 185 |
| 69 | 217 | 215 | 213 | 212 | 210 | 208 | 206 | 204 | 202 | 201 | 199 | 197 | 196 | 194 | 192 | 191 | 190 | 188 | 187 | 186 |
| 70 | 218 | 217 | 215 | 213 | 211 | 210 | 208 | 206 | 204 | 202 | 200 | 199 | 197 | 195 | 193 | 192 | 190 | 189 | 188 | 187 |
| 71 | 219 | 218 | 216 | 214 | 212 | 211 | 209 | 207 | 205 | 203 | 202 | 200 | 198 | 197 | 195 | 193 | 191 | 190 | 189 | 188 |
| 72 | 221 | 219 | 218 | 216 | 214 | 212 | 210 | 208 | 206 | 205 | 203 | 201 | 200 | 198 | 196 | 194 | 193 | 191 | 190 | 189 |
| 73 | 222 | 220 | 219 | 217 | 215 | 213 | 212 | 210 | 208 | 206 | 204 | 202 | 201 | 199 | 198 | 196 | 194 | 192 | 191 | 190 |
| 74 | 223 | 221 | 220 | 218 | 216 | 214 | 213 | 211 | 209 | 207 | 206 | 204 | 202 | 200 | 199 | 197 | 196 | 194 | 192 | 191 |



without top or bottom neck. The volume of this prover at 60 F and atmospheric pressure is determined by calibrating with water "to contain" with a "to deliver" test measure.

**2083** Pressure gages and other equipment items which can create air pockets are removed. These items will have their volumes determined separately. All valves and openings on the bottom side and vertical sides of the prover shall be closed prior to the calibration.

**2084** The calibration of the prover begins by emptying "to deliver" test measures of water into the prover, allowing the required drain period for each test measure after each emptying into the prover (see Par. 2043). The volume and temperature of water in each test measure are recorded. As the level of water rises and reaches the lowest and each succeeding opening, from which pressure gages and other equipment items were removed, these openings are plugged to eliminate any air pockets. The prover is completely filled with test liquid from the test measure, the volume of the test liquid remaining in the test measure when the prover becomes full is determined (see Par. 2034), and this volume is subtracted from the total volume. From the record of the volume and temperature of each test measure, the volume corrected for temperature, as described in Par. 2123 through Par. 2125, is determined; to this is added the volume of the pressure gages and other removed equipment.

**2085** The calibration is repeated until two successive readings agree within 0.02 per cent of the prover volume. The average of these two volumes is used.

### Calibration of a Bidirectional Piston Displacement Prover (See Fig. 22)

**2086** The following paragraphs describe the method of calibrating a bidirectional piston displacement prover, "to deliver" at 60 F and atmospheric pressure, using either "to deliver" or "to contain" test measures. Essentially, this consists of establishing the length of stroke of the piston so that the desired volume of liquid is repetitively delivered into a test measure.

**2087** The first operation is to close the expansion chamber valve and connect the inlet of the prover to a suitable source of test liquid under pressure. The cylinder, hoses, lines, and valves are filled with the test liquid; and the air is completely purged from all parts of the prover by pumping liquid into the prover while, at the same time, causing the piston to move back and forth through the cylinder to its stops. During these filling operations, the test liquid may be discharged to a suitable sump or other vessel. While this shuttling of the piston is being performed, air or vapor should be blown out the vent on the downstream side of the piston for each stroke. When the prover is free of air and full of test liquid from the source to the outlet valve, the vent line valves at each end of the cylinder should be closed.

**2088** The second operation is to move the piston to either extremity of the cylinder until it stops and prepare to receive the test liquid into a suitably sized test measure, preferably having a capacity equal to the desired displaced volume of the prover.

**2089** The third operation is to record the pressure in the prover with the entire system completely full of test liquid under supply pump pressure. With the piston in a stopped position at either end of the cylinder, the two-position control valve is changed to permit the test liquid from the prover to run into the test measure. The volume of the liquid in the test measure is recorded. This volume is corrected for any temperature differences, as described in Par. 2123 through Par. 2125.

**2090** The fourth operation is to adjust the stroke length of the piston (by means of the adjustment device) to make the displaced volume of a single stroke exactly equal to some nominal volume, e.g., 50.00 gal. This is done by adjusting the piston stroke after every successive delivery into the test measure until the measure indicates that the desired displacement has been established. These runs are conducted as in the third operation, and the number of them required will depend on the accuracy with which the stroke adjustment is made after each run.

**2091** The calibration is repeated after the piston stroke has been finally adjusted to insure repetitive displacements within 0.02 per cent of the prover volume. The piston stop should be locked in place by suitable means and sealed.

**2092** After the prover has been calibrated, it should be thoroughly drained of the calibrating liquid, particularly if water was employed, flushed thoroughly, and filled with the liquid which will be employed in subsequent meter proving. After filling, and while the prover is idle, the expansion chamber should be opened to both ends of the cylinder to allow for thermal expansion of the liquid. When used for proving meters, the expansion chamber should be closed off from the prover, and the bypass line across the piston should be tightly closed.

### Calibration of the Unidirectional Piston Displacement Prover (See Fig. 23)

**2093** The following paragraphs describe the method of calibrating a unidirectional free-piston displacement prover, "to deliver" at 60 F and atmospheric pressure, using a non-temperature-compensated master meter unit.

**2094** The unidirectional piston displacement prover is calibrated by determining the volume of liquid displaced by the movement of a piston from one reference point to another reference point in a continuous length of pipe, either upstream or downstream from the operating meter or meters. The volume between such reference points is the prover volume.

**2095** A master meter calibration unit, having a

**2072** The calibration is repeated until two successive volume determinations agree within 0.02 per cent of the prover volume. The average of these two volumes shall be used.

**2073** The upper gage glass scale is permanently marked and mounted on the upper neck and sealed.

### Calibration of Double-Weir Prover with Auxiliary Volume Determination (Reading) Chamber (See Fig. 12)

**2074** The following paragraphs describe the method of calibrating with water a prover with weirs at the upper and lower reference levels and with an auxiliary chamber for close determination of total volume, "to deliver" at 60 F and atmospheric pressure. Either "to deliver" or "to contain" measures may be used.

**2075** The first operation is to establish the lower reference level of the prover with valve **A** open. This is established as outlined in Par. 2069.

**2076** The second operation is to establish the upper reference level for the body of the prover, as follows: Close valve **A** and fill the prover until it freely overflows the top weir into the reading chamber. When the flow over the top weir ceases, make temporary upper reference level marks on the shell of the prover opposite the liquid level in the gage glasses. Draw approximately 3 in. of water from the prover; then refill it to freely overflow the top weir a second time, making sure the level in the reading chamber is well below the overflow connection. Repeat the operation a minimum of three times, and until a definite upper reference level has been established. Establish permanent reference marks on the shell of the prover at this upper reference level.

**2077** The third operation is to establish the volume of the prover between weir or reference levels, as follows: With valve **A** closed, drain the reading chamber through valve **C**. Connect a withdrawal hose to the prover at some convenient valve below the bottom reference level and fill the hose with water, making certain all air has been purged. A pump may be employed, providing it can be purged of all air and does not leak. Fill the prover until it overflows the top weir, then disconnect the water supply. Check all connections for leaks and make certain that the liquid level of the top gage glasses corresponds to the permanent reference marks for the upper reference level or overflow line. Begin withdrawal into a suitably sized test measure, noting the volume and temperature of each withdrawal. Continue withdrawal until the liquid level is only slightly above the bottom reference level as determined by observing the lower gage glasses. The condition of the withdrawal equipment and/or pump shall be the same at the end of the last withdrawal as it was at the beginning of the first withdrawal. Close the valve on the prover through which withdrawal has been made. Drain the remainder of the water through valve **B** into an appropriate smaller test measure (see Par. 2034). Examine the liquid level indicated in the lower gage glasses. If the liquid level coincides with the permanent reference marks opposite each gage glass as previously established, then the total volume withdrawn, corrected for temperature effect as outlined in Par. 2123 through Par. 2125 where necessary, is the fixed volume of the prover at 60 F and atmospheric pressure. This volume includes the internal volume of the prover between the upper and lower weirs plus the contents of the lower weir box and connections to valve **B**.

**2078** The calibration is repeated until two successive readings agree within 0.02 per cent of the prover volume. The average of these two volumes is used.

**2079** The fourth operation is to calibrate the auxiliary reading chamber. Close valve **A** and fill the reading chamber with water to a level near the top of the gage glass scale. Disconnect the water supply; connect the withdrawal hose to valve **C**; fill the hose with water, making certain that it is free from air; and observe all connections for leaks. Make a temporary reference mark on the shell of the reading chamber opposite the liquid level and observe for several minutes to make certain the liquid level remains the same and that the system is free from leaks. Record the temperature of the water in the reading chamber. Withdraw the water into a test measure and mark the liquid level on the shell of the chamber after each withdrawal.

**2080** Continue the withdrawals until the level has been lowered almost to the lower reference level which was established on the main prover in the first operation.

**2081** Measure the overall length of the reading chamber between the top reference point and the liquid level after this last withdrawal. Using the reading and the temperature-corrected volume measured, compute the length of the chamber equivalent to desired unit volumes. Repeat the fourth operation until two successive readings agree within 0.02 per cent of the measured reading chamber volume. The average of these two readings shall be used to mark and subdivide the gage glass reading scale. Mark volumes on the scale so that the fixed volume determined in the third operation (the volume between upper and lower weir plus the volume of the lower weir box and connections to valve **B**) is near the lower end of the gage glass scale. Mount the scale so that the point representing the fixed volume between weirs of the prover shall coincide with the permanent lower reference level on the reading chamber. Attach firmly and seal the scale. This locates the line representing the fixed volume of the prover at the same elevation as the knife edge on the lower weir. The scale so marked and mounted will be direct-reading and will show the sum of the fixed volume and the overflow volume for the prover.

