CASE 2243: Application of GULF for an amendment of RULE 309 (a).

Case No.

2243

pplication, Transcript,

mall Exhibit, Etc.

BEFORE THE OIL CONSERVATION COMMISSION
OF THE STATE OF NEW MEXICO

IN THE MATTER OF THE HEARING
CALLED BY THE OIL CONSERVATION
COMMISSION OF NEW MEXICO FOR
THE PURPOSE OF CONSIDERING:

CASE No. 2243
Order No. R-1959

APPLICATION OF GULF OIL CORPORATION
FOR AN AMENDMENT OF RULE 309 (a).

ORDER OF THE COMMISSION

BY THE COMMISSION:

This cause came on for hearing at 9 o'clock a.m. on April 13, 1961, at Hobbs, New Mexico, before the Oil Conservation Commission of New Mexico, hereinafter referred to as the "Commission."

NOW, on this 28th day of April, 1961, the Commission, a quorum being present, having considered the testimony presented and the exhibits received at said hearing, and being fully advised in the premises,

FINDS:

(1) That due public notice having been given as required by law, the Commission has jurisdiction of this cause and the subject matter thereof.

(2) That Rule 309 (a) should be revised in order to facilitate the administration of requests for approval of automatic custody transfer systems.

(3) That Form C-106, attached to this order as Exhibit A, should be adopted, and that Rule 1103 should be amended to include said form.

IT IS THEREFORE ORDERED:

(1) That Rule 309 (a) is hereby revised to read in its entirety as follows:

RULE 309-A. CENTRAL TANK BATTERIES

Oil shall not be transported from a lease until it has been received and measured in a facility of an approved design located on the lease. Such facilities shall permit the testing of each well at reasonable intervals and may be comprised of manually gauged closed stock tanks for which proper strapping tables have

been prepared, with a maximum of sixteen proration units producing into said tanks, or of automatic custody transfer (ACT) equipment. The use of such automatic custody transfer equipment shall be permitted only after compliance with the following:

1. The operator shall file with the Commission Form C-106, Notice of Intention to Utilize Automatic Custody Transfer Equipment, and shall receive approval thereof prior to transferring oil through the ACT system. The carrier shall not accept delivery of oil through the ACT system until Form C-106 has been approved.

2. Form C-106 shall be submitted in quadruplicate to the appropriate District Office of the Commission and shall be accompanied (in quadruplicate) by the following:

(a) Plat of the lease showing thereon all wells which will be produced into the ACT system.

(b) Schematic diagram of the ACT equipment, showing thereon all major components such as surge tanks and their capacity, extra storage tanks and their capacity, transfer pumps, monitors, reroute valves, treaters, samplers, strainers, air and gas eliminators, back pressure valves, metering device (indicating type and capacity, i. e., whether automatic measuring tank, positive volume metering chamber, weir-type measuring vessel, or positive displacement meter). Schematic diagram shall also show means employed to prove accuracy of measuring device.

(c) Letter from transporter agreeing to utilization of ACT system as shown on schematic diagram.

3. Form C-106 will not be approved by the Commission unless the ACT system is to be installed and operated in compliance with the following:

(a) Provision must be made for accurate determination and recording of uncorrected volume and applicable temperature, or of temperature corrected volume. The overall accuracy of the system shall equal or surpass manual methods.

(b) Provision must be made for representative sampling of the oil transferred for determination of API gravity and BS&W content.

(c) Provision must be made if required by either the producer or the transporter of the oil to give adequate assurance that only merchantable oil is run by the ACT system.

(d) Provision must be made for set-stop counters to stop the flow of oil through the ACT system at or prior to the time

the allowable has been run. All counters shall provide non-reset totalizers which shall be visible for inspection at all times.

(e) All necessary controls and equipment must be enclosed and sealed, or otherwise be so arranged as to provide assurance against, or evidence of, accidental or purposeful mismeasurement resulting from tampering.

(f) All components of the ACT system shall be properly sized to ensure operation within the range of their established ratings. All components of the system which require periodic calibration and/or inspection for proof of continued accuracy must be readily accessible. The frequency and methods of such calibration and/or inspection shall be as set forth in Rule 309-A, 4-c.

(g) The control and recording system must include adequate fail-safe features which will provide assurance against mismeasurement in the event of power failure, or the failure of the ACT system's component parts.

(h) 1. The ACT system and allied facilities shall include such fail-safe equipment as may be necessary, including high level switches in the surge tank or overflow storage tank which, in the event of power failure or malfunction of the ACT or other equipment, will shut down all artificially lifted wells connected to the ACT system and will shut-in all flowing wells at the well-head or at the header manifold, in which latter case all flowlines shall be pressure tested to at least 1½ times the maximum well-head shut-in pressure prior to initial use of the ACT system and each two years thereafter.