### Calibration of Closed Vapor-Condensing Prover (See Fig. 24)

**2082** The following paragraphs describe the method of calibrating a closed vapor-condensing prover



**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | Specific Gravity 60F/60F | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.580 | 0.581 | 0.582 | 0.583 | 0.584 | 0.585 | 0.586 | 0.587 | 0.588 | 0.589 | 0.590 | 0.591 | 0.592 | 0.593 | 0.594 | 0.595 | 0.596 | 0.597 | 0.598 | 0.599 |
| 75 | 224 | 223 | 221 | 219 | 218 | 216 | 214 | 212 | 211 | 209 | 207 | 205 | 203 | 202 | 200 | 199 | 197 | 195 | 193 | 192 |
| 76 | 226 | 224 | 222 | 220 | 219 | 217 | 215 | 214 | 212 | 210 | 208 | 207 | 205 | 203 | 201 | 200 | 198 | 197 | 195 | 193 |
| 77 | 227 | 225 | 223 | 221 | 220 | 218 | 217 | 215 | 213 | 211 | 210 | 208 | 206 | 205 | 203 | 201 | 200 | 198 | 196 | 195 |
| 78 | 228 | 226 | 225 | 223 | 221 | 219 | 218 | 216 | 214 | 213 | 211 | 209 | 207 | 206 | 204 | 202 | 201 | 199 | 198 | 196 |
| 79 | 230 | 228 | 226 | 224 | 222 | 221 | 219 | 217 | 215 | 214 | 212 | 211 | 209 | 207 | 206 | 204 | 202 | 201 | 199 | 197 |
| 80 | 231 | 229 | 227 | 225 | 224 | 222 | 220 | 218 | 217 | 215 | 213 | 212 | 210 | 209 | 207 | 205 | 204 | 202 | 200 | 199 |
| 81 | 233 | 231 | 229 | 227 | 225 | 223 | 221 | 220 | 218 | 216 | 215 | 213 | 211 | 210 | 208 | 206 | 205 | 203 | 202 | 200 |
| 82 | 234 | 232 | 230 | 228 | 226 | 225 | 223 | 221 | 219 | 217 | 216 | 214 | 213 | 211 | 209 | 208 | 206 | 205 | 203 | 201 |
| 83 | 235 | 234 | 232 | 230 | 228 | 226 | 224 | 222 | 220 | 219 | 217 | 215 | 214 | 212 | 211 | 209 | 207 | 206 | 204 | 203 |
| 84 | 237 | 235 | 233 | 231 | 229 | 227 | 226 | 224 | 222 | 220 | 218 | 217 | 215 | 213 | 212 | 210 | 209 | 207 | 206 | 204 |
| 85 | 238 | 236 | 235 | 233 | 231 | 229 | 227 | 225 | 223 | 221 | 220 | 218 | 216 | 215 | 213 | 211 | 210 | 209 | 207 | 206 |
| 86 | 240 | 238 | 236 | 234 | 232 | 230 | 228 | 226 | 225 | 223 | 221 | 219 | 218 | 216 | 215 | 213 | 211 | 210 | 208 | 207 |
| 87 | 241 | 239 | 237 | 235 | 234 | 232 | 230 | 228 | 226 | 224 | 222 | 221 | 219 | 217 | 216 | 214 | 212 | 211 | 210 | 208 |
| 88 | 243 | 241 | 239 | 237 | 235 | 233 | 231 | 229 | 227 | 226 | 224 | 222 | 221 | 219 | 217 | 215 | 214 | 212 | 211 | 209 |
| 89 | 244 | 242 | 240 | 238 | 236 | 235 | 233 | 231 | 229 | 227 | 226 | 224 | 222 | 220 | 218 | 217 | 215 | 214 | 212 | 211 |
| 90 | 246 | 244 | 242 | 240 | 238 | 236 | 235 | 232 | 231 | 229 | 227 | 225 | 224 | 222 | 220 | 218 | 217 | 215 | 214 | 212 |
| 91 | 248 | 245 | 243 | 241 | 239 | 237 | 236 | 234 | 232 | 230 | 228 | 227 | 225 | 223 | 222 | 220 | 218 | 217 | 215 | 214 |
| 92 | 249 | 247 | 245 | 243 | 241 | 239 | 237 | 235 | 234 | 232 | 230 | 228 | 226 | 225 | 223 | 222 | 220 | 218 | 216 | 215 |
| 93 | 251 | 249 | 247 | 244 | 242 | 240 | 239 | 237 | 235 | 233 | 231 | 230 | 228 | 226 | 225 | 223 | 221 | 219 | 218 | 216 |
| 94 | 252 | 250 | 248 | 246 | 244 | 242 | 240 | 238 | 236 | 235 | 233 | 231 | 229 | 227 | 226 | 225 | 223 | 221 | 219 | 218 |
| 95 | 254 | 252 | 250 | 248 | 245 | 243 | 241 | 240 | 238 | 236 | 235 | 233 | 231 | 229 | 227 | 226 | 224 | 223 | 221 | 219 |
| 96 | 256 | 253 | 251 | 249 | 247 | 245 | 243 | 241 | 239 | 237 | 236 | 234 | 232 | 231 | 229 | 227 | 226 | 224 | 223 | 221 |
| 97 | 257 | 255 | 253 | 251 | 249 | 247 | 245 | 242 | 241 | 239 | 237 | 236 | 234 | 232 | 231 | 229 | 227 | 225 | 224 | 222 |
| 98 | 259 | 257 | 255 | 252 | 251 | 248 | 246 | 244 | 242 | 240 | 239 | 237 | 235 | 234 | 232 | 230 | 229 | 227 | 225 | 224 |
| 99 | 261 | 259 | 256 | 254 | 252 | 250 | 248 | 246 | 244 | 242 | 240 | 238 | 237 | 235 | 233 | 232 | 230 | 228 | 227 | 225 |
| 100 | 263 | 260 | 258 | 256 | 254 | 252 | 249 | 247 | 245 | 243 | 242 | 240 | 238 | 236 | 235 | 233 | 231 | 230 | 228 | 227 |
| 101 | 265 | 262 | 260 | 258 | 256 | 253 | 251 | 249 | 247 | 245 | 243 | 241 | 239 | 238 | 236 | 235 | 233 | 231 | 230 | 228 |
| 102 | 267 | 264 | 262 | 260 | 258 | 255 | 253 | 251 | 248 | 246 | 245 | 243 | 241 | 239 | 237 | 236 | 234 | 233 | 231 | 230 |
| 103 | 269 | 266 | 264 | 262 | 260 | 257 | 255 | 252 | 250 | 248 | 246 | 244 | 243 | 241 | 239 | 237 | 236 | 234 | 233 | 231 |
| 104 | 271 | 269 | 266 | 264 | 262 | 259 | 257 | 254 | 252 | 250 | 248 | 246 | 244 | 242 | 241 | 239 | 237 | 235 | 234 | 232 |
| 105 | 273 | 271 | 268 | 266 | 264 | 261 | 259 | 256 | 254 | 252 | 250 | 248 | 246 | 244 | 242 | 240 | 238 | 236 | 235 | 234 |
| 106 | 275 | 272 | 270 | 268 | 266 | 264 | 261 | 258 | 256 | 254 | 252 | 250 | 248 | 246 | 244 | 242 | 240 | 238 | 236 | 235 |
| 107 | 277 | 275 | 272 | 270 | 268 | 266 | 263 | 261 | 258 | 256 | 254 | 252 | 250 | 248 | 246 | 244 | 242 | 240 | 238 | 236 |
| 108 | 279 | 277 | 274 | 272 | 270 | 268 | 265 | 263 | 261 | 258 | 256 | 254 | 252 | 249 | 248 | 246 | 244 | 242 | 240 | 238 |
| 109 | 281 | 279 | 277 | 274 | 272 | 270 | 268 | 265 | 263 | 260 | 258 | 256 | 254 | 252 | 249 | 247 | 246 | 244 | 242 | 240 |
| 110 | 284 | 281 | 279 | 276 | 274 | 272 | 270 | 268 | 265 | 263 | 260 | 258 | 256 | 254 | 252 | 250 | 248 | 246 | 244 | 242 |
| 111 | 286 | 283 | 281 | 279 | 276 | 274 | 272 | 270 | 267 | 265 | 263 | 260 | 258 | 256 | 254 | 252 | 250 | 248 | 246 | 244 |
| 112 | 288 | 286 | 283 | 281 | 278 | 276 | 274 | 272 | 269 | 267 | 265 | 263 | 260 | 258 | 256 | 254 | 252 | 250 | 248 | 246 |
| 113 | 290 | 288 | 286 | 283 | 281 | 278 | 276 | 274 | 272 | 269 | 267 | 265 | 263 | 260 | 258 | 256 | 254 | 252 | 250 | 248 |
| 114 | 292 | 290 | 288 | 285 | 283 | 281 | 278 | 276 | 274 | 272 | 270 | 267 | 265 | 263 | 260 | 258 | 256 | 254 | 252 | 250 |
| 115 | 295 | 292 | 290 | 288 | 285 | 283 | 281 | 278 | 276 | 274 | 272 | 270 | 267 | 265 | 263 | 260 | 258 | 257 | 255 | 253 |
| 116 | 297 | 295 | 292 | 290 | 287 | 285 | 283 | 280 | 278 | 276 | 274 | 272 | 270 | 268 | 265 | 263 | 261 | 259 | 257 | 255 |
| 117 | 300 | 297 | 294 | 292 | 290 | 288 | 285 | 283 | 281 | 278 | 276 | 274 | 272 | 270 | 268 | 265 | 263 | 261 | 259 | 257 |
| 118 | 302 | 299 | 297 | 295 | 292 | 290 | 287 | 285 | 283 | 280 | 278 | 276 | 274 | 272 | 270 | 268 | 266 | 264 | 262 | 259 |
| 119 | 305 | 302 | 299 | 297 | 295 | 292 | 290 | 287 | 285 | 283 | 281 | 278 | 276 | 274 | 272 | 270 | 269 | 266 | 264 | 262 |
| 120 | 307 | 304 | 302 | 299 | 297 | 294 | 292 | 290 | 287 | 285 | 283 | 281 | 279 | 276 | 274 | 272 | 271 | 269 | 266 | 265 |
| 121 | 309 | 306 | 304 | 302 | 299 | 297 | 294 | 292 | 290 | 288 | 285 | 283 | 281 | 279 | 277 | 275 | 273 | 271 | 269 | 267 |
| 122 | 311 | 308 | 306 | 304 | 302 | 299 | 297 | 294 | 292 | 290 | 288 | 285 | 283 | 281 | 279 | 277 | 275 | 273 | 271 | 270 |
| 123 | 314 | 311 | 308 | 306 | 304 | 301 | 299 | 296 | 294 | 292 | 290 | 288 | 285 | 283 | 281 | 280 | 277 | 275 | 274 | 272 |
| 124 | 316 | 314 | 311 | 308 | 306 | 304 | 302 | 299 | 297 | 294 | 292 | 290 | 288 | 285 | 283 | 282 | 279 | 278 | 276 | 274 |
| 125 | 318 | 316 | 313 | 310 | 308 | 306 | 304 | 302 | 299 | 297 | 294 | 292 | 290 | 288 | 286 | 283 | 282 | 280 | 278 | 276 |
| 126 | 320 | 318 | 316 | 312 | 310 | 308 | 306 | 304 | 302 | 299 | 297 | 295 | 292 | 290 | 288 | 286 | 284 | 282 | 280 | 278 |
| 127 | 323 | 320 | 318 | 314 | 313 | 310 | 308 | 306 | 304 | 302 | 299 | 297 | 294 | 293 | 291 | 288 | 286 | 284 | 282 | 281 |
| 128 | 326 | 323 | 320 | 318 | 315 | 313 | 310 | 308 | 306 | 304 | 302 | 299 | 297 | 295 | 293 | 291 | 289 | 286 | 285 | 283 |

**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | Specific Gravity 60F/60F | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.600 | 0.601 | 0.602 | 0.603 | 0.604 | 0.605 | 0.606 | 0.607 | 0.608 | 0.609 | 0.610 | 0.611 |
| 20 | 145 | 144 | 143 | 142 | 141 | 140 | 140 | 139 | 139 | 138 | 138 | 137 |
| 21 | 145 | 144 | 143 | 142 | 141 | 141 | 140 | 140 | 139 | 139 | 138 | 138 |
| 22 | 146 | 145 | 144 | 143 | 142 | 141 | 141 | 140 | 140 | 139 | 139 | 138 |
| 23 | 147 | 146 | 144 | 144 | 143 | 142 | 141 | 141 | 140 | 140 | 139 | 139 |
| 24 | 147 | 146 | 145 | 144 | 143 | 142 | 142 | 141 | 141 | 140 | 140 | 139 |
| 25 | 148 | 147 | 146 | 145 | 144 | 143 | 142 | 142 | 141 | 141 | 140 | 140 |
| 26 | 149 | 147 | 146 | 145 | 145 | 144 | 143 | 142 | 142 | 141 | 141 | 140 |
| 27 | 149 | 148 | 147 | 146 | 145 | 145 | 144 | 143 | 142 | 142 | 141 | 141 |
| 28 | 150 | 149 | 148 | 147 | 146 | 145 | 144 | 144 | 143 | 142 | 142 | 141 |
| 29 | 151 | 150 | 148 | 147 | 146 | 146 | 145 | 144 | 144 | 143 | 142 | 142 |
| 30 | 151 | 150 | 149 | 148 | 147 | 146 | 145 | 145 | 144 | 144 | 143 | 143 |
| 31 | 152 | 151 | 150 | 149 | 148 | 147 | 146 | 145 | 145 | 144 | 144 | 143 |
| 32 | 153 | 151 | 150 | 150 | 148 | 147 | 147 | 146 | 145 | 145 | 144 | 144 |
| 33 | 153 | 152 | 151 | 150 | 149 | 148 | 147 | 146 | 146 | 145 | 145 | 144 |
| 34 | 154 | 153 | 151 | 151 | 150 | 149 | 148 | 147 | 146 | 146 | 145 | 145 |
| 35 | 155 | 153 | 152 | 151 | 150 | 149 | 148 | 148 | 147 | 146 | 146 | 145 |
| 36 | 155 | 154 | 153 | 152 | 151 | 150 | 149 | 148 | 148 | 147 | 146 | 146 |
| 37 | 156 | 155 | 154 | 153 | 151 | 150 | 150 | 149 | 148 | 147 | 147 | 146 |
| 38 | 157 | 155 | 154 | 153 | 152 | 151 | 150 | 150 | 149 | 148 | 147 | 147 |
| 39 | 157 | 156 | 155 | 154 | 153 | 152 | 151 | 150 | 149 | 149 | 148 | 147 |
| 40 | 158 | 157 | 156 | 155 | 153 | 152 | 151 | 151 | 150 | 149 | 149 | 148 |
| 41 | 159 | 157 | 156 | 155 | 154 | 153 | 152 | 151 | 151 | 150 | 149 | 149 |
| 42 | 159 | 158 | 157 | 156 | 155 | 154 | 153 | 152 | 151 | 150 | 150 | 149 |
| 43 | 160 | 159 | 158 | 157 | 156 | 154 | 153 | 153 | 152 | 151 | 150 | 150 |
| 44 | 161 | 160 | 158 | 157 | 156 | 155 | 154 | 153 | 152 | 152 | 151 | 150 |
| 45 | 162 | 160 | 159 | 158 | 157 | 156 | 155 | 154 | 153 | 152 | 152 | 151 |
| 46 | 162 | 161 | 160 | 159 | 158 | 157 | 156 | 155 | 154 | 153 | 152 | 152 |
| 47 | 163 | 162 | 161 | 160 | 158 | 157 | 156 | 155 | 154 | 154 | 153 | 152 |
| 48 | 164 | 163 | 162 | 160 | 159 | 158 | 157 | 156 | 155 | 154 | 154 | 153 |
| 49 | 165 | 164 | 162 | 161 | 160 | 159 | 158 | 157 | 156 | 155 | 154 | 153 |
| 50 | 166 | 165 | 163 | 162 | 161 | 160 | 159 | 158 | 157 | 156 | 155 | 154 |
| 51 | 167 | 166 | 164 | 163 | 162 | 161 | 160 | 159 | 158 | 157 | 156 | 155 |
| 52 | 168 | 167 | 165 | 164 | 163 | 162 | 160 | 159 | 158 | 158 | 157 | 156 |
| 53 | 169 | 167 | 166 | 165 | 164 | 163 | 161 | 160 | 159 | 158 | 157 | 157 |
| 54 | 170 | 168 | 167 | 166 | 165 | 164 | 162 | 161 | 160 | 159 | 158 | 157 |
| 55 | 171 | 169 | 168 | 167 | 166 | 165 | 163 | 162 | 161 | 160 | 159 | 158 |
| 56 | 172 | 170 | 169 | 168 | 167 | 166 | 164 | 163 | 162 | 161 | 160 | 159 |
| 57 | 173 | 172 | 170 | 169 | 168 | 167 | 166 | 164 | 163 | 162 | 161 | 160 |
| 58 | 174 | 173 | 171 | 170 | 169 | 168 | 167 | 165 | 164 | 163 | 162 | 161 |
| 59 | 175 | 174 | 172 | 171 | 170 | 169 | 168 | 166 | 165 | 164 | 163 | 162 |
| 60 | 176 | 175 | 173 | 172 | 171 | 170 | 169 | 168 | 166 | 165 | 164 | 163 |
| 61 | 177 | 176 | 174 | 173 | 172 | 171 | 170 | 169 | 168 | 167 | 166 | 164 |
| 62 | 178 | 177 | 175 | 174 | 173 | 172 | 171 | 170 | 169 | 168 | 167 | 166 |
| 63 | 179 | 178 | 177 | 175 | 174 | 173 | 172 | 171 | 170 | 169 | 168 | 167 |
| 64 | 180 | 179 | 178 | 176 | 175 | 174 | 173 | 172 | 171 | 170 | 169 | 168 |
| 65 | 181 | 180 | 179 | 177 | 176 | 175 | 174 | 173 | 172 | 171 | 170 | 169 |
| 66 | 182 | 181 | 180 | 178 | 177 | 176 | 175 | 174 | 173 | 172 | 171 | 170 |
| 67 | 183 | 182 | 181 | 179 | 178 | 177 | 176 | 175 | 174 | 173 | 172 | 171 |
| 68 | 184 | 183 | 182 | 180 | 179 | 178 | 177 | 176 | 174 | 174 | 173 | 172 |
| 69 | 185 | 184 | 183 | 181 | 180 | 179 | 178 | 177 | 175 | 175 | 174 | 173 |
| 70 | 186 | 185 | 184 | 182 | 181 | 180 | 179 | 177 | 176 | 175 | 174 | 174 |
| 71 | 187 | 186 | 185 | 183 | 182 | 181 | 180 | 178 | 177 | 176 | 175 | 174 |
| 72 | 188 | 187 | 186 | 184 | 183 | 182 | 181 | 179 | 178 | 177 | 176 | 175 |
| 73 | 189 | 188 | 187 | 185 | 184 | 183 | 182 | 180 | 179 | 178 | 177 | 176 |
| 74 | 190 | 189 | 188 | 186 | 185 | 184 | 183 | 181 | 180 | 179 | 178 | 177 |



large provers. The best practice is to send small provers to the National Bureau of Standards for calibration and certification. It is possible, and permissible, to calibrate such a prover by using a certified 5-gal measure, a certified 1-gal measure, or both, and suitable glass graduates. If it is convenient to dry such a prover after each emptying, it may be calibrated "to contain"; and when so calibrated, and so used, it will be most accurate for measurement of liquid hydrocarbons. If the prover is for use in calibrating large provers using water, then it is more suitable to calibrate it "to deliver." In either case, the calibration operation will be done by pouring the measured volumes of water from a "to deliver" test measure into the prover.

**2063** The first operation is to thoroughly dry the inside of the prover if it is to be calibrated "to contain." If it is to be calibrated "to deliver," the first operation is to fill the prover with water and then empty it, allowing it to drain in accordance with Par. 2043.

**2064** The second operation is to place the prover in a level position, checking with a leveling instrument.

**2065** The third operation is to determine the volume of the prover. The water is poured into the prover from the certified test measure, one measure at a time. A record of the temperature of the water in each measure is kept and suitably recorded, according to the procedure outlined in Par. 2123 through Par. 2125. The prover is filled to a whole-gallon volume level near the center of the neck. This level is marked on the gage as the temporary reference level. The temperature in the prover is determined and, after making any necessary temperature corrections, this temporary reference level is reset as required.

**2066** The calibration is repeated until two successive volume determinations agree within 0.02 per cent of the prover volume. The average of these two volumes shall be used.

**2067** The fourth operation is to calibrate the upper neck, above and below the now established reference level, by adding and/or extracting water and measuring this water in a glass graduate, starting with the prover filled to the established reference level. This may be done conveniently by the use of a syringe. The prover reference level and scale graduations are permanently marked on the gage scale; the scale is firmly and adequately fastened and sealed as required.

### Calibration of Prover with Single Weir for Lower Reference Level and with Top Neck (See Fig. 11)

**2068** The following paragraphs describe the method of calibrating with water a prover with a single weir for lower reference level and with a top neck, "to deliver" at 60 F and atmospheric pressure. Either "to deliver" or "to contain" test measures may be used.

**2069** The first operation is to establish the lower reference level of the prover by first filling the prover with water to a level several inches above the weir box knife edge. After the water supply valve is closed, the water in the prover is drained through the weir box drain valve until flow ceases. Temporary reference level identification marks are made on the lower gage glass scale. Water is added and the procedure repeated until the reference level has been definitely established. A minimum of three checks shall be made. Permanent reference marks are established on the prover shell and the gage glass scale for the lower reference level.

**2070** The second operation is to calibrate the top neck of the prover. The weir box drain valve is closed and the prover is filled to a point near the top of the upper gage glass scale. The withdrawal hose is attached to a convenient drain connection and filled with water, care being taken to ascertain that the hose is free of air. A temporary mark is established on the upper gage glass scale opposite the liquid level, which is observed for several minutes to make certain that it remains the same and that the system is free from leaks. The starting temperature of the water in the prover is recorded. The water is withdrawn into a suitably sized test measure. Throughout the period when the water is within the reading length of the gage glass, each decrement is temporarily marked on the scale and the temperature of each withdrawal is recorded according to Par. 2123. The overall length between the upper and lower reference points on the gage glass scale is measured. Using this length and correcting the volume for temperature, the length of scale equivalent to a convenient increment of corrected volume is computed and a suitable reading scale is prepared.

**2071** The third operation is to establish the volume of the prover. The withdrawals are continued with the use of test measures of suitable size. A pump may be employed, providing it can be purged of air and does not leak. The temperature and volume are recorded for each withdrawal, as described in Par. 2123. The withdrawal is completed through the weir box drain connection by the use of smaller test measures. When all flow has ceased, the liquid level as shown in the lower gage glass is examined. This level must coincide with the marks established in the first operation at the lower reference level. The total volume of water withdrawn, corrected for temperature as outlined in Par. 2123 through Par. 2125, shall be recorded as the calibrated volume of the prover at 60 F and atmospheric pressure. The condition of the drain hose, pump, and other withdrawal equipment shall be the same at the end of the last withdrawal as it was at the beginning of the first withdrawal. The last withdrawal may be a partial test measure volume. This partial test measure is converted into linear inches of upper neck. A temporary upper reference level is established near the center of the upper gage glass scale as required to bring the volume of the prover below the upper reference level to a whole unit of volume. The scale is set to correspond with the final reference level.

using water as a calibrating liquid. Either "to contain" or "to deliver" test measures may be used.

**2050** Fill the prover to overflowing with water, being sure the withdrawal line is free of air. The water inlet valve shall then be closed, and the water source shall be disconnected at the inlet valve.

**2051** The first operation is to calibrate the upper neck. The water drawoff valve is opened slightly until the water level appears at the extreme top of the upper gage glass, then the valve is closed. This point is temporarily noted on the gage scale, and the water withdrawals are started. Decrements are marked on the gage scale as the water is withdrawn, one measure at a time, from the prover into a suitable measure. When the level is near the midpoint of the upper gage glass, at the completion of a withdrawal, a temporary mark is made and identified as the assumed upper reference level. Withdrawals are then continued, one at a time, and the scale marked as before as long as the liquid level remains in sight in the upper gage glass. These measured divisions may be subdivided as desired to complete the calibration of the upper neck.

**2052** The second operation is to calibrate the body of the prover. Withdrawals are continued, one measure at a time, using a conveniently sized measure, until the water level is approximately at the top of the lower gage glass. From this point, withdrawals are continued with the measure used in the first operation, and the lower gage scale is marked in such decrements. The lower reference level for the uncorrected nominal volume of the prover is set on a whole decrement mark on the lower gage glass. The volume withdrawn is corrected for water temperature variations which may have occurred during the calibration, as described in Par. 2123 through Par. 2125, and the lower reference level is marked temporarily on the scale.

**2053** The third operation, if necessary, is to calibrate the lower neck below the lower reference level. Withdrawal is continued, one test measure at a time, below the lower reference level until the liquid level reaches the lower end of the gage scale, the scale being marked at each measured level. The lower gage scale is then subdivided as required.

**2054** The calibration is repeated until two successive volume determinations have been obtained which agree within 0.02 per cent of the nominal prover volume. The average of these two volumes shall be used. The upper reference level and the lower reference level are both then permanently marked on the scales.

**2055** The fourth operation is to permanently mark all required graduations on both upper and lower scales and to attach the scales securely and permanently to the prover necks, sealing each as required.

### Calibration of Prover with Top Neck and Bottom Drain Valve (See Fig. 9)

**2056** The following paragraphs describe the method of calibrating a prover with top neck and bottom drain valve for lower reference level, "to deliver" at 60 F and atmospheric pressure, using water as a calibrating liquid. Either "to contain" or "to deliver" test measures may be used.

**2057** The first operation is to disconnect the piping below the bottom valve and make provision to withdraw water through the bottom valve into a test measure, through a hose or pipe sloped for free and complete drainage into the test measure. The bottom valve and the check drain are closed to ascertain that they do not leak. Tests are made for leakage by pouring a small volume of water into the prover. The bottom valve is opened, draining this water through the drain hose; thus the prover and drain hose are emptied, but the hose is left wet. The bottom valve is closed again, and the prover is filled with water to the extreme top of the upper gage glass. This liquid level is temporarily marked on the scale.

**2058** The second operation is to calibrate the upper neck. Withdrawals are made using a suitable test measure. Decrements are marked on the gage scale as the water is withdrawn. Withdrawals are continued, one at a time, as long as the liquid level remains in sight in the upper gage glass.

**2059** The third operation is to calibrate the body of the prover. Withdrawals are made through the bottom valve, using a conveniently sized test measure, until all the water has been withdrawn. The last withdrawal may be a partial test measure volume which must be determined accurately to the nearest cubic inch (see Par. 2034). This partial test measure volume is converted into linear inches of upper neck. A temporary upper reference level is established near the center of the scale, as required, to bring the volume of the prover below the upper reference level to a whole unit of volume. The gage scale is marked at this temporary upper reference level. Throughout this third operation temperature corrections are carefully made by following instructions in Par. 2123 through Par. 2125.

**2060** The calibration is repeated, starting with the prover filled to the new temporary upper reference level, until two successive volume determinations are obtained which agree within 0.02 per cent of the nominal prover volume. The average of these two volumes shall be used. The upper reference level is temporarily marked on the gage glass, or on a part of the prover immediately adjacent to the scale, so that the scale may be removed for permanent marking.

**2061** The fourth operation is to mark permanently all required graduations on the upper gage glass scale; adjust it to the upper reference level; and attach the scale securely and permanently to the prover neck, sealing as required.

### Calibration of Small Portable Provers with Top Neck and Closed Bottom (See Fig. 26)

**2062** Small provers with top necks and closed bottoms are used to prove small meters and to calibrate



**TABLE II (Continued)**

| Temperature (Degrees Fahrenheit) | Specific Gravity 60F/60F | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.600 | 0.601 | 0.602 | 0.603 | 0.604 | 0.605 | 0.606 | 0.607 | 0.608 | 0.609 | 0.610 | 0.611 |
| 75 | 191 | 190 | 189 | 187 | 186 | 185 | 184 | 182 | 181 | 180 | 179 | 178 |
| 76 | 192 | 191 | 190 | 188 | 187 | 186 | 185 | 183 | 182 | 181 | 180 | 179 |
| 77 | 193 | 192 | 191 | 189 | 188 | 187 | 186 | 184 | 183 | 182 | 181 | 180 |
| 78 | 194 | 193 | 192 | 190 | 189 | 188 | 187 | 185 | 184 | 183 | 182 | 181 |
| 79 | 196 | 194 | 193 | 192 | 190 | 189 | 188 | 186 | 185 | 184 | 183 | 182 |
| 80 | 197 | 196 | 194 | 193 | 191 | 190 | 189 | 187 | 186 | 185 | 184 | 182 |
| 81 | 199 | 197 | 195 | 194 | 193 | 191 | 190 | 188 | 187 | 186 | 185 | 183 |
| 82 | 200 | 198 | 197 | 195 | 194 | 192 | 191 | 190 | 188 | 187 | 186 | 184 |
| 83 | 201 | 199 | 198 | 196 | 195 | 194 | 192 | 191 | 189 | 188 | 187 | 185 |
| 84 | 203 | 201 | 199 | 198 | 196 | 195 | 193 | 192 | 191 | 189 | 188 | 186 |
| 85 | 204 | 202 | 201 | 199 | 198 | 196 | 195 | 193 | 192 | 191 | 189 | 188 |
| 86 | 205 | 204 | 202 | 200 | 199 | 197 | 196 | 195 | 193 | 192 | 190 | 189 |
| 87 | 207 | 205 | 203 | 202 | 200 | 199 | 197 | 196 | 194 | 193 | 192 | 190 |
| 88 | 208 | 206 | 205 | 203 | 202 | 200 | 199 | 197 | 196 | 194 | 193 | 192 |
| 89 | 209 | 208 | 206 | 205 | 203 | 201 | 200 | 199 | 197 | 196 | 194 | 193 |
| 90 | 211 | 209 | 207 | 206 | 204 | 203 | 201 | 200 | 198 | 197 | 195 | 194 |
| 91 | 212 | 210 | 209 | 207 | 206 | 204 | 203 | 201 | 200 | 198 | 197 | 195 |
| 92 | 213 | 212 | 210 | 209 | 207 | 205 | 204 | 202 | 201 | 200 | 198 | 197 |
| 93 | 215 | 213 | 212 | 210 | 208 | 207 | 205 | 204 | 202 | 201 | 199 | 198 |
| 94 | 216 | 215 | 213 | 211 | 210 | 208 | 207 | 205 | 203 | 202 | 201 | 199 |
| 95 | 218 | 216 | 215 | 213 | 211 | 210 | 208 | 207 | 205 | 203 | 202 | 200 |
| 96 | 219 | 217 | 216 | 214 | 213 | 211 | 209 | 208 | 206 | 205 | 203 | 202 |
| 97 | 221 | 219 | 217 | 216 | 214 | 212 | 211 | 209 | 208 | 206 | 205 | 203 |
| 98 | 222 | 221 | 219 | 217 | 216 | 214 | 212 | 211 | 209 | 208 | 206 | 205 |
| 99 | 224 | 222 | 221 | 219 | 217 | 215 | 214 | 212 | 211 | 209 | 207 | 206 |
| 100 | 225 | 224 | 222 | 220 | 219 | 217 | 215 | 214 | 212 | 210 | 209 | 207 |
| 101 | 227 | 225 | 223 | 222 | 220 | 218 | 217 | 215 | 213 | 212 | 210 | 209 |
| 102 | 228 | 226 | 225 | 223 | 222 | 220 | 218 | 217 | 215 | 213 | 212 | 210 |
| 103 | 230 | 228 | 227 | 225 | 223 | 222 | 220 | 218 | 216 | 215 | 213 | 212 |
| 104 | 231 | 229 | 228 | 226 | 225 | 223 | 222 | 220 | 218 | 216 | 215 | 213 |
| 105 | 232 | 231 | 229 | 228 | 226 | 224 | 223 | 221 | 220 | 218 | 216 | 215 |
| 106 | 234 | 232 | 231 | 229 | 228 | 226 | 224 | 223 | 221 | 220 | 218 | 216 |
| 107 | 235 | 234 | 232 | 230 | 229 | 228 | 226 | 224 | 223 | 221 | 219 | 218 |
| 108 | 236 | 235 | 234 | 232 | 230 | 229 | 227 | 226 | 224 | 223 | 221 | 220 |
| 109 | 238 | 236 | 235 | 233 | 232 | 230 | 229 | 227 | 226 | 224 | 223 | 221 |
| 110 | 240 | 238 | 236 | 235 | 233 | 232 | 230 | 229 | 227 | 226 | 224 | 223 |
| 111 | 242 | 240 | 238 | 236 | 234 | 233 | 231 | 230 | 228 | 227 | 225 | 224 |
| 112 | 244 | 242 | 240 | 238 | 236 | 234 | 233 | 231 | 230 | 228 | 227 | 225 |
| 113 | 246 | 244 | 242 | 239 | 237 | 235 | 234 | 233 | 231 | 230 | 228 | 227 |
| 114 | 248 | 246 | 244 | 242 | 239 | 237 | 235 | 234 | 233 | 231 | 230 | 228 |
| 115 | 250 | 248 | 246 | 244 | 242 | 239 | 237 | 235 | 234 | 232 | 231 | 229 |
| 116 | 253 | 250 | 248 | 246 | 244 | 242 | 239 | 237 | 235 | 234 | 232 | 231 |
| 117 | 255 | 253 | 250 | 248 | 246 | 244 | 241 | 239 | 237 | 235 | 234 | 232 |
| 118 | 258 | 255 | 253 | 250 | 248 | 246 | 244 | 241 | 239 | 237 | 235 | 233 |
| 119 | 260 | 258 | 256 | 253 | 251 | 248 | 246 | 244 | 241 | 239 | 237 | 235 |
| 120 | 263 | 260 | 258 | 256 | 253 | 251 | 248 | 246 | 244 | 241 | 239 | 236 |
| 121 | 265 | 263 | 261 | 259 | 256 | 254 | 251 | 248 | 246 | 244 | 241 | 239 |
| 122 | 268 | 266 | 264 | 262 | 259 | 257 | 254 | 251 | 248 | 247 | 243 | 241 |
| 123 | 270 | 268 | 266 | 264 | 262 | 260 | 257 | 254 | 251 | 249 | 246 | 244 |
| 124 | 272 | 270 | 269 | 267 | 265 | 263 | 260 | 257 | 254 | 252 | 249 | 246 |
| 125 | 274 | 272 | 271 | 269 | 267 | 265 | 263 | 261 | 258 | 255 | 252 | 249 |
| 126 | 276 | 275 | 273 | 271 | 269 | 268 | 266 | 264 | 261 | 258 | 256 | 253 |
| 127 | 279 | 277 | 275 | 273 | 271 | 270 | 268 | 267 | 264 | 262 | 259 | 256 |
| 128 | 281 | 279 | 277 | 275 | 273 | 272 | 270 | 269 | 267 | 266 | 263 | 260 |

# APPENDIX C

## GENERAL INFORMATION ON METER OPERATION

### SCOPE

In the operation of positive displacement meters in various services or in metering different liquids, there are many practices or procedures being followed by various meter operators. Many of these procedures, although not presently standardized, are very useful and helpful. The following paragraphs include such practices—in many cases, in considerably more detail than is included in Sect. I through Sect. V of this standard. For the most part, these suggestions are categorized either by type of service or type of liquid.

### FREQUENCY OF METER MAINTENANCE OR PROOF

Because of the many varying sizes, services, fluids measured, flow rates, and pressures, it is difficult to establish a definite schedule of meter maintenance for all installations. A very practical approach to a determination of when to repair or inspect a meter will be found in a continuous log or plot of the factors (or accuracies) obtained from that meter. A sharp deviation or an abnormal trend in meter performance from that previously experienced is indicative of improper operation and signifies that the mechanical condition of the meter should be investigated. The periodic plotting of a meter accuracy curve may also be used as a guide to the frequency of meter repairs.