2. As an alternative to the requirements of paragraph (h) 1 above, the producer shall provide and shall at all times maintain a minimum of available storage capacity above the normal high working level of the surge tank to receive and hold the amount of oil which may be produced during maximum unattended time of lease operation.

4. (a) In all ACT systems employing automatic measuring tanks, weir-type measuring vessels, positive volume metering chambers, or any other volume measuring container, the container and allied components shall be properly calibrated prior to initial use and shall be operated, maintained, and inspected as necessary to ensure against incrustation, changes in clingage factors, valve leakage or other leakage, and improper action of floats, level detectors, etc.

(b) In all ACT systems employing positive displacement meters, the meter(s) and allied components shall be properly calibrated prior to initial use and shall be operated, maintained, and inspected as necessary to ensure against mismeasurement of oil.

(c) The measuring and recording devices of all ACT systems shall be checked for accuracy at least once each month unless exception to such determination has been obtained from the Secretary-Director of the Commission. API Standard 1101, "Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter," shall be used where applicable. Meters may be proved against Master Meters, Portable Prover Tanks, or Prover Tanks permanently installed on the lease. If permanently installed Prover Tarks are used, the distance between the opening and closing levels and the provision for determining the opening and closing readings shall be sufficient to detect variations of 5/100 of one percent. Reports of determinations shall be filed on the Commission Form entitled "Meter Test Report," or on another acceptable form and shall be submitted in duplicate to the appropriate District Office of the Commission.

(d) To obtain exception to the requirement of paragraph (c) above that all measuring and recording devices be checked for accuracy once each month, either the producer or transporter may file such a request with the Secretary-Director of the Commission setting forth all facts pertinent to such exception. The application shall include a history of the average factors previously obtained, both tabulated and plotted on a graph of factors versus time, showing that the particular installation has experienced no erratic drift. The applicant shall also furnish evidence that the other interested party has agreed to such exception. The Secretary-Director may then set the frequency for determination of the system's accuracy at the interval which he deems prudent.

5. Failure to operate an automatic custody transfer system in compliance with this rule shall subject the approval thereof to revocation by the Commission.

(2) That Form C-106, attached to this order as Exhibit A, is hereby adopted, and that Rule 1103 is hereby amended to include said form.

(3) That the effective date of this order shall be May 1, 1961.

DONE at Santa Fe, New Mexico, on the day and year hereinabove designated.

STATE OF NEW MEXICO
OIL CONSERVATION COMMISSION

EDWIN L. MECHEM, Chairman

E. S. WALKER, Member

A. L. PORTER, Jr., Member & Secretary

esr/

EXHIBIT A
CASE NO. 2283 - ORDER NO. R-1959

Form C-106 ACT Permit No.

NOTICE OF INTENTION

TO UTILIZE AUTOMATIC CUSTODY TRANSFER EQUIPMENT

Operator Field

Address County

Lease(s) to be served by this ACT Unit

Pool(s) to be served by this ACT Unit

Location of ACT System: Unit Sec Twp Rge

Order No. authorizing commingling between leases if more than one lease is to be served by this system Date

Order No. authorizing commingling between pools if more than one pool is to be served by this system Date

Authorized transporter of oil from this system

Transporter's address

Maximum expected daily through-put for this system: Bbls/day

If system fails to transfer oil due to malfunction or otherwise, waste by overflow will be averted by: (Check One)

A. ☐ Automatic shut-down facilities as required by Section (3) h-1 of Rule 309-A.

B. ☐ Alternative (3) h-2, providing adequate available capacity to receive production during maximum unattended time of lease operation.

If A above is checked, will flowing wells be shut-in at the header manifold or at the well-head? Maximum well-head shut-in pressure

If B above is checked, how much storage capacity is available above the normal high working level of the surge tank? Bbls.

What is the normal maximum unattended time of lease operation? Hours

What device will be used for measuring oil in this ACT Unit? (Check One)

☐ Positive displacement meter ☐ Weir-type measuring vessel

☐ Positive volume metering chamber ☐ Other; Describe

Remarks:

I hereby certify that the information given above is true and complete to the best of my knowledge and that the subject ACT system will be installed and operated in accordance with Rule 309-A.

Approved, Oil Conservation Commission By

By Title

Title Date Date

Approval of Form C-106 does not eliminate the necessity of an approved C-110 prior to running any oil or gas from this system.

BEFORE THE
OIL CONSERVATION COMMISSION
HOBBS, NEW MEXICO
APRIL 13, 1961

IN THE MATTER OF

CASE 2243 Application of Gulf Oil Corporation for an amendment of Rule 309 (a). Applicant, in the above-styled cause, seeks an amendment of Rule 309 (a) to permit the installation of lease automatic custody transfer equipment without the necessity of notice and hearing.