If as many as four proof runs must be made without obtaining two results which check each other within the pre-established allowable deviation, it is usually expedient to average the four factors obtained for these four runs and accept this average as the established meter factor. However, lack of reproducibility of reasonably consistent meter factors within tolerance may be indicative of mechanical defects. If inspection discloses mechanical defects, the meter shall be repaired and proved before being returned to service. It is frequently necessary to start a new log or plot of factors at this point.

### PORTABLE MASTER METER

In using the portable master meter to prove meters at isolated locations, as outlined in Par. 3036 and Par. 3037, a flexible hose is usually used to hook up the master meter to the stationary meter. Experience has shown that such flexible hose is subject to expansion under pressure, and this should not be overlooked. In the case where the portable master meter is hooked up to a prover tank to prove the master meter, or where it is hooked up to the stationary meter to prove the stationary meter against the master, the pressure condition in the flexible hose should be the same when the meter is shut down as it was when the meter was started. Failure to observe this condition might yield inconsistent meter performance information.

### BULK PLANT AND LOADING RACK METERS

Occasionally discrepancies are observed between the loading rack metered volume of liquid and the indicated capacity of the truck compartment. Assuming that the meter has been carefully and properly proved, the discrepancy may be attributable to one or more of the following:

1. An error in the indicated capacity of the truck compartment, either because of inaccurate calibration or because of change in the truck tank as a result of an accident or distortion.
2. Faulty compartment valves.
3. Compartment not being completely empty before filling.
4. The use of a tractor with a fifth wheel of different height.

If discrepancies persist—particularly with trucks known or believed to be accurately calibrated, and with valves and air eliminators operating satisfactorily—improper functioning of the loading rack meter is indicated, and an immediate investigation is necessary. If discrepancies cannot be reconciled in any other way, and if different test measures were used to calibrate the meter prover and the truck compartments, the test measures should be rechecked. Truck compartments should not be calibrated by using loading rack meters, or vice versa, because of evaporation conditions and temperature changes in the liquids involved. Similarly, it is frequently not possible to reconcile the volume delivered to a truck by loading rack meter with the volume delivered from that truck by truck meter because of temperature change and evaporation conditions. However, comparison of loading rack metered quantities and truck compartment capacities furnishes a valuable running spot check on the accuracy of both.

Excessive truck topping-off periods should be avoided. An operator, in filling a truck, should watch the loading rack meter and begin slowing down the flow shortly before the indicated compartment capacity is reached. The final shutoff should be made by using the meter reading rather than by attempting to "float" the compartment marker exactly. This can be accomplished automatically with a quantity-predetermining device. Because appreciable errors are not uncommon when visual truck compartment marker loadings are made, it is suggested that customers be billed by the loading rack meter reading rather than by the truck compartment indicated capacity.





27), or 10-gal capacity but may be larger. To establish uniform volume calibration, it is essential that the volume of test measures be determined and certified by an unbiased agency. The National Bureau of Standards (NBS) is established as the certifying agency. A certification will be made by the NBS on the basis of using water as the calibrating liquid (see Fig. 30, 31, and 32). When using a test measure that has been calibrated by the NBS, the *actual* capacity as shown on the certificate, report, or letter should be used rather than the nominal capacity. Laboratory graduates may be used for measuring partial volumes of a test measure.

**2042** Measures may be calibrated either "to contain" or "to deliver." A measure certified "to contain" will contain the volume specified, regardless of the type of liquid used, because the measure must be dried before each filling. A measure certified "to deliver" will be accurate only when water is used and must be wetted and drained before each occasion of use, according to Par. 2043. This standard recognizes that inaccurate measurement may result when liquids other than water are measured from a test measure or prover calibrated with water "to deliver" because of the variation in the amount of these liquids which will adhere to the interior surface of the vessel, and because of the difference in the drainage characteristics of these liquids. Notwithstanding, this standard adopts water as the prover-calibrating liquid; but when desirable and agreeable to all concerned, a hydrocarbon of low vapor pressure, such as *kerosine or fuel oil, may be used instead of water.* A visual inspection of any test measure should be made prior to each time the measure is used to ascertain that the measure capacity has not been altered by dents or corrosion products. Test measures should be returned to the National Bureau of Standards periodically for a recalibration and resealing.

**2043** The letter or purchase order accompanying a test measure being sent to the National Bureau of Standards * for calibration should state exactly how the measure is to be calibrated; i.e., whether it is to be calibrated "to contain" or "to deliver." If the gage scale of the test measure can be adjusted so that any difference between the indicated and the actual capacity is not greater than one part in 2,000 (0.05 per cent), the NBS will so adjust the scale and will affix a seal to it showing the identification number, year of test, and either the word "contains" or "delivers," depending upon the manner in which the test measure was calibrated. For measures which have been calibrated by the NBS "to deliver," the measure must first be filled with water and drained immediately prior to each occasion of use because it was calibrated in that condition. The drainage time for test measures of 10-gal capacity or smaller shall be 10 sec from the time the flow ceases and dripping commences, and 30 sec for measures exceeding 10 gal in capacity.

**2044** The design of a 5-gal measure shall be as shown in Fig. 26 or Fig. 27. The measure shall be made of metal, and the internal surface of the container shall be corrosion-resistant. The thickness of the metal walls and bottom shall not be less than 22 United States gage (0.029 in.). The thickness of the reinforcing bands or ribs shall not be less than 16 United States gage (0.059 in.). The seams joining the metal shall be filled with metal to eliminate crevices and pockets where liquid may be held by capillary attraction when the measure is emptied. Excess solder or welding material shall be removed from the inside of the measure. The bail shall be substantial and attached by strong trunnions to the outside of the neck so that there will be no distortion of the measure when lifted full of liquid. The gage glass scale shall be graduated in cubic inches, with at least 15 cubic-inch graduations above the zero setting and 15 cubic-inch graduations below the zero setting. Provision shall be made for adjusting, locking, and sealing the gage glass scale. The test measure must be so designed and used that it will be level when readings are taken, whether it be hung by the notch in the bail or set on a level surface.

**2045** Smaller test measures shall be similar to the 5-gal test measure shown in Fig. 26. The neck diameter shall be large enough to permit cleaning the inside of the measure by hand and shall have at least 10 cubic-inch gage scale graduations both above and below the zero setting. A larger test measure shall be similar to the 5-gal test measure, with appropriate increases in metal thickness and gage scale range.

**2046** A test measure is a delicate instrument and should be handled with great care to avoid damage which may alter its volume. A strong padded case shall be provided for storing and transporting the measure.

**2047** In case of dispute between interested parties over the accuracy of a test measure, the test measure in question shall be sent to the National Bureau of Standards, which shall be the final judge of the test measure accuracy.

#### Calibration of Prover with Necks Top and Bottom (See Fig. 14)

**2048** Two methods may be used to calibrate the lower and upper necks of volumetric provers. The first method consists of determining and marking the actual capacity of the prover on the scale and is detailed in the following paragraphs. The second method consists of installing previously marked scales and preparing suitable tank tables in appropriate units of measurement. Each method has certain advantages and disadvantages, but either may be used if mutually agreeable.

**2049** The following paragraphs describe the method of calibrating a prover with necks top and bottom, "to deliver" at 60 F and atmospheric pressure,

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* Mailing address: National Bureau of Standards, Washington 25, D. C.

Shipping address: National Bureau of Standards, Attention: Capacity, Density, and Fluid Meters Section, Washington 25, D. C.

This prover is closed and is suitable for most liquids (see Fig. 23).

**2028** The master meter prover is a positive displacement meter which has been previously proved by a test measure or by a prover of the volumetric or gravimetric type. The master meter prover is suitable for all liquids (see Fig. 25).

**2029** The gravimetric prover is a suitable vessel mounted upon weigh scales in which the test draft is weighed accurately. The weight of the test draft is converted to volume units. This prover may be open or closed and may be used for all liquids (see Fig. 19 and Fig. 20).

## PROCEDURES FOR THE CALIBRATION OF VOLUMETRIC PROVERS

### General

**2030** Two general methods for the calibration of volumetric provers are recognized. These are: 1, calibration by means of test measures and water; and, 2, calibration by means of master meters. The first is the preferred method and involves the determination of the volume of water withdrawn from the prover by gravity flow into certified test measures, or pouring water from test measures into the prover. The recommendations for calibrating provers which are covered in this section are based upon withdrawing water into the test measures. It may be expedient in certain types of installations, however, to reverse the procedures described by emptying full test measures of water into the prover. In both cases, the appropriate water volume corrections in Table I of Appendix B must be applied when the average temperature of the filled prover differs from the temperature of the water in the individual test measures.

The second method involves the use of a preproved master meter (or meters) where prover tanks are so large as to make the use of test measures impractical, or where the nature of the prover is not conducive to water calibration with test measures. By means of this method, the water or stable petroleum liquid used may be metered into or out of the prover and proper volumetric corrections applied where necessary.

**2031** When a prover is to be used at pressures substantially above atmospheric pressure, the prover volume should be determined at those pressures and a table of volume correction factors for test pressures prepared (see Par. 2116 through Par. 2122).

**2032** The calibration of provers may be simplified, when possible, by placing the prover, test measures, and test liquid in a constant-temperature enclosure for sufficient time to allow the equipment and test liquid to reach an equilibrium temperature. Similarly, it is desirable to conduct the calibration under these conditions so that the temperature of the equipment and test liquid will not change during the calibration. Whenever a temperature change occurs during the calibration, corrections must be made in accordance with Par. 2123 through Par. 2125. In order to prevent accumulation of air bubbles on the inside of the walls, the prover should not be allowed to stand full of water longer than necessary before its calibration.

**2033** In calibrating provers with test measures, whether measuring into or out of a prover, normal practice is to fill each measure to its exact certified capacity. A practical method of doing this is to overfill the measure slightly and then bring the liquid level to the exact capacity by withdrawing it into a suitable syringe. The quantity of liquid in the syringe is then released into the next filling of the test measure.

**2034** In several of the following calibration methods it is necessary to determine accurately the volume of a partially filled test measure. This may be done with suitable glass graduates or as follows: Determine the tare weight of the test measure, the gross weight of the completely filled test measure, and the gross weight of the partially filled test measure by an accurately calibrated weigh scale. Determine the net weights of the completely filled and partially filled test measure by subtraction. The volume of test liquid in the partially filled test measure is equal to the volume of the completely filled test measure multiplied by the net weight of the partially filled test measure and divided by the net weight of the completely filled test measure. The tare weight of a "to contain" test measure must be determined with the measure dry. The tare weight of a "to deliver" measure must be determined immediately after it has been filled, dumped, and drained for the prescribed time (see Par. 2043). If temperature changes occur, corrections must be made in accordance with Par. 2123 through Par. 2125.

**2035** At the completion of a calibration the data sheets should be used to prepare a suitable certificate for the prover (see Fig. 36, 41, and 42). All parties witnessing the calibration should sign this certificate as well as the data sheets.

### Preparation of Prover for Calibration

**2036** The following general procedures apply to the calibration of both permanently installed and portable volumetric provers.

**2037** The prover shall be clean internally. If the prover is portable, it shall be set plumb and level.

**2038** All devices and instruments which affect the internal volume of the prover, such as spray lines, thermometers, and gage glasses, shall be in place. There are certain exceptions which are described in Par. 2083.

**2039** Provers, including all valves, fittings, and blinds holding the test liquid, shall be tested for leaks.

**2040** Provision should be made for convenient filling and withdrawal of test liquid.

### Test Measures

**2041** Test measures used for calibrating volumetric provers are ordinarily of 1-, 5- (see Fig. 26 and Fig.



Meter systems with electrically operated remote registers require special care in the design and installation of electrical equipment and wiring. Proper protection of electrical equipment before installation is essential. Periodic inspection and maintenance of both transmitters and remote receivers are necessary to assure that the system is dry and the electrical contacts are clean. Good operating practice requires the frequent (at least daily) comparison of totalizers on the rack meter registers with those on the remote registers. Low or high line voltage, voltage fluctuation, or interruption of current will cause trouble. If any of these conditions exists, necessary steps should be taken, in accordance with the meter manufacturer's recommendation, to correct or minimize the condition.

## TANK TRUCK METERS

Meters used in tank truck service where liquids are delivered into customers' storage tanks must be accurate within certain tolerances set up by law, regulation, or the interested parties, as the case may be. The performance of truck meters is influenced by the nature and type of auxiliary equipment and by whether or not air or vapor is prevented from passing through the meter. When the meter and its auxiliary equipment are an integral part of the delivery vehicle, the meter should be proved periodically as it is installed on the vehicle to simulate actual delivery conditions, inasmuch as its performance may be affected by installation and connecting piping.

Fig. 9 and Fig. 29 show a prover of the open volumetric type for proving a meter installed on a truck where gravity discharge is used. Such an open prover may be either portable or stationary and must be so placed that the relative positions of the meter and prover will be the same as when the meter is discharging to a customer's underground tank. In many cases, it may be expedient to secure the negative head by placing the truck on a ramp to elevate it from the prover tank. Where truck discharge is accomplished by pumping, it is not usually necessary to maintain this elevation difference between the truck and the meter prover.

Proving the meter is done by making drafts from a truck compartment. If gravity delivery is used, the compartment shall be approximately one-half full of liquid. If pumping is employed, the compartment may contain any quantity of liquid in excess of the capacity of the prover. In any event, test drafts to determine the accuracy of the meter shall be on continuous liquid runs without consideration of air conditions. Two test runs shall normally be made and recorded. Meters shall be adjusted if required, and runs shall be repeated until two consecutive tests are within the required accuracy. Meter performance expressions generally used in proving meters on tank trucks are given in Sect. IV, and a suggested report form on which to record meter-proving data is provided in Appendix A.

It is essential in truck metering to assure that the air eliminator, vacuum release valves, or air vent lines are installed and are functioning properly to prevent the passage of air or vapors through the meter during normal truck deliveries. Specific tests on the truck-metering equipment illustrated in Fig. 2 and Fig. 29 should be made to determine that the air eliminator is functioning properly and that the meter is not receiving quantities of air from the truck. Such tests are usually made during the proof of a meter by withdrawing the first portion of the total test draft from one compartment until emptied, then switching to a second compartment for the remainder of the test draft.

The proving of truck meters must simulate operating conditions in every way, insofar as type of liquid and rate of flow are concerned, in order to provide accuracy of measurement of the highest order.

The truck should be in a reasonably level position while being unloaded. Multiple-compartment trucks shall be so operated that liquid can flow through the delivery line to the truck meter from only one compartment at any one time, and only to the truck meter. Two or more compartments which can only be operated together are herein considered to be one compartment. Where more than one outlet is possible from a truck meter, provision shall be made to deliver from only one outlet at any one time, the direction of discharge flow being clearly indicated.

In operating truck meters, occasions may arise when the deliveries through accurately proved and properly operated truck meters may vary from the indicated truck compartment capacities. Such discrepancies may be the result of one or more of the following conditions:

1. Truck compartments may be inaccurately calibrated or may be damaged or distorted. Reconciliation may be obtained by rechecking the truck meter, the test measures used to calibrate the truck, and the truck capacity itself.

2. The truck may be loaded with internal valves closed and its calibration made with them open, or vice versa.

3. If the truck is calibrated with internal valves open, cross valves or manifold valves may be leaking or air may have been trapped in the discharge lines during loading.

4. If the truck is calibrated with internal valves closed, leaks in these valves would cause apparent meter inaccuracy.

5. Overloading or underloading may be caused by errors in attempting to load to compartment markers.

6. The truck may not be level during loading or unloading.

7. A sizable cumulative discrepancy may result from small overdeliveries for each of partial truck or compartment deliveries, or from alternating partial deliveries with full-compartment bypassed deliveries.

8. The height of the fill pipe on underground tanks may prevent complete unloading.

9. The hose siphon may be broken before all liquid is drained from long compartment lines.

10. The temperature of liquid in the truck may change between loading and unloading.

The truck meter installation should be checked frequently to make sure that the meter and accessory equipment are firmly secured in place. A truck involved in an accident should have its metering equipment checked and proved before it is re-used. The truck tank should also be recalibrated.

## PIPELINE METERS

The degree of accuracy required in products pipelines or crude oil pipelines is usually sufficiently high to justify the application of all principles advocated in this standard. Written agreements are frequently prepared to cover the measurement operations of the participating parties, and many times individual companies prepare their own manuals of practice intended to produce metered measurements within their desired tolerances.

The care and precision with which pipeline meters are proved and operated normally constitute a very important pipeline operating function because of the large volumes measured, usually on a continuous basis.

There are many details in the successful and accurate operation of meters in the field which cannot easily be described in a text or manual but which are essential to good metering. These are skills which the meter operator must acquire through training and experience in the field. They include such things as quality meter repair and maintenance work; the elimination of human errors; the detection of leaking valves; the recognition of air troubles; and astuteness in determining specific gravities, flow rates, meter readings, and temperature readings.

It is recommended that pipeline meter installations normally be equipped with permanently installed meter-proving equipment. In such an operation the "permanently installed master meter method" may be used at the discretion of the owners. Provision may also be made for the temporary installation of previously proved master meters in series with the regular operating meters for meter-proving purposes. When meters are equipped with removable measuring chambers or mechanisms as a unit, such a unit may be removed from the meter case and installed in a test case for proving at a testing laboratory. A preproved unit is installed in the case after removal of the original unit for proving, where such procedure is agreeable to the parties involved.

Foremost among the provers employed are the top and bottom graduated-neck provers, the single- and double-weir provers, the water displacement provers, the gravimetric provers, and the unidirectional and bidirectional piston displacement provers. Frequently the master meter method of proving is used in conjunction with one of these types of provers.

Products pipeline meters should be proved by a method which eliminates or mitigates evaporation in the test draft during the meter proof (see Par. 3005 and Par. 3021).

It is usually necessary in pipeline metering to control or apply proper corrections for variations in operating flow rates, meter case operating pressures, temperatures, and type of liquid or liquids being metered. Temperatures of the metered liquid are read to the nearest 0.1 F and API gravities to the nearest 0.1 deg; pressures are determined with sufficient accuracy to minimize errors resulting from liquid compressibility.

Because of the extreme temperature variation to which liquids transported by pipeline are often subjected, it is recommended that ASTM D 1250 Table 6 be used for liquids under 100 deg API gravity, and Table 24 be used for liquids above 100 deg API equivalent.

Many operators prove meters on every batch of liquid they measure or for significant changes in flow rates; others have adopted the policy of proving for every liquid which varies approximately 5 deg API gravity or more from the previous liquid.

In the operation of meters in pipeline service, particularly when the custody of the liquid being metered is changed from shipper to transporter or from transporter to consignee, there are a number of practices which, if followed, will lead to a more general understanding among the parties involved of the responsibilities of each. Some of these recommended practices are as follows:

1. A representative of the meter owner shall conduct the overall general measurement program, making available to all interested parties complete records of such measurements.

2. A representative of the meter owner shall conduct the calibration of the prover involved.

3. A representative of the other party, or parties, involved shall be privileged to witness the calibration of the prover involved.

4. A certificate of the calibration shall be prepared by the owner. Both parties shall sign the certificate, indicating agreement of the capacity determined. Each interested party shall receive a copy of the prover tank calibration certificate.

5. A representative of the meter owner shall perform all provings of the meter involved.

6. A representative of the other party, or parties, involved shall be privileged to witness all provings on the meter involved and shall receive a copy of the proving reports.

7. Temperatures, pressures, and meter readings, as well as other necessary data, shall be taken and recorded by the owner of the meter at intervals agreed upon by all parties involved.

8. Records of the data recorded shall be furnished by the owner to all interested parties as promptly as possible.



section consistent with the necessary strength. The exposed parts of the well should be insulated. The insulation should extend at least 12 in. around the tank wall from the thermometer well. The thermometer well shall be deep enough for proper immersion of the thermometer.

**2017** Location of thermometers in the prover is important. For the most part, the use of two thermometers is recommended in volumetric provers larger than 10 gal and not over 500 gal. Three thermometers should be used in prover vessels larger than 500 gal. One thermometer should be in the upper third of the main body of the prover, a second in the lower third of the main body of the prover; and a third thermometer, if used, should be near the center of the main body of the prover. For piston provers, the thermometers should be located at the extremities of the meter prover section. The temperature of the liquid shall be the average of the readings of the thermometers used. For gravimetric provers thermometers are not required.

**2018** Pressure gages are required in closed provers. The gages shall be reliable and of suitable range, calibrated to an accuracy of one per cent of full-scale reading. Gage connections shall be short to avoid trapping of vapors or liquids. In general, *Instruments and Apparatus, Part 2: Pressure Measurement,* supplement to *ASME Power Test Codes,* shall be followed.

**2019** Gravimetric provers may be of either the open or closed types, similar to volumetric provers (see Par. 2003 through Par. 2005). The weigh scale may be equipped either with a weigh beam and counterpoise or with an automatic indicating dial. The scale graduations shall be no greater than 0.02 per cent of the maximum scale capacity. The maximum capacity of the scale should be approximately 20 per cent greater than the gross weight of the weigh tank when filled with the test liquid and including all attachments to the tank. Piping connections to the weigh tank shall be such that no drag is introduced which might affect the accuracy of the scale. The tolerance of the weigh scale shall be the value of one of the minimum graduations on the weigh beam or reading dial (see *National Bureau of Standards Handbook H 44: Specifications, Tolerances, and Regulations for Commercial Weighing and Measuring Devices* or revisions thereof). When in use, gravimetric provers should be protected from air currents or other disturbances. The weigh scales should be installed level and plumb on suitable foundations. The mounting of the weigh tank on the scale shall be such that the load is centered and on a stiff frame. Typical designs of gravimetric provers are shown in Appendix A (see Fig. 19 and Fig. 20).

## DESCRIPTION OF PROVERS

**2020** There are two general types of provers—volumetric and gravimetric. The several kinds of volumetric provers are:

*a.* Top and bottom graduated-neck prover (see Fig. 14).

*b.* Top graduated-neck prover (see Fig. 9, 10, and 26).

*c.* Single-weir prover (see Fig. 11).

*d.* Double-weir prover (see Fig. 12).

*e.* Vapor-condensing prover (see Fig. 24).

*f.* Bidirectional piston prover (see Fig. 21 and Fig. 22).

*g.* Unidirectional piston prover (see Fig. 23).

*h.* Master meter prover (see Fig. 25).

**2021** The top and bottom graduated-neck prover is a vessel which has a reduced cross-section, or neck, located at both top and bottom to enable a more accurate determination of incremental volume. It may be used as either an open or closed prover and is suitable for most liquids. Both the top and bottom necks should have gage glasses, or other suitable means, for indicating accurately the liquid level or the interface of test liquid. There may be one or more gage scales on each neck (see Fig. 9 and Fig. 14).

**2022** The top graduated-neck prover is a vessel which has a reduced cross-section, or neck, at the top only and may be either open or closed. In use, the bottom level is determined by completely draining the vessel with suitable valving or by inverting the vessel (see Fig. 9, 10, and 26).

**2023** The single-weir prover is a vessel which has a reduced cross-section at the top and a weir overflow to establish the bottom level. It may be used as either an open or closed prover and is suitable for most liquids (see Fig. 11).

**2024** The double-weir prover is a vessel which has weir overflow connections at both top and bottom. The top weir overflows into a supplementary vessel of reduced cross-section for determination of the incremental volume of the overflow. This prover may be used either open or closed and is suitable for most liquids (see Fig. 12).

**2025** The vapor-condensing prover is a pressure vessel without necks or gage glasses at either top or bottom. Its total volume is accurately determined and, in use, the vessel is completely emptied and completely filled. It is used only for high-vapor-pressure products, such as LPG, where the vapors can be condensed as the vessel is filled (see Fig. 24).

**2026** The bidirectional piston prover is a cylindrical pressure vessel in which a sealed free piston reciprocates and displaces a fixed volume in each direction. The end of each stroke is accurately established by suitable stops. This prover is used closed and is suitable for most liquids (see Fig. 21 and Fig. 22).

**2027** The unidirectional piston prover is one in which a sealed free piston moves in a section of pipe in one direction only, to displace a predetermined volume between two known points in the cylinder. These points are indicated by suitable mechanical or electrical devices or both. The piston may be removed from, and reinserted in, the pipe for each proving run.

**2004** A prover should have a capacity sufficient to provide for a test run of adequate duration so that the proving results obtained are acceptable to all parties concerned. It is suggested that the capacity of the prover be such that approximately 95 per cent of the total liquid entering the prover can be delivered at the proving flow rate. In any event, the capacity of a prover shall not be less than the volume delivered in 1 min through the meter to be proved. It is preferable, however, that the capacity be 1½ to 2 times the volume delivered in 1 min.

**2005** Volumetric prover tanks shall be constructed sufficiently strong and rugged to prevent significant distortion of the vessel when full of liquid at the proving pressure. These prover tanks shall be constructed for complete drainage of liquid to a lower reference level without trapping pockets of liquid. Changes of cross-sections should be gradual and of sufficient slope, so that as the prover is filled, gas bubbles will not be trapped but will travel to the top of the prover; and as the prover is emptied, the liquid will drain quickly. The prover tank should be as self-cleaning as possible in order that corrosion products, valve grease, and foreign matter will not collect inside the prover. Provision should be made for periodic, visual internal inspection of the prover tanks. Gage glasses should be of such type that they may be cleaned (swabbed) without removal from the prover tanks. The appurtenances, later described, should be installed in convenient locations for quick and practical operation and ready and precise readability. Typical designs of volumetric prover tanks are shown in Appendix A.

**2006** The design and material used in constructing a closed pressure-type prover will depend on the maximum pressure to which the prover may be subjected and the characteristics of the liquid to be metered. Provers for a pressure of over 15 psig shall be designed and constructed in compliance with *Unfired Pressure Vessels*, Section VIII of *ASME Boiler and Pressure Vessel Code*, and applicable state regulations and local codes. Such provers should have a name plate, permanently affixed and bearing the code designation, an identification number, and maximum allowable working pressure.

**2007** Prover inlet connections, prover outlet connections, or both, should be provided to take care of the particular type of installation involved. For example, for a water displacement or vapor-condensing prover, the test liquid inlet is at the top; in a vapor or gas displacement prover, the test liquid inlet is at the bottom. The prover outlet connection should be of adequate size to permit rapid emptying of the tank between proving runs.

**2008** Bleeder valves should be installed on water displacement provers near the top of the upper neck and the bottom of the lower neck for removal of emulsion from the interfaces between the test liquid and the water. A vent should be provided at the highest point of the prover for removing entrained gases.

**2009** The gas displacement prover should have uniform pressure regulation to maintain the internal pressure above the vapor pressure of the test liquid throughout the proving run.

**2010** The inside diameter of the necks on provers shall be such that the smallest readable graduation represents no more than 0.02 per cent of the total volume of the prover, except that the inside diameter of the necks shall be at least 3½ in.

**2011** The capacity of the upper neck falling within the gage glass length shall be at least 2.0 per cent of the prover volume, and the capacity of the lower neck falling within the gage glass length shall be at least 1.0 per cent of the prover volume, except for variations shown in Fig. 14 for water displacement provers. When meters of large capacity are being proved, a longer reading range may be required to provide observation of the liquid level during the time required for manipulating the valves.

**2012** Gage glasses shall be a minimum of ⅝ in. in inside diameter, preferably larger. Gage glass fittings used for volume measurement should be installed directly into the walls of the neck or body of the prover. Additional gage glasses may be provided to cover the main body of the prover. The suggested maximum length for a gage glass is 24 in. to minimize errors resulting from temperature differences between the liquid in the gage glass and in the prover.

**2013** The gage glass scales shall be subdivided in the desired increments. Scales shall be securely mounted behind or immediately adjacent to the gage glasses; they shall have suitable provisions for vertical adjustment and sealing into a permanent position. Such scales should be made of a corrosion-resistant material.

**2014** Accurate temperature measurement of the test liquid both at the meter and in the prover (except gravimetric) is essential. In general, *Instruments and Apparatus, Part 3: Temperature Measurement*, supplement to *ASME Power Test Codes*, should be followed. All thermometers should be checked with a certified test thermometer frequently enough to assure continued accurate indication.

**2015** It is recommended that industrial thermometers having a suitable range be used, graduated in single degrees or less and accurate to 1 F or better. They shall be installed directly through the prover shell (preferably without a well), with a minimum stem immersion of 12 in. but a preferred stem immersion of one-third of the prover radius. The use of averaging resistance-type thermometers, as specified in *API Standard 2500: Measuring, Sampling, and Testing Crude Oil*, is acceptable and may prove advantageous in volumetric provers of large capacity.

**2016** If thermometer wells (for etched-stem glass thermometers) are used in a prover, the wells should be of the plain type, filled with mercury or other suitable liquid. The thermometer well should be constructed so that it has the smallest possible diameter and metallic



9. Either or both parties may place seals on the meter or its appurtenances (not to interfere with normal operations). Seals shall not be broken by either party without the permission of the other party, or parties, involved.

10. When either party finds evidence of mismeasurement through a meter, that party may demand an immediate proving test. If the proving shows that the factor is constant and within the agreed tolerance, the meter shall remain in service. Otherwise, a new factor shall be determined to the satisfaction of all parties involved. Application of such a factor should commence immediately.

11. Where more than one meter is available, the total flow shall be distributed so as to assure that each meter operates within its minimum and maximum flow rates.

12. When a meter starts the measurement of a particular batch or tender, it shall be referred to as the "regular" meter and shall continue operating on that batch of liquid as long as it is in operating order. In the event of breakdown, evidence of mismeasurement, or necessity for proving, a standby meter may be used. If the standby is required because of failure of the regular meter, then it becomes the regular meter and should be proved as such.

13. The standby meter need not be proved unless it becomes the regular meter; however, the use of the standby meter should be limited to very short intervals. Should a standby meter be used for more than three hours, it should be classed as the regular meter.

14. No changes shall be made in a meter adjustment, temperature compensator, gravity selector, or register change gears subsequent to a previously witnessed meter proving without the approval of all parties concerned.

15. When meters immediately downstream from a pump must be proved, provision shall be made to keep the stream moving through the pump immediately prior to, during, and after the proving in order that stream temperatures during the proving will not be affected.

16. If, during any delivery through a meter, there have been significant variations in temperatures, pressures, or rates of flow, the hourly or periodic meter readings shall be separately adjusted and the sum of the separate periodic measurements shall be considered the correct total amount of the delivery.