BEFORE:

A. L. Porter

TRANSCRIPT OF PROCEEDINGS

MR. PORTER: The hearing will come to order, please. We will proceed at this time with Case 2243.

Before we get underway with the testimony I would like to call for appearances.

MR. BUELL: Guy Buell, Pan American Petroleum Corporation.

MR. BUSHNELL: H. T. Bushnell, Amerada.

MR. ANDERSON: R. M. Anderson, Sinclair.

MR. ROBINSON: Ed Robinson, Texaco Incorporated.

MR. Mc GANNON: R. L. McGannon, Standard Oil Company of Texas.

MR. PORTER: Mr. Kastler is the district lawyer for Gulf Oil Company, Roswell district. Mr. Kastler, the Commission

recognizes you at this time.

MR. KASTLER: Mr. John H. Hoover.

MR. PORTER: Mr. Hoover, come forward and be sworn.

(Witness sworn)

DIRECT EXAMINATION

BY MR. KASTLER:

Q Would you state your name, where you reside, by what company you are employed and your position.

A John Hoover, Roswell New Mexico, Gulf Corporation Production Engineer.

Q As Gulf Production Engineer, Mr. Hoover, have you previously appeared before the New Mexico Oil Commission and testified particularly in regard to automatic custody transfer systems?

A Yes, sir.

Q Are you familiar with all of Gulf Oil's automatic custody transfers in New Mexico at this time?

A Yes, sir.

MR. KASTLER: Are the witness's qualifications accepted by the Commission?

MR. PORTER: Yes.

Q MR. KASTLER: Would you outline what Gulf Oil is seeking in this application?

A We are asking for a consideration of the revision of Statewide Rule No. 309 to establish a procedure for adminis-

trative approval of automatic custody transfer systems.

Q Why are you seeking this?

A We feel that in the past there have been numerous ACT installations that have been approved and installed that have been similiar in design to our own case. We had 10 ACT hearings in 1960, and each of the hearings involved the same basic equipment for the ACT. We have Exhibit 1 which is a representative sample of the ACT equipment, and exhibit that we use in each one of these hearings. The ACT starts at the outlet of the surge tank where it is transferred to pipe lines on this exhibit. We had surge tanks which were not merely part of the ACT, but we started with that because we had some controls. We had a high level and a low level switch to start andstop the pump, and in some cases we installed emergency high level switches which would shut in the event of full storage. In other instances we utilized emergency high level switches but in the alternative we provided for overflow to additional storage tank.

The next term to be used in Exhibit 1, going through basic equipment which I mentioned before and which was similar to ours - - in each one we have a pump strainer, a proportioning type sampler, a meter with a non-reset counter, safety shutdown switch and stop counter, lease shut-in valve connector for proving the meter. We further believe that the hearings are time consuming and expensive to the producer as well as to the Commission and we feel that administrative approval can be given for automatic custody

transfer system installations. There is a matter of timing in that - - for example you have proceedings on the lease, and it is desirable if you can put the final battery in initially and we have found from experience that it can take from four to six weeks from the time of application until approval, another month for mailing will elapse, or more, to order the material and getting it installed, so therefore you have two or two and one half months from the time that you make application until the battery is installed.

In our opinion, the administrative approval for ACT could be given in less time than it takes to make application and set it for hearing.

Q Mr. Hoover, what particular proposal or proposals does Gulf hope to be adopted for the accomplishment of this purpose?

A We have our proposal which is marked Exhibit No. 2. This would be a revision to the Statewide Rule No. 309 but adding a subparagraph C. I might say we have some extra copies of the proposed rule upon the corner table if anybody would like them.

Q Do you wish to offer Exhibit No. 2 in this case?

A Yes.

Q Would you read it, please.

"RULE 309 - CENTRAL TANK BATTERIES

(c) The Secretary-Director of the Commission shall have authority to grant exceptions to Rule 309 (a), to permit the use of automatic custody transfer equipment without

notice or hearing, provided application for administrative approval has been filed in due form and such application contains the following:

(1) Lease plat.

(2) Schematic sketch of the proposed automatic custody transfer system indicating the function of each of the various components.

(3) Application states that the proposed installation is basically similar in design and operation to one previously approved by the Commission, giving case, order number and date of approval for the installation. If one not previously approved, complete description of the installation should be included.

(4) Application evidences that the pipe line purchaser has approved the installation.

(5) Installation would incorporate the use of safety shut down devices to shut-in the lease in the event of full storage; or in the alternative, provide sufficient storage to handle the production during the unattended hours.

(6) Automatic custody transfer equipment shall incorporate a safety shut down device to prevent the delivery of unmetered oil."

It was our thought that a safe guard against a malfunction

of the meter would prevent the delivery of oil if the meter is not registering.

(7) Installation shall have a set-stop counter to stop the delivery of oil when all legal allowable for the month has been run.

The Secretary-Director may, upon his own motion, after receipt of the application, set the matter for hearing if, in his opinion, conditions should be encountered which will tend to involve waste or impair correlative rights."

Q In your opinion is this proposal adequate protection against waste and does it protect correlative rights?

A Yes, in my opinion it does.

Q Were Exhibits 1 and 2 prepared by you or at your direction and under your supervision?

A Yes, sir.

MR. KASTLER: Mr. Porter, that concludes our direct testimony. I would like to move at this time for acceptance for Exhibits 1 and 2 into evidence.

MR. PORTER: Without objection Exhibits 1 and 2 will be admitted in the record.

Does anyone have a question of Mr. Hoover?

CROSS EXAMINATION

BY MR. MORRIS:

Q Can you be of any assistance in defining the word "similar" as you have used it in paragraph 3?

A Yes, sir. In my opinion, I would say similar - - if we have a pump or a strainer in the system - - in that order - - and somebody wanted to put the strainer in front of the pump or put the aerator to it somewhere else, or if the sampler is located at a different place, it is still the same equipment that is used, although maybe not in the same order. I would say it is basically similar.

Q Would you say the element then is similar in design in incorporating all the same basic elements, but permits a re-arrangement of those elements?

A Yes, sir. In considering one installation against the next installation we have utilized the same equipment without the same order and that would be basically similar.

Q Would it be possible to leave out one of the elements and still find that it was basically similar?

A I believe you could leave out a pressure gauge and it would still be basically similar. If you left out a pump, no, it would not be.

Q Mr. Hoover, still refering to paragraph 3, the last sentence where you refer to obtaining approval where a system not previously approved is being proposed, do you feel that a rule as you propose here is sufficiently certain in requiring what must be submitted when this approval is being asked for? In other words, if you have a system that you are asking approval for this rule does not specify into what detail description must be given of the

various components. Do you feel some amplification should be inserted here?

A Well, possibly so. We feel the whole thing should be left open and maybe the Commission, maybe the producer and Commission - - think it is like the one previously approved it could be still set for hearing. The possibility is left open in that paragraph 3, but each producer may have a little different idea.

In our own case, all of our ACT installations are similar and if we deviate from it, why then we would expect to explain it.

Q Mr. Hoover, in the event the Commission should adopt the rule as you have proposed it and Gulf was making an application for an automatic custody transfer system not exactly similar to one already approved, would it be Gulf's interpretation of this rule that the complete description of the installation would be submitted to the Commission filling out each detail every facet of the installation or just what would be Gulf's interpretation of what information would be submitted, generally speaking?

A It would be our opinion that we would make maps of what we prepared to submit at a hearing.

Q You would submit full information?

A Yes, and we have taken the attitude that we are trying to give the Commission by application the same information that we have time after time given them at a hearing.

Q According to your rule it's somewhat indefinite, is it not, just what constitutes a complete description of the installation? In other words, that would be left to everyone's yardstick as to what they considered a complete description of the installation?

A We are speaking of the ACT existing in this case.

MR. MORRIS: No further questions.

MR. PORTER: Does anyone else have a question of Mr. Hoover?

EXAMINATION

BY MR. PAYNE:

Q Mr. Hoover, refering to paragraph 5, I notice that you would include the use of a safety shutdown device to shut the lease in the event of full storage. Would this shut in the lease in a well head or header?

A It might do both.

Q Then, sir, do you propose to pressure test your flow line in the event that you're going to shut it in at the header?

A In our case where we have the lease shut-in valve we have also installed a shut-in valve at the well. I think that insofar as testing the full line it wouldn't be necessary to test all flow lines. Some may have higher pressures than others. It has been our experience in checking back over a period of about 2 1/2 years where we have very accurate records of flow line breaks

we found that over that 2 1/2 year period we only lost 77 barrels of oil in five instances of flow line breaks. And in one of them a truck ran over the line.

Q Would you show on your maps, Mr. Hoover, what the maximum well head shut-in pressure would be?

A It certainly would be done. I don't think that based on our passed experience that it's absolutly necessary to go into the flow line business end of it because we have noworry about the flow line and we have had no breaks up to this time on ACT batteries.

Q Refering to the alternative here that you'd have enough storage to handle production during the unattended hours, would you show on your applicsation what the maximum unattended period would be?

A Yes, sir, that could be shown.

Q And all the maximum through out on the system?

A It could be shown on there. I don't think that it's necessary. It seems like if the producer has an approved operator that should be left to his discretion.

Q It isn't going to do the Commission much good to know the unattended hours unless they know the capacity of the system, how much oil it's going to be producing.