17. For all hourly or periodic net delivery computations, the line temperatures, pressures, and rates of flow shall normally be the average of the readings at the start and finish of the hour or period. Under conditions where relatively large and uneven changes occur, the average for the hour or period shall be determined from representative readings made throughout the hour or period.

## CRUDE OIL METERS

In general, the recommendations described in the foregoing paragraphs for proving products pipeline meters hold also for crude oil meters.

It must be recognized that some types of crude oil will adhere to, and form a film on, the walls of the prover tank and may make the liquid level in gage glasses difficult to determine. The extent may vary depending on several factors, such as crude oil characteristics, wax, temperature, or frequency of use. For this reason, periodic inspections of the internal surfaces of the prover tank must be made to maintain the true volume of the prover tank, either by cleaning the internal surfaces or recalibrating the tank. In general, a properly designed vessel can be operated in a manner such that internal deposition of wax, viscous crude oil, or foreign material can be minimized; or it may be preferable to use a proving method which will eliminate these difficulties.

Since crude oils in general have considerably higher viscosity than products, the accuracy of meters in crude oil service normally varies less with change in flow rate than is the case when metering refined products.

In some instances, as in the proving of meters employed in gathering operations where a calibrated section of the lease tank is being used as a meter prover, it shall be permissible to run the test liquid from the prover through the meter.

Meters on crude oil gathering systems present varying problems which require careful attention for satisfactory operation. Flow rates may fluctuate widely and are frequently intermittent. During periods of no flow or low flow, water and sediment may settle out in the meter case and cause corrosion and abrasion of the working parts. Air is frequently drawn into gathering system lines and, if not eliminated, will cause erroneous meter readings. It is advisable to provide meters in crude oil gathering line service with adequate straining and gas (air or vapor) elimination equipment unless shutoff valves are installed which will stop the flow before air can enter the line to the meter. Bleeders should also be provided to draw water and sediment from the meter case. Frequent inspections should be made to detect wear on the meter before it has progressed to the point at which it would seriously affect the meter performance.

## LPG METERS

Many of the operating procedures described in this standard for the operation of bulk plant and loading rack meters, tank truck meters, and pipeline meters are applicable to the operation of LPG meters as these meters may be used in any of such services. However, there are certain factors which become more important in the metering of LPG than in the metering of other liquids.

LPG is more compressible and has a higher coefficient of thermal expansion than the heavier hydrocarbons. Any deviation of operating temperatures and pressures from proving temperatures and pressures will introduce greater inaccuracies in metering LPG than in metering the heavier hydrocarbons. These same factors require extremely accurate pressure, temperature, and specific gravity determinations during proving of the meter. Thus the calibration of instruments for the determination of temperature, pressure, and specific gravity is extremely critical. Thermometers with graduations of 0.2 F, read to 0.1 F, are quite often used for LPG meter proving.

LPG has a lower viscosity than most hydrocarbons, and the range of accurate flow measurement for a given installation may be less for LPG than for other liquids.

Vaporization of LPG before or in the meter is a possible source of measurement error. It is important, when operating LPG meters near the vapor pressure of the product, to maintain vapor elimination and pressure regulation equipment in satisfactory operating condition to avoid the passage of vapor through the measuring chamber.

LPG must be kept under pressure while being metered to maintain it in liquid form, and this fact gives rise to certain problems in connection with its measurement.

The considerations of special import in the proving of meters in LPG service arise from the following:

1. LPG is normally handled and metered under relatively high operating pressures, necessitating the application of meters designed for such working pressures and requiring closed provers.

2. LPG flashes to its vapor phase when pressure is reduced below its bubble point. For this reason it is mandatory, in metering such liquids, to maintain the pressure high enough so that no vapor is released during the time it is passed through the meter. If there is any tendency to flash vapor in or ahead of the meter, the liquid measurement will be in error, inasmuch as most meters will measure gases as well as liquid. LPG has a higher coefficient of thermal expansion and is more compressible as compared to motor grade gasolines or distillates. For this reason, adequate and accurate accounting of temperature and pressure variations is essential to precision measurement and to meter proving.

3. It is inadvisable to use the water displacement method of meter proving for meters measuring dried LPG because of the absorption of water.



truck meters must be installed so that the outlet drain level is at a higher elevation than the body of the liquid in the meter.

**1032** Meters shall be installed in such a manner as to minimize the effect of vibrating strains and the possibility of mechanical damage.

## INSTALLATION OF METERS ON LOADING RACKS

**1033** Fig. 4 is a schematic diagram showing a typical meter installation at a loading rack for low-vapor pressure liquids.

**1034** Loading piping shall be designed to prevent drainage of liquid from the meter, and to assure that the terminus of undelivered liquid will occur at the same point in the piping every time the flow through the meter is stopped by closing the normally used loading valve.

## INSTALLATION OF METERS IN OIL WELL SERVICE

**1035** Fig. 5, 6, and 7 are schematic diagrams which embody the essential items of a metering installation used to measure crude oil, condensate, or distillate produced from wells. These installations should be designed to prevent flashing caused by restrictions such as strainers, thermometers, or other types of reduction in the pipe area.

**1036** The meter shall be installed between the oil-gas separator and the liquid outlet control valve on the oil-gas separator, according to Par. 1024 and 1037 and Fig. 5, 6, or 7.

**1037** In intermittent flow installations, the outlet control valve must provide a positive shutoff to prevent separator drainage. Single-seated valves are recommended for this service. In continuous flow installations, pilot-operated or mechanically float-operated valves may be used. Pilot-operated valves shall be of the snap-acting, normally closed type; i.e., closing with pilot supply failure. Where a throttling type of control valve is used, the flow rate should never be permitted to drop below the minimum allowable flow rate of the meter.

**1038** Where open proving equipment is used, as in Fig. 5, a meter-proving connection shall be installed and suitably valved so that flow may be diverted into the prover and still maintain the normal operating meter pressure and flow rate.

**1039** Where closed proving equipment is used, as in Fig. 6 and Fig. 7, a meter-proving connection may be installed upstream or downstream of the liquid outlet control valve. A means shall be provided to maintain the normal operating meter pressure and flow rate. Means may also be provided to maintain the prover at the required reference pressure.

## INSTALLATION OF METERS IN CRUDE OIL PIPELINE GATHERING SERVICE

**1040** Fig. 8 is a schematic diagram which embodies the essential items for a fixed meter installation on gravity or pumped gathering lines.

**1041** An adequate means shall be provided to assure that the stream is shut off positively before air or vapor from the producer tanks enters the meter. As shown in Fig. 8, either a liquid level shutoff valve or a manually set predetermining device should be used in each installation. The particular type of device used might perform other functions than to assure that no air or vapor enters the meter. For example, the manually set quantity-predetermining device could also be used to assure that the lease allowable is not exceeded.

# SECTION II—METER PROVERS AND THEIR CALIBRATION

## SCOPE

**2001** This section covers equipment to be used in proving positive displacement meters employed in the several different categories previously mentioned. Procedures for the calibration of the different types of meter provers are also included.

## GENERAL PROVISIONS

**2002** Positive displacement meters may be proved by volumetric or gravimetric methods. The provers described in this section may be either stationary or portable. Proving consists fundamentally in the measurement of a quantity of liquid delivered by a meter in a container of known volume or in which the contents can be weighed, or of that delivered by a previously proven meter.

**2003** Proving systems entirely closed to the atmosphere are essential for liquids of high vapor pressure. Open provers, with or without evaporation control, or closed provers may be used for liquids with low vapor pressure (see Fig. 9, 10, 11, 12, 13, 19, and 26). With closed provers evaporation control may be obtained by employing a second low-vapor-pressure immiscible liquid (water displacement method—see Fig. 15 and Fig. 16). Gas presaturated with the liquid being metered (gas displacement method) or the vapor from the metered liquid (vapor displacement method—see Fig. 17 and Fig. 18) may be used to isolate the test liquid from the atmosphere. Some closed provers confine the test liquid under sufficient pressure to preclude evaporation while displacing a precalibrated volume of liquid from the prover by mechanical means (piston displacement method—see Fig. 21 through Fig. 23). In other closed provers, the vapors are condensed and allowance is made for their condensed volume (vapor-condensing method—see Fig. 24).

elimination of protective devices can prove to be desirable.

**1014** Meters shall be installed in a plumb and level position and in such a manner that they will not be subjected to undue strain and vibration. Provision should be made to minimize meter distortion caused by piping expansion and contraction.

**1015** Where the flow rate is too great for any one meter, the installation of a bank of meters connected in parallel is recommended, especially where they are required in continuous service. Such installations should provide a standby meter or meters for shutdowns, breakdowns, and certain types of provings, thereby assuring complete flexibility and continuous operation. If meters are installed in battery form and a multimeter totalizer is used, it is necessary also that each individual meter have a register.

**1016** Special consideration should be given to properly positioning each meter and its auxiliary equipment and piping so as to minimize the commingling of the different liquids handled through them.

**1017** Meter installations should be protected from excessive pressures caused by thermal expansion of the liquid.

**1018** Valves used in a meter installation which may affect measurement accuracy must be capable of rapid, yet smooth opening and closing and must provide a positive shutoff.

**1019** Meters shall be adequately protected from pressure pulsations and excessive surges. This may require the installation of surge tanks, expansion chambers, relief valves, and/or other protective devices.

**1020** Meter installations shall be provided with either manual or automatic means to permit proving the meter under the same conditions of flow rate, pressure, and liquid characteristics as exist during the normal operation of the meter.

**1021** A reliable thermometer, or a thermometer well permitting the use of a temperature-measuring device, should be installed in or near the inlet or outlet of a meter to permit determination of the liquid temperature of the metered stream. The thermometer specifications and installation details are similar to those prescribed for the prover tank thermometer in Par. 2014 through Par. 2017 of Sect. II. If temperature-compensated meters are used, a suitable means for checking the operation of the compensating device is required.

**1022** A reliable recording or indicating pressure gage of suitable range, and accurate within one per cent of its scale range, shall be installed in or near the inlet or outlet of every meter where determination of the meter case pressure is required (see Par. 2018).

**1023** Any bypass around a meter or battery of meters shall be provided with an acceptable blanking device.

**1024** Any automatic device such as a flow-limiting valve or restricting orifice, where required, shall be installed downstream from the meter to prevent flows in excess of the maximum rated capacity of the meter. Where a pressure-reducing means is required on the inlet side of a meter, it shall be installed as far upstream from the meter as possible. It shall be adjusted so that sufficient pressure will be maintained on the outlet side of the meter to prevent any vaporization of the metered liquid.

**1025** Meter installations shall be made so that the meter will operate within its pressure range and flow range to yield measurements within the desired tolerance.

**1026** When placing a new meter installation in service, suitable means should be taken to protect the meter from damage by entrained foreign matter, such as slag, welding spatter, or thread cuttings, which might be carried to the metering mechanism by the initial passage of liquid. Temporary replacement of the meter by a spool, a bypass around the meter, removal of the metering element, or installation of a suitable protective device ahead of the meter are suggested means of accomplishing such protection.

**1027** To prevent gumming of the meter mechanisms, pipe compounds should be applied to male threads only.

## INSTALLATION OF METERS IN PIPELINE SERVICE

**1028** Fig. 1 (see Appendix A for Fig. 1 through Fig. 42) is a schematic diagram which embodies the essential items for a fixed meter installation in crude oil or products pipeline service. The diagram is presented in this form to provide a working basis for the design of a meter installation. Certain items may or may not be required for a particular installation.

## INSTALLATION OF METERS ON TANK TRUCKS

**1029** Fig. 2 and Fig. 3 are schematic diagrams which embody the essential items of metering systems installed on tank trucks. All such installations shall include adequate gas (air or vapor) elimination equipment. Special consideration should be given to the design of tank outlet connections equipped for gravity delivery to minimize the entrance of air. In the case of deliveries by gravity through a demountable hose, the air eliminator vent shall be conducted to the downstream side of the meter. In deliveries by truck pump, with delivery hose permanently attached to meter outlet and with the hose remaining liquid-filled, the air or vapor eliminator vent shall be piped to the top of the truck compartment, or to a suitable condensate tank.

**1030** Truck meters fed by a truck pump shall be equipped with back-pressure valves, or other suitable means, where an added back pressure is required to make the air eliminator operate effectively and to keep the meter full of liquid.

**1031** To prevent drainage of the meter, gravity

# APPENDIX D

## NOMENCLATURE AND DEFINITIONS

This glossary of terms is provided to effect standardization of equipment nomenclature, procedural and functional terms, and phrases peculiar to positive displacement metering in the petroleum industry. Manufacturers' trade names have not been included, but their equipment has been categorized under terms broadly descriptive of purpose or function. Some terms are coined or colloquial but are sufficiently expressive to be included.

1. *Accuracy curve (performance curve):* A graph of a meter's performance, showing meter accuracy or meter factor as the ordinate and actual rate of flow as the abscissa.

2. *Adjustment (of registration):* The means by which the relationship between the volume indicated by the meter register and the actual volume of liquid passing through the meter is changed.

3. *Air eliminator (separator):* A device designed to separate and remove gases (air or vapor) from the flowing stream.

4. *API gravity:* See definition No. 28.

5. *Auxiliary equipment:* The equipment which is installed in conjunction with a meter, such as an air eliminator, strainer, vacuum breaker, or regulating valve, to permit or facilitate the use or operation of the meter.

6. *Batch:* An integral and complete movement of one specific type of liquid, usually designated as such when moved through a pipeline. (Sometimes referred to as a "tender.")

7. *Battery or bank of meters:* An installation of meters connected in parallel.

8. *Blanking device:* A positive mechanical means placed in a line to prevent flow of liquid. (Sometimes referred to simply as a "blind.")

9. *Blind:* See definition No. 8.

10. *Bubble point:* The temperature-pressure condition of a liquid under which the first vapor evolution begins.

11. *Calibrate a volumetric or gravimetric prover:* To establish the true volume of a volumetric meter prover or the accuracy of the scale of a gravimetric prover.

12. *Choke:* A flow-restricting device, sometimes fixed, installed in a line.

13. *Compressibility, apparent:* The algebraic sum of the true compressibility of a liquid and the enlargement of the confining container as a result of pressure.

14. *Compressibility, true:* The absolute decrease in volume of a liquid caused by an increase in pressure.

15. *"Contain":* A condition of calibration of a vessel, wherein the volume of the vessel is determined starting with the internal surfaces dry and free of the calibrating liquid; i.e., the vessel will "contain" its calibrated volume.

16. *Counter:* A term sometimes used when referring to a meter register. (See definitions No. 62 through No. 75 for preferred nomenclature.)

17. *"Deliver":* A condition of calibration of a vessel, wherein the volume of the vessel is determined starting with the internal surfaces wetted with the calibrating liquid; i.e., the vessel will "deliver" its calibrated volume.

18. *Delivery, over-or-under:* The volume obtained by subtracting the meter registration from the quantity measured in the prover and expressing the difference in units such as cubic inches per test measure, cubic inches per gallon, or cubic inches per barrel. Overdelivery will be indicated if the algebraic result has a plus sign; underdelivery will be indicated if it has a minus sign.

19. *Delivery (test draft):* The actual volume delivered by a meter as measured in a prover.

20. *Drainage time for test measures:* The drainage time for test measures of 10-gal capacity or smaller shall be 10 sec from the time the flow ceases and dripping commences, and 30 sec for measures exceeding 10-gal capacity.