A Yes, sir. If the rule - - say you have that stipulated in the rules, that you comply with that, it certainly could be done. I just think that it's not necessary. In other words,

on a conventional battery we could tell them to put in 5, 6 or 7 tan tanks. We put in the tanks necessary to operate it and there's no difficulty on an ACT battery. If we put anything in - - if we lose the dollar, we have lost the biggest part of that dollar. I'd like to emphasize that point; if there is any loss, the producer in certainly the biggest loser.

Q Comparing this with a conventional battery, do you propose to limit this administrative approval to a situation where no more than 16 proration units are going to be producing through the system?

A No, sir, it's not our intention to limit the well.

Q Rule 309 preferably does limit it to 16 proration units in one battery.

A Yes, sir. We would not make any change there.

Q Mr. Hoover, as you well know, the Commission ordinarily requires meter tests on an ACT. I see nothing in your rule proposing that be changed.

A No, sir. It was our thought under present procedure, when the approval is given by order that meters would be tested once a month and reported to the Commission. Under administrative approval there would be no change in that. Testing would still be set forth.

Q Under your proposed rule, would approval be limited to situations where only one lease was involved?

A No, sir.

Q Administrative approval could also be granted if more than one pool were involved?

A I was talking about getting into commingling, where two pools go through the same ACT system.

Q Yes.

A I believe commingling is taken care of by another order. The commingling part shouldn't even enter into the ACT.

Q Do you think there is a connection in this respect? Let's assume commingling has been approved administratively and it requires seperate measurement of the production from each pool. Then you come in for administrative approval of an ACT system to handle this commingled production. Now, are you going to show in either application whether your bad oil is rerouted back through the production meter?

A I don't believe that that was intent of our rule. We feel that when the oil gets into our ACT unit it is a production matter and it's not in the ACT.

Q How could the Commission determine if the bad oil was being rerun through a production meter and treated? You wouldn't show in your commingling application because it wouldn't be pertinent. Now if you didn't show in the ACT application, then the Commission would never know.

A I believe the order says on commingling that a schedule be given of the installation.

Q Do you propose to show it?

A That is on the commingling.

Q When you use commingling and not using ACT, you don't have this problem, so would you show then where the bad oil line goes on your ACT application?

A It's not necessary in my opinion.

Q Now, I noticed that you don't have any monitor on your diagrammatic sketch. Do you feel it should be shown when it's used?

A On an ACT installation a monitor is required by the purchaser.

Q All purchasers?

A I believe it is. There may be some isolated cases; however, I believe in the majority of cases it would be required, so therefore when you get approval the purchaser evidences that he approves the installation and it would take care of the monitor and so forth.

Q If they don't require a monitor at what figure do you place your set stop counter? At what figure do you place your set stop counter to prevent over running the allowable?

A That is set at the monthly allowable.

Q So that if a monitor was not required and you were delivering some bad oil, you wouldn't actually be running your allowable, would you?

A It would be corrected by the sampler, according to the sampler, that's right. You would be a bit less.

MR. PARKE: Thank you.

MR. PORTER: Mr. Hoover, do you know what the current practices are by the purchasers of pipe lines concerning whether they set the actual allowable figure in there or whether they allow a factor for BF&W?

THE WITNESS: No, sir, I don't know.

MR. PORTER: Does anyone else have any questions of the witness?

EXAMINATION

BY MR. MORRIS:

Q Mr. Hoover, these paragraphs 1 through 7 in your Exhibit No. 2 are intended to be general requirements, are they not?

A Yes, I would say mainly that would be right.

Q They were not intended to be specific and you would not contemplate, would you, that each company would always submit the same information to the Commission on a request for administrative approval?

A It would be very similar, I think.

Q Don't you feel, Mr. Hoover, that in some cases the application would have to be sent back for more and further statements on some or another particular part of the ACT that maybe the Commission would require, whereas the operator in his own mind might have felt the Commission would not require certain information in this regard?

A Possibly.

MR. MORRIS: Thank you.

REDIRECT EXAMINATION

BY MR. KASTLER:

Q In paragraph h you have said that the application evidences that the pipe line purchaser has approved the installation. I quote, "pipe line" do you mean the pipe line company that is connected with the well or parts for whose account it's being purchased, the oil is being purchased?

A The pipe line company.

MR. KASTLER: Thank you.

MR. PORTER: At this time, we are going to recess the hearing until 1:30. I will ask that you remove all of your papers and brief cases from the cafeteria because it is being used for the lunch hour.

(Whereupon recess was taken at 11:25 a.m.)

(Hearing reconvened at 1:30 p.m.)

MR. PORTER: The hearing will come to order, please.

We have Mr. Hoover still on the witness stand.

Does anyone have a question, now? The witness may be excused. Call Mr. Nutter to the stand.

MR. MORRIS: Let the records show the witness was sworn in the previous case.

DIRECT EXAMINATION

BY MR. MORRIS:

Q Will the witness please state his name and position.

A Dan Nutter, Chief Engineer for the New Mexico Oil Conservation Commission.

Q Mr. Nutter, in your official capacity have you made a study of Rule 309 (c)?

A Yes, sir, I have.

Q As a result of your study, do you feel that a revision of that rule is necessary at this time?

A Yes, sir, I believe that it is. Mr. Hoover testified this morning that his company alone had had 10 cases involving automatic custody transfers which involved hearings during the last year and multiply the number of cases of that one major company has had by the number of companies and number of applications that have been set for hearing and it does become quite a financial as well as time consuming burden to both the operators and Commission.

Q Mr. Nutter, have you prepared a proposed revision of Rule 309 which you could offer as an alternative to that offered by Gulf?

A Yes, sir.

Q Would you explain in detail your proposed rule?

A Yes, sir, I will. We started out with Rule 309 - A. CENTRAL TANK BATTERIES and used the identical sentence which is used in the first paragraph of the existing rule with the exception that where it reads "shall not be transported from the

lease until received and measured in tanks - - " we have substituted it "in a facility of an approved design located on the lease. Such facilities shall permit the testing of each well at reasonable intervals and may be comprised of manually gauged closed stock tanks for which proper strapping tables have been prepared, with a maximum of sixteen proration units producing into said tanks or of automatic custody transfer (ACT) equipment. The use of such automatic custody transfer equipment shall be permitted only after compliance with the following:"

In the rule we set forth certain procedures that the operator will follow in order to obtain approval of ACT equipment without the necessity of a hearing.

Q Mr. Nutter as I understand it, the basic requirement of Rule 309 (a) will remain the same, that oil must be measured on the lease, but under the present rule it's required to be measured in tanks whereas under the proposed rule it would either be measured in tanks or in an automatic custody transfer system, is that correct?

A Correct.

Q And the sixteen-unit limitation that is now placed on 309 (a), how will that be changed under your proposed rule?

A You will notice in the construction of this paragraph you can insert parenthesis around the words starting with "manually gauged closed stock tanks". We have two systems which can be used to measure oil on this lease, manually gauged closed stock

tanks with a maximum of sixteen tanks or we have ACT and I want to make that clear, that the sixteen proration units is not intended to apply to ACT.

Q Why did you apply the sixteen units limitation when tankage is used rather than when an ACT is to be used?

A Because of the ACT normally is handling oil faster. You can permit oil to be produced by a single facility than by a conventional tank battery. There is a tendency when you are using a conventional tank battery on a very large lease to have quite a number of large tanks and there is considerable evaporative loss. We feel that there is also a fire hazard when large tank batteries are constructed which handle more than sixteen wells, but with the use of ACT system, a lot of this hazard is eliminated.

Q Mr. Nutter, would you now go into the various provisions and requirements for the use of ACT equipment under your proposed rule?

A Yes, sir. First of all, I would like to mention that we prepared copies of this change attached to which is a form 106 which we have drawn up for use today in this case. By reading Rule No. 309 (a) paragraph 1;

"1. The operator shall file with the Commission Form C-106, Notice of Intention to Utilize Automatic Custody Transfer Equipment, and shall receive approval thereof prior to transferring oil through the ACT system. The carrier shall not accept delivery of oil through the ACT system until Form C-106 has been approved.

2. Form C-106 shall be submitted in quadruplicate to the appropriate District Office of the Commission and shall be accompanied (in quadruplicate) by the following:"

I would like to point out that with each one of these forms, copies of this application don't have to be accompanied by copies of attachment number 1 to each application. The reason for copies, I might point out, is that we would contemplate that one approved copy would be required for the producer, one for the transporter and one would remain in the District Office files and one would go to the Santa Fe office file.

And now reading subparagraph (a) in paragraph 2,

"(a) Plat of the lease showing thereon all wells which will be produced into the ACT system.

(b) Schematic diagram of the ACT equipment, showing thereon all major components such as surge tanks and their capacity, extra storage tanks and their capacity, transfer pumps, monitors, reroute valves, treaters, samplers, strainers, air and gas eliminators, back pressure valves, metering device (indicating type and capacity, i.e., whether automatic measuring tank, positive volume metering chamber, weir-type measuring vessel, or positive displacement meter). Schematic diagram shall also show means employed to prove accuracy of measuring device.

(c) Letter from transporter agreeing to utilization of ACT system as shown on schematic diagram."

Those are the three attachments that would come in with

each application.

Q Mr. Nutter, this attachment that will come in with the applications are designed, are they not, to give the Commission all the information that they would ordinarily require at a hearing as we have held in the past on ACT systems?

A We feel that the attachments plus the information that is filed in form No. C-106 would give sufficient information.