21. *Equilibrium pressure:* The vapor pressure of a liquid at a given temperature, expressed in pounds per square inch gage. (See definition No. 99.)

22. *Filter:* A vessel usually installed upstream from a meter and equipped with a medium intended to remove foreign matter from the flowing stream.

23. *Filter-separator:* Same as No. 22 but intended to remove water in addition to foreign matter.

24. *Flash:* To suddenly release pressure on a liquid, resulting in partial or complete vaporization sometimes known as flashing.

25. *Flow-rate-limiting device:* A mechanical device installed in a line and operated in such a manner as to prevent the rate of flow through the meter from exceeding the maximum desired flow rate.

26. *Graduate, laboratory:* A glass cylinder, usually graduated in milliliters.

27. *Graduated neck:* A portion of a prover at either its top or bottom or both, of reduced cross-section, graduated to permit close incremental reading of the volume in the prover.

28. *Gravity, API:* A measure of the specific gravity of a liquid hydrocarbon as indicated by a hydrometer having a scale graduated in degrees API. The relation between API gravity and specific gravity is:

$$\text{API gravity at 60 F} = \frac{141.5}{\text{specific gravity, 60 F/60 F}} - 131.5$$

29. *Gravity, specific:* The ratio of the weight of a given volume of liquid hydrocarbon to the weight of the same volume of distilled water, both liquids being at a

temperature of 60 F and both weights being corrected for the buoyancy of air.

30. *Gravity selector:* A mechanism used to adjust a temperature compensator to change its performance according to the coefficient of thermal expansion of the liquid being metered.

31. *High-vapor-pressure liquid:* A liquid which, at the proving temperature of the meter, has an absolute vapor pressure equal to or higher than existing atmospheric pressure.

32. *Intermediate gears:* The gear or system of gears which transmits the motion of the measuring element to the register, ticket printer, or both.

33. *Laboratory graduate:* See definition No. 26.

34. *Low-vapor-pressure liquid:* A liquid which, at the proving temperature of the meter, has an absolute vapor pressure less than existing atmospheric pressure.

35. *LPG (liquefied petroleum gas):* Any material which is composed predominately of any of the following hydrocarbons or mixtures of them: propane, propylene, butanes (*n*butane or *iso*butane), and butylenes.

36. *Master meter:* A proved meter which serves as a prover, either portable or stationary, connected in series with the meter or meters to be proved.

37. *Measurement, reference conditions of:* The temperature and pressure conditions to which the volume, as determined by the meter, is to be corrected. The temperature to which volume measurements are to be corrected is usually 60 F. The reference pressure is atmospheric pressure, the absolute vapor pressure of the liquid at 60 F, or a mutually agreed upon pressure.

38. *Measuring chamber:* The portion of a meter which contains the measuring element.

39. *Measuring element:* The portion of a meter which moves within the measuring chamber so as to divide the liquid into segments as the liquid passes through the meter.

40. *Meniscus:* The curved surface at the end of a liquid column (see Par. 3015).

41. *Meter, positive displacement:* A device installed in a piping system in which flowing liquid is constantly and mechanically isolated into segments of known volume. These segments of liquid are counted as they are displaced and their accumulated total continuously and instantaneously indicated in units of liquid quantity by the meter register. These fixed-quantity liquid segments are united as they emerge from the measuring element, along with that portion of liquid which "slips" through the clearances between the moving parts of the measuring element. Positive displacement meters are generally differentiated by the type of mechanism employed to isolate the liquid segments, i.e., by the nature of their measuring element. The terms used to describe the most common types of measuring elements are: 1, nutating disc; 2, reciprocating piston; 3, oscillating piston; 4, vane-type rotary; 5, bucket-type rotary; 6, lobed rotary; 7, helical rotary; and, 8, certain combinations of these.

42. *Meter accuracy:* A number by which the meter registration is divided to obtain the actual volume of liquid passed through the meter. It is the reciprocal of the *meter factor* (see definition No. 48). When proving a meter, it is obtained by:

$$\text{Meter accuracy} = \frac{\text{meter registration}}{\text{quantity measured in prover}} = \frac{1}{\text{meter factor}}$$

and actual throughput is obtained by:

$$\text{Actual throughput} = \frac{\text{meter registration}}{\text{meter accuracy}}$$

43. *Meter capacity, maximum:* The maximum rate of flow through a meter, as recommended by the meter manufacturer, for any specific liquid.

44. *Meter capacity, minimum:* The minimum rate of flow through a meter, as recommended by the meter manufacturer, for any specific liquid.

45. *Meter case:* The outer portion of a meter which encloses the measuring chamber.

46. *Meter characteristic:* A term somewhat broader in scope than the term "meter performance"; the meter performance under varying operating conditions.

47. *Meter cover:* The portion of a meter case which must be removed to expose the measuring chamber and the measuring element.

48. *Meter factor:* A number obtained by dividing the actual quantity of liquid passed through a meter into a prover or master meter by the indicated meter registration during the proof. It is the reciprocal of *meter accuracy* (see definition No. 42). When proving a meter, it is obtained by:

$$\text{Meter factor} = \frac{\text{quantity measured in prover}}{\text{meter registration}} = \frac{1}{\text{meter accuracy}}$$

and actual throughput is obtained by:

Actual throughput = (meter registration) (meter factor)

49. *Meter performance:* An expression of the relationship between the quantity of a given liquid indicated by a meter register and the actual quantity of that liquid which passed through the meter for the corresponding period (see Par. 4002).

50. *Meter reading:* The number of units of volume, or equivalent thereof, read directly from a meter register at any particular moment.

51. *Meter registration:* The difference between opening and closing meter readings during an interval of operation of a meter.

52. *Meter slippage:* The volume of the liquid, at any flow rate, which passes through a meter without causing registration.

53. *Over-or-under delivery:* See definition No. 18.

54. *Over-or-under registration:* See definition No. 76.

# MEASUREMENT OF PETROLEUM LIQUID HYDROCARBONS BY POSITIVE DISPLACEMENT METER

## SECTION I—INSTALLATION

### SCOPE

**1001** This section covers the installation of positive displacement meters, their auxiliary proving equipment, and other accessories.

### CHOICE OF METERS AND AUXILIARY EQUIPMENT

**1002** All types of meter installations must meet certain fundamental requirements. These include accurate proving facilities; adequate protective devices, such as strainers, relief valves, and air or vapor eliminators; and dependable pressure and flow controls. A further fundamental installation requirement is that physical conditions during operations and proving should be identical.

**1003** The following should be considered when selecting a meter and its auxiliary equipment:

*a.* Range of operating rates of flow and whether flow is continuous or intermittent.

*b.* Maximum operating pressure and maximum allowable pressure drop.

*c.* Type of liquid, or liquids, meter will measure, including viscosity and corrosivity.

*d.* Temperature range under which meter will operate and the applicability of automatic temperature compensation.

*e.* Type of register or ticket printer required and the application of quantity-predetermining devices.

*f.* Degree of accuracy desired and ease of meter registration adjustment.

*g.* Type and method of proving to be employed.

*h.* Applicability of auxiliary meter register equipment.

*i.* Methods, cost, and frequency of routine maintenance.

*j.* The quantity and size of foreign matter and the quantity of water which may be carried in the liquid stream.

*k.* Space available for meter installation.

**1004** Automatic temperature compensators and gravity selectors, if installed, shall be chosen to respond to operating conditions within the measurement tolerances required.

**1005** Manufacturers should be consulted regarding specifications of their metering equipment, such as minimum and maximum flow rates, operating pressures, operating temperatures, materials of construction, and installation details.

### GENERAL INSTALLATION DETAILS

**1006** Each meter shall be installed in such a manner as to prevent passage of air or vapor through it. In some cases, it may be necessary to install air elimination equipment ahead of the meter in order to accomplish this objective.

**1007** The entire installation shall be such that air will not be introduced into the system through holes, leaky valves, piping, glands of pump shafts, or connecting lines. The piping shall have no high points or pockets where air or vapor might accumulate and be carried to the meter by the added turbulence of an increased rate of flow.

**1008** Meters other than those designed for flow in both directions shall be installed so that the flow cannot be reversed.

**1009** Spring-loaded or self-closing valves shall be of such design that they will not open to admit air when subjected to hydraulic hammering or to a vacuum.

**1010** Any condition which tends to contribute to the release of vapor from the liquid should be avoided by proper design of the system.

**1011** Meters and piping shall be installed so that accidental drainage or vaporization of liquid is avoided.

**1012** Lines from the meter to the prover shall be installed so that the possibility of trapping air or vapor is minimized. This can sometimes be accomplished by sloping the meter calibration line upward to the prover tank. The distance between a meter and its prover should be as short as possible.

**1013** Meter installations should be made in a manner which will result in the maximum dependable operating life. In certain services, this requires that protective devices be installed to remove from the liquid abrasive or other entrained particles which could stop or cause premature wear of the metering mechanism. If strainers, filters, sediment traps, settling tanks, water absorbents, a combination of these items, or other suitable devices are required, they shall be installed in such a manner as to prevent flashing of the liquid prior to its passage through the meter. These may be installed singly or in interchangeable battery form, depending on the importance of continuous service. In other services where the liquid is clean, or where the type of meter installed does not require or warrant protection, the

## INTRODUCTION

This standard has been prepared as a guide to the design, installation, and operation of positive displacement metering systems for liquid hydrocarbons. Meter provers and their calibration are included as these are considered part of a complete metering system, even though a prover may be portable and serve meters in several areas.

A positive displacement meter is a device installed in a piping system in which flowing liquid is constantly and mechanically isolated into segments of known volume. These segments of liquid are counted as they are displaced and their accumulated total continuously and instantaneously indicated in units of liquid quantity by the meter register. These fixed-quantity liquid segments are united as they emerge from the measuring element, along with that portion of liquid which "slips" through the clearances between the moving parts of the measuring element.

The degree of approach to accuracy or tolerance in measurement for the purpose of business transactions is usually set by law, by regulation, or by mutual agreement between contracting parties. It is not the intent of this standard to set tolerances for such purposes, but only to set forth methods by which acceptable approaches to accuracy can be achieved.

Compliance with the provisions of this standard will result in a degree of approach to measurement accuracy which may not be necessary under all conditions. When not required, certain provisions which produce maximum approach to accuracy may be disregarded. The compulsory verb form "shall" has been used in all provisions where a deviation from the recommended practice is likely to adversely affect measurement.

Most of the material in this standard is general in that it applies to the metering of different liquids and to meters in different services. In certain cases, information is given for a particular liquid or for a particular service. Examples of liquids are liquefied petroleum gas (LPG) and crude oil; examples of services are pipelines and loading racks. It will be observed that information for several different liquids may apply to a specific service installation. For example, meters in pipeline service may handle crude oil or any petroleum product, including LPG. Thus, for information in this standard on the design, installation, and operation of a pipeline metering system, the general material, the specific paragraphs on pipeline metering, and the paragraphs on types of liquid to be metered should be consulted.

Sect. I covers meter installation, and Sect. II covers meter provers and prover calibration details. These sections will be useful to the engineer in the design of a metering system. Sect. II will be most useful to those responsible for the calibration of meter provers. Sect. III, on meter-proving procedures; Sect. IV, on meter performance; and Sect. V, on operation and maintenance of metering systems, must be considered in the design of metering systems. Sect. V will be especially useful to those responsible for the operation of a metering system. This standard is not intended to be a substitute for an operating procedure, but rather it may be used as a guide in preparing an operating procedure for a specific metering installation. Helpful information on several practices which are being followed by some meter operators, but which are not yet considered standard, may be found in Appendix C.

This standard contains information on the metering of LPG. It may be desirable to meter liquids other than LPG (see definition) but with physical characteristics similar to LPG. In such case, the information on LPG metering may be a useful guide. However, the user is cautioned to consider carefully each such installation inasmuch as the liquids may have other characteristics rendering an LPG metering system inadequate.





55. *Positive displacement meter:* See definition No. 41.

56. *Pressure loss:* The differential pressure in the flowing liquid stream (which will vary with flow rate) between the inlet and outlet of a meter, as determined from tests made in accordance with *Instruments and Apparatus, Part 2: Pressure Measurement,* supplement to *ASME Power Test Codes.*

57. *Prove:* To determine the meter performance or the relationship between the volume of liquid which actually passes through a meter and the volume indicated by the meter.

58. *Prover, gravimetric meter:* A closed or open vessel mounted on a weigh scale to permit accurate determination of the weight of a quantity of liquid which has been previously measured in volumetric units by a meter. The weight of liquid is then converted, by use of the average specific gravity, to volumetric units to compare with the volume measured by the meter (see Fig. 19 and Fig. 20).

59. *Prover, volumetric meter:* A closed or open vessel designed especially for accurate determination of the quantity of a liquid delivered into or out of it during a meter proof run. The quantity of liquid either is observed from the liquid level or is known from previous calibration of a fixed-volume vessel.

60. *Quantity-predetermining device:* A mechanical apparatus by means of which a desired quantity of liquid to be measured can be pre-set on a meter register; it is operated in such a manner that when this desired quantity has been discharged through the meter, the device automatically stops the flow through the meter.

61. *Reference pressure:* See definition No. 37.

62. *Register:* A device which indicates the quantity passed through a meter (see Par. 4002).

63. *Register, electronic:* A meter register operated by electronic means rather than by mechanical means.

64. *Register, mechanical:* A meter register operated by mechanical components such as shafts and gears.

65. *Register, multimeter totalizer:* A meter register which indicates the total registration of two or more meters.

66. *Register, remote reading:* A meter register which is located at a point distant from the meter.

67. *Register, remote ticket-printing:* A ticket-printing register which is located at a point distant from the meter.

68. *Register, round reading:* A register, the face of which is usually circular and on which the registration is indicated by a series of pointers driven through a spur gear system.

69. *Register, straight reading:* A register, the face of which is a series of numbers appearing in line on parallel wheels driven by a system of pawls.

70. *Register, ticket-printing:* An auxiliary device which, when operated, prints the meter registration on paper inserted therein.

71. *Register, ticket-printing, identifying:* A device similar to No. 70, in which a symbol or symbols are installed to record on the ticket pertinent information such as location, meter number, or batch number.

72. *Register drive, direct:* A positive direct mechanical drive, such as shafts or gears, which connects a meter and a meter register.

73. *Register drive, electric:* An electric mechanism which connects a meter and a meter register. This may be of the selsyn, pulse, or another type.

74. *Register drive, friction:* A dry-face clutch or similar type of frictional mechanism which connects a meter and a meter register.

75. *Register drive, magnetic:* A magnetic clutch mechanism which connects a meter and a meter register.

76. *Registration, over-or-under:* The volume obtained by subtracting the quantity measured in the prover from the meter registration and expressing the difference in units such as cubic inches per test measure, cubic inches per gallon, or cubic inches per barrel. Overregistration will be indicated if the algebraic result has a plus sign; underregistration will be indicated if it has a minus sign.

77. *Reid vapor pressure:* See definition No. 100.

78. *Running start-and-stop method:* A meter-proving method wherein the opening and closing meter readings of the test run are determined at flowing conditions.

79. *Seal, capillary:* The liquid seal which reduces slippage between moving parts of a meter.

80. *Seal, mechanical:* The seal (packing) which reduces slippage between moving parts of a meter.

81. *Settling tank:* A vessel installed upstream from a meter, wherein the velocity of the stream is reduced sufficiently to permit foreign matter and water to settle out of the flowing stream.

82. *Slippage:* See definition No. 52.