Q You have detailed the information under paragraph 3, have you not, as to what provisions must be made and that these provisions must be shown on the form and these are explained under paragraph 3?

A Yes, sir. The provisions that you include in paragraph 3 (a) through (h) would be shown either in the schematic diagram or in the form C-106 itself.

Q Would you now go through paragraph 3 covering the individual provisions thereunder and explain where necessary?

A Yes, sir. Paragraph 3 starts:

"3. Form C-106 will not be approved by the Commission unless the ACT system is to be installed and operated in compliance with the following:

(a) Provision must be made for accurate determination and recording of uncorrected volume and applicable temperature corrected volume. The overall accuracy of the system shall equal or surpass manual methods."

I might point out that quite a number of these are API

standards. As a matter of fact, we have several publications by the American Petroleum Institute which we anticipate we will offer as exhibits in this case, the first being API Bulletin 2509 (a) dated August 1956. In this bulletin the API makes it clear that this is not a standard but is to be considered as a progress report. ACT was new at this time but this was a progress report on what has been accomplished to date in working out standards for ACT systems. We also had here a copy of a preliminary proof of API Bulletin 2502 which will when accompanied by the API in all probability be recommended practice rather than a progress report. New, Bulletin 2502 is expected to be released sometime this year. A lot of language in 2502 is the same as in the old 2509 (a); however, there have been some changes. This is not to be construed as a final copy of API standards that will come out.

Q Mr. Nutter, would you, in going through these basic requirements point out where they do or do not conform to the specifications of the API? You don't intend that your provisions should necessarily be revised if the API changes its specifications? We are proposing this as a rule change in final form, are we not?

A Yes, sir. If anything, these particular changes should come out of the API then it would be certainly appropriate for the Commission to consider amending the rule to conform with those.

Q It wouldn't be amended automatically to conform?

A No, sir. In paragraph 3, subparagraph (a) it calls

for either the uncorrected volume and the temperature or the temperature corrected volume. In the old bulletin that the API put out in '56, they said the average temperature.

Now, reading subparagraph (b):

"(b) Provision must be made for representative sampling of the oil transferred for determination of API gravity and BS&W content."

That is the exact wording of the old bulletin and also the exact wording of the new bulletin.

Subparagraph (c) reads:

"(c) Provision must be made if required by either the producer or the transporter of the oil to give adequate assurance that only merchantable oil is run by the ACT system."

The old bulletin provided that a monitor would be installed if required by mutual agreement. The new bulletin reads that the monitor will be installed if required by either party instead of either the producer or transporter of the oil.

Paragraph (d) is worded differently from the API. However, essentially it's the same thing. It reads as follows:

"(d) Provision must be made for set-stop counters to stop the flow of oil through the ACT system at or prior to the time the allowable has been run. All counters shall provide non-reset totalizers which shall be visible for inspection at all times."

Under paragraph (e), it reads as follows:

"(e) All necessary controls and equipment must be enclosed and sealed, or otherwise be so arranged as to provide assurance against

or evidence of, accidental or purposeful mismeasurement resulting from tampering."

Q What do you understand the words "all necessary controls" to mean?

A Only the API can answer that. I would say "all necessary controls" means all the important controls. There are some controls on ACT systems that are certainly necessary, but I don't think there's any need for all this safe guarding on them, so this is the important control, subject to tampering.

Reading subparagraph (f):

"(f) All components of the ACT system shall be properly sized to ensure operation within the range of their established ratings. All components of the system which require periodic calibration and/or inspection for proof of continued accuracy must be readily accessible. The frequency and methods of such calibration and/or inspection shall be as set forth in Rule 309-A, 4-c"

We have inserted this part about the frequency and method calibration that would be set forth in Rule 309-A, 4-c.

Under subparagraph (g) provides:

"(g) The control and recording system must include adequate fail-safe features which will provide assurance against mismeasurement in the event of power failure, or the failure of any ACT system's component parts."

That's API. Subparagraph (h) - 1 is not API.

(h) - 1. The ACT system and allied facilities shall in-

clude such fail-safe equipment as may be necessary, including high level switches in the surge tank or overflow storage tank which, in the event of power failure or malfunction of the ACT or other equipment, will shut down all artifically lifted wells connected to the ACT system and will shut-in all flowing wells at the well-head or at the header manifold, in which latter case all flowlines shall be pressure tested to at least 1 1/2 times the maximum well-head shut-in pressure prior to initial use of the ACT system and once each year thereafter."

Q There, where you used the words "in which latter case", that is where the flowing wells are going to be shut-in at the header manifold?

A That is correct.

Paragraph 2 of section (h) reads:

"2. As an alternative to the requirements of paragraph (h) 1 above, the producer shall provide and shall at all times maintain a minimum of available storage capacity above the normal high working level of the surge tank to receive and hold the amount of oil which may be produced during maximum unattended time of lease operation."