83. *Specific gravity:* See definition No. 29.

84. *Standard conditions:* Pressure at sea level equals 14.696 psia (760 mm Hg); temperature equals 60 F.

85. *Standing start-and-stop method:* A meter-proving method wherein the opening and closing meter readings of the test run are determined at no-flow conditions.

86. *Strainer:* A device installed upstream from a meter and equipped with screen wire or another medium intended to remove foreign matter from the stream.

87. *Temperature compensator:* A mechanism which, in response to temperature changes in the flowing stream, automatically changes the meter registration in accordance with the coefficient of thermal expansion for which the device was designed.

88. *Tender:* See definition No. 6.

89. *Test measures:* Vessels (see Par. 2041 through Par. 2047) designed especially for the precision measurement of volume of liquid in (or near) 1-, 5-, 10-gal or larger quantities and usually certified for accuracy of measurement by the National Bureau of Standards.

90. *Test run:* A single complete test required to prove a meter.

91. *Throughput, gross:* The indicated throughput corrected only for meter performance.

92. *Throughput, indicated (uncorrected):* The difference between the opening meter reading and the closing meter reading.

93. *Throughput, net:* The gross throughput corrected to 60 F and the reference pressure, and including a correction for basic sediment and water where applicable.

94. *Vacuum breaker:* An automatic means for preventing a partial vacuum from being formed at a specific point in a piping system.

95. *Valve, back-pressure:* A mechanical device for maintaining a uniform upstream pressure.

96. *Valve, differential:* A mechanical device for maintaining a fixed difference in pressure between two points in a metered stream.

97. *Vapor eliminator (separator):* See definition No. 3.

98. *Vapor-equalizing line:* A conduit installed to connect the vapor spaces of the vessel being filled and the one being emptied.

99. *Vapor pressure (absolute, true):* The pressure of a vapor corresponding to a given temperature at which the liquid and vapor are in equilibrium. (See also definitions No. 21, 31, 34, and 100.)

100. *Vapor pressure, Reid:* The vapor pressure of a liquid at 100 F, as determined by the standard Reid vapor pressure test [*ASTM Designation D 323-58: Standard Method of Test for Vapor Pressure of Petroleum Products (Reid Method)*].

101. *Volume, standard unit of:* The United States gallon containing 231 U.S. cubic inches. One U.S. barrel contains 42 U.S. gallons. The British imperial gallon contains 277.420 British cubic inches or 277.418 U.S. cubic inches or 1.200955 U.S. gallons. The U.S. barrel contains 34.9722 imperial gallons.

102. *Weigh tank:* A vessel mounted upon a weigh scale in such a manner that any change in the weight of the liquid in the vessel is accurately reflected by the indicating mechanism of the weigh scale.

## CONTENTS

# PARAGRAPH INDEX

## APPLICABLE TO VARIOUS TYPES OF LIQUID HYDROCARBONS

*Code:* 1 = crude oil
2 = low-vapor-pressure product
3 = high-vapor-pressure product
4 = LPG

| Paragraph | Group | Paragraph | Group | Paragraph | Group | Paragraph | Group |
|---|---|---|---|---|---|---|---|
| 1001 | 1,2,3,4 | 2022 | 1,2,3,4 | 2084 | 3,4 | 3021 | 1,2 |
| 1002 | 1,2,3,4 | 2023 | 1,2,3,4 | 2085 | 3,4 | 3022 | 1,2 |
| 1003 | 1,2,3,4 | 2024 | 1,2,3,4 | 2086 | 1,2,3,4 | 3023 | 1,2,3,4 |
| 1004 | 1,2,3,4 | 2025 | 3,4 | 2087 | 1,2,3,4 | 3024 | 1,2,3,4 |
| 1005 | 1,2,3,4 | 2026 | 1,2,3,4 | 2088 | 1,2,3,4 | 3025 | 1,2,3,4 |
| 1006 | 1,2,3,4 | 2027 | 1,2,3,4 | 2089 | 1,2,3,4 | 3026 | 1,2,3,4 |
| 1007 | 1,2,3,4 | 2028 | 1,2,3,4 | 2090 | 1,2,3,4 | 3027 | 1,2,3,4 |
| 1008 | 1,2,3,4 | 2029 | 1,2,3,4 | 2091 | 1,2,3,4 | 3028 | 1,2,3,4 |
| 1009 | 1,2 | 2030 | 1,2,3,4 | 2092 | 1,2,3,4 | 3029 | 1,2,3,4 |
| 1010 | 1,2,3,4 | 2031 | 1,2,3,4 | 2093 | 1,2,3,4 | 3030 | 3,4 |
| 1011 | 1,2,3,4 | 2032 | 1,2,3,4 | 2094 | 1,2,3,4 | 3031 | 3,4 |
| 1012 | 1,2,3,4 | 2033 | 1,2,3,4 | 2095 | 1,2,3,4 | 3032 | 1,2,3,4 |
| 1013 | 1,2,3,4 | 2034 | 1,2,3,4 | 2096 | 1,2,3,4 | 3033 | 1,2,3,4 |
| 1014 | 1,2,3,4 | 2035 | 1,2,3,4 | 2097 | 1,2,3,4 | 3034 | 1,2,3,4 |
| 1015 | 1,2,3,4 | 2036 | 1,2,3,4 | 2098 | 1,2,3,4 | 3035 | 1,2,3,4 |
| 1016 | 1,2,3,4 | 2037 | 1,2,3,4 | 2099 | 1,2,3,4 | 3036 | 1,2,3,4 |
| 1017 | 1,2,3,4 | 2038 | 1,2,3,4 | 2100 | 1,2,3,4 | 3037 | 1,2,3,4 |
| 1018 | 1,2,3,4 | 2039 | 1,2,3,4 | 2101 | 1,2,3,4 | 3038 | 1,2 |
| 1019 | 1,2,3,4 | 2040 | 1,2,3,4 | 2102 | 1,2,3,4 | 3039 | 1,2,3,4 |
| 1020 | 1,2,3,4 | 2041 | 1,2,3,4 | 2103 | 1,2,3,4 | 3040 | 1,2,3,4 |
| 1021 | 1,2,3,4 | 2042 | 1,2,3,4 | 2104 | 1,2,3,4 | 3041 | 1,2,3,4 |
| 1022 | 1,2,3,4 | 2043 | 1,2,3,4 | 2105 | 1,2,3,4 | 3042 | 1,2,3,4 |
| 1023 | 1,2,3,4 | 2044 | 1,2,3,4 | 2106 | 1,2,3,4 | 3043 | 1,2,3,4 |
| 1024 | 1,2,3,4 | 2045 | 1,2,3,4 | 2107 | 1,2,3,4 | 3044 | 1,2,3,4 |
| 1025 | 1,2,3,4 | 2046 | 1,2,3,4 | 2108 | 1,2,3,4 | 3045 | 1,2,3,4 |
| 1026 | 1,2,3,4 | 2047 | 1,2,3,4 | 2109 | 1,2,3,4 | 3046 | 1,2,3,4 |
| 1027 | 1,2,3,4 | 2048 | 1,2,3,4 | 2110 | 1,2,3,4 | 3047 | 1,2,3,4 |
| 1028 | 1,2,3,4 | 2049 | 1,2,3,4 | 2111 | 1,2,3,4 | 3048 | 1,2,3,4 |
| 1029 | 1,2,3,4 | 2050 | 1,2,3,4 | 2112 | 1,2,3,4 | 3049 | 1,2,3,4 |
| 1030 | 1,2,3,4 | 2051 | 1,2,3,4 | 2113 | 1,2,3,4 | 3050 | 1,2,3,4 |
| 1031 | 1,2 | 2052 | 1,2,3,4 | 2114 | 1,2,3,4 | 3051 | 1,2,3,4 |
| 1032 | 1,2,3,4 | 2053 | 1,2,3,4 | 2115 | 1,2,3,4 | 3052 | 1,2,3,4 |
| 1033 | 1,2 | 2054 | 1,2,3,4 | 2116 | 1,2,3,4 | 3053 | 1,2,3,4 |
| 1034 | 1,2 | 2055 | 1,2,3,4 | 2117 | 1,2,3,4 | 3054 | 1,2,3,4 |
| 1035 | 1,2,3 | 2056 | 1,2,3,4 | 2118 | 1,2,3,4 | 3055 | 1,2,3,4 |
| 1036 | 1,2,3 | 2057 | 1,2,3,4 | 2119 | 1,2,3,4 | 3056 | 1,2 |
| 1037 | 1,2,3 | 2058 | 1,2,3,4 | 2120 | 1,2,3,4 | 3057 | 1,2 |
| 1038 | 1,2 | 2059 | 1,2,3,4 | 2121 | 1,2,3,4 | 3058 | 1,2,3,4 |
| 1039 | 1,2,3 | 2060 | 1,2,3,4 | 2122 | 1,2,3,4 | 3059 | 1,2,3,4 |
| 1040 | 1,2,3 | 2061 | 1,2,3,4 | 2123 | 1,2,3,4 | 3060 | 1,2,3,4 |
| 1041 | 1,2,3 | 2062 | 1,2,3,4 | 2124 | 1,2,3,4 | 4001 | 1,2,3,4 |
| 2001 | 1,2,3,4 | 2063 | 1,2,3,4 | 2125 | 1,2,3,4 | 4002 | 1,2,3,4 |
| 2002 | 1,2,3,4 | 2064 | 1,2,3,4 | 3001 | 1,2,3,4 | 4003 | 1,2,3,4 |
| 2003 | 1,2,3,4 | 2065 | 1,2,3,4 | 3002 | 1,2,3,4 | 4004 | 1,2,3,4 |
| 2004 | 1,2,3,4 | 2066 | 1,2,3,4 | 3003 | 1,2,3,4 | 4005 | 1,2,3,4 |
| 2005 | 1,2,3,4 | 2067 | 1,2,3,4 | 3004 | 1,2,3,4 | 4006 | 1,2,3,4 |
| 2006 | 1,2,3,4 | 2068 | 1,2,3,4 | 3005 | 1,2,3,4 | 4007 | 1,2,3,4 |
| 2007 | 1,2,3,4 | 2069 | 1,2,3,4 | 3006 | 1,2,3,4 | 4008 | 1,2,3,4 |
| 2008 | 1,2,3,4 | 2070 | 1,2,3,4 | 3007 | 1,2,3,4 | 4009 | 1,2,3,4 |
| 2009 | 1,2,3,4 | 2071 | 1,2,3,4 | 3008 | 1,2,3,4 | 4010 | 1,2,3,4 |
| 2010 | 1,2,3,4 | 2072 | 1,2,3,4 | 3009 | 1,2,3,4 | 4011 | 1,2,3,4 |
| 2011 | 1,2,3,4 | 2073 | 1,2,3,4 | 3010 | 1,2,3,4 | 4012 | 1,2,3,4 |
| 2012 | 1,2,3,4 | 2074 | 1,2,3,4 | 3011 | 1,2,3,4 | 5001 | 1,2,3,4 |
| 2013 | 1,2,3,4 | 2075 | 1,2,3,4 | 3012 | 1,2,3,4 | 5002 | 1,2,3,4 |
| 2014 | 1,2,3,4 | 2076 | 1,2,3,4 | 3013 | 1,2,3,4 | 5003 | 1,2,3,4 |
| 2015 | 1,2,3,4 | 2077 | 1,2,3,4 | 3014 | 1,2,3,4 | 5004 | 1,2,3,4 |
| 2016 | 1,2,3,4 | 2078 | 1,2,3,4 | 3015 | 1,2,3,4 | 5005 | 1,2,3,4 |
| 2017 | 1,2,3,4 | 2079 | 1,2,3,4 | 3016 | 1,2,3,4 | 5006 | 1,2,3,4 |
| 2018 | 1,2,3,4 | 2080 | 1,2,3,4 | 3017 | 1,2,3,4 | 5007 | 1,2,3,4 |
| 2019 | 1,2,3,4 | 2081 | 1,2,3,4 | 3018 | 1,2 | 5008 | 1,2,3,4 |
| 2020 | 1,2,3,4 | 2082 | 3,4 | 3019 | 1,2 | | |
| 2021 | 1,2,3,4 | 2083 | 3,4 | 3020 | 1,2 | | |

# ALPHABETICAL INDEX



## FOREWORD

Prior to 1942, research on the accuracy of positive displacement meters was conducted at the University of Oklahoma by the ASME Research Committee on Fluid Meters. The API Pipeline Technology Committee became interested in this project. The Joint ASME-API Committee for Volumeter Research was appointed to guide the research. This committee included representatives with special knowledge of, and experience in, the technical phases of the meter measurement of liquid petroleum hydrocarbons, namely, design, research, testing, and operation of positive displacement meters. The committee also included qualified representatives of all the major positive displacement meter manufacturers. The research program was completed, and the results were published in the *Transactions of the American Society of Mechanical Engineers*, May 1943. Following the completion of the research program, it became evident that uniform metering procedures should be developed. The joint committee was then charged with the preparation of such procedures.

The tentative standard methods prescribed in *Bulletin No. TS 381: Proving Positive Displacement Meters* of the California Natural Gasoline Association; the standard specifications for cold-water meters of the American Water Works Association; and National Bureau of Standards Handbooks H 29, H 44, and H 45, adopted by the National Conference on Weights and Measures, were reviewed. Data were obtained from interested operators, manufacturers, and various technical groups.

In 1955 the name of the committee was changed to Joint ASME-API Petroleum PD Meter Committee. The API part of the committee was transferred from a subcommittee of the API Pipeline Technology Committee to full committee status in the API Department of Technical Services. The ASME part of the committee retained status as Subcommittee No. 11 under the ASME Research Committee on Fluid Meters. In late 1957, the joint status with the American Society of Mechanical Engineers was discontinued and the API Committee on Positive Displacement Metering Measurement was organized.

Although this edition of the standard is sponsored only by the American Petroleum Institute, the Institute gives full and complete acknowledgment to the contribution made by the American Society of Mechanical Engineers in developing the required technical material to assure accurate and successful measurement of liquid hydrocarbons by the use of the positive displacement meter. Full acknowledgment is given to the Joint ASME-API Petroleum PD Meter Committee for the work done in compiling this standard, and to the ASME Research Committee on Fluid Meters for the guidance given through the years in making this standard technically correct.

The American Petroleum Institute takes no position as to whether or not any method contained herein is covered by an existing patent, nor as to the validity of any patent alleged to cover any such method. Furthermore, the information contained in this standard does not grant the right, by implication or otherwise, for manufacture, sale, or use in connection with any method, apparatus, or product covered by letters patent; nor does it insure anyone against liability for infringement of letters patent.

This standard may be used by anyone desiring to do so, but the American Petroleum Institute shall not be held responsible or liable in any way either for any loss or damage resulting therefrom or for any violation of any federal, state, or municipal regulations with which it may conflict.

This standard does not endorse or advocate the preferential use of the positive displacement meter, or any other type of meter, as compared with other means for measuring liquid hydrocarbons. Its purpose, rather, is to describe and illustrate methods and practices which are commercially acceptable in the use of positive displacement meters. This standard is not intended to restrict in any way the future development of positive displacement meters, nor to affect in any way metering equipment of any type already installed and in operation.

The American Petroleum Institute recognizes that meters which do not come within the definition of a positive displacement meter as defined herein are being used in the metering of liquid hydrocarbons. The users of these other types of meters may find sections of this standard useful, especially those on proving and installation.