Q Explain there, please, what you mean by the above, the "high working level of the surge tank".

A The surge tank is the tank from which it actually is transfered from the lease to the pipe line. The reason it is called that is because it surges up and down to the pipe line, comes on and goes off. Ordinarily there is a high working level and a low working level on a surge tank with the range of drainage from that tank between those two levels. It comes on when the level reaches a high working level and goes off and disconnects the flow of oil from the pipe line when the oil reaches the low level. Ordinarily there is a variable capacity for storing the oil, if the power should fail, for example. Now, you can have a high level float switch up in the upper part of that tank which will shut-in the lease in paragraph (h) - 1 above or in your maximum unattended time of lease operations - - that's the time the pumper isn't out there. In case of power failure, if your capacity in the surge tank plus your flow capacity in the other tanks that are connected to the surge tank, if that amount of capacity is sufficient to store the oil while power is off or while the system is shut down for mechanical failure, then the shutting off of the well isn't necessary because you wouldn't have any waste of oil. There is no one out there, the well just overflows the tank. That's the reason for sections 1 and 2 in subparagraph (h). This is not an API. This is, however, a provision that has been entered in every single ACT system order in one form or the other.

Q You refer to the fail-safe features in paragraph (h), and you also refer to fail-safe features in paragraph (g)

above. Would you explain the difference between the fail-safe features between the two paragraphs?

A In paragraph (g) it only goes to prevent oil from going into the pipe line without being metered in the event of a failure. In paragraph (h) it prevents the waste of oil in case there is a failure of some sort or other. They are two seperate fail-safe systems.

Q Would you proceed, now, with paragraph 4, please.

A Yes, sir. Paragraph 4 is divided into two sections. The first part is devoted to the ACT system that employs meters. Subparagraph (a) is for the vessel type system. It reads:

4. (a) In all ACT systems employing automatic measuring tanks, weir-type measuring vessels, positive volume metering chambers, or any other volume measuring container, the container and allied components shall be properly calibrated prior to initial use and shall be operated, maintained, and inspected as necessary to ensure against incrustation, changes in clingage factors, valve leakage or other leakage, and improper action of floats, level detectors, etc.

(b) In all ACT systems employing positive displacement meters, the meter(s) and allied components shall be properly calibrated prior to initial use and shall be operated, maintained, and inspected as necessary to ensure against mismeasurement of oil."

Subparagraph (c) goes into the details of the measurement of these vessels. It reads as follows:

"(c) The measuring and recording devices of all ACP systems shall be checked for accuracy at least once each month unless exception to such determination has been obtained from the Secretary-Director of the Commission. API Standard 1101, "Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter," shall be used where applicable. Determinations - -" now, what we mean by "determinations" is the determination that the system is accurate. "Determinations may be made against Master Meters, Portable Prover Tanks, or Prover Tanks permanently installed on the lease. If permanently installed Prover Tanks are used, the distance between the opening and closing levels and the provision for determaning the opening and closing readings shall be sufficient to detect variations of .05%. Reports of determinations shall be filed on the Commission Form entitled "Meter Test Report," or on another acceptable form and shall be submitted in duplicate to the appropriate District Office of the Commission."

API Standard 1101 is, or course, entitled "Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter". This book has a section on installing meter provers and their calibration, meter proving procedure, performance operation and maintenance of metering systems, particularity on meter proving procedures. Now, I think most of the pipe lines and most of the producers are using the API standards and specifications for proving these meters. This rule would require that they do it where applicable. Now, this is on positive displacement meters.

However, these provisions are in many cases applicable in chamber volume cases also. This part about the permanently installed prover tank has in mind the system where you use the surge tank or in other large diameter storage tanks for proving a meter. You can't gauge the oil by a tape with enough accuracy to determine if the meter is functioning correctly in a larger tank of that sort, so actually what this provides for is measuring the opening and closing level and reading and keeping within a tolerance of .05%, which would probably call for psych classes. I don't know how you't get that accuracy if you didn't have a psych class. What we mean by "another acceptable form" is that many of the engineering companies provide a service in having a very excellent form which they are in the habit of using. If they do have all of the details in the information, we would certainly not be adverse in accepting such a report as that.

Q Would you continue with paragraph (d) and number 5, please.

A Subparagraph (d) outlines the procedure in order to obtain acceptance to that provision of subparagraph (c) which requires that the meters be checked once a month. However, the API in its section on proving frequency, refers to positive placement meters and says the calibration should be determined by the degree of accuracy required and it recommended that meters shall be calibrated at least once a month. Subparagraph (d) reads as follows:

"d) To obtain exception to the requirement of paragraph (c) above that all measuring and recording devices be checked for accuracy once each month, either the producer or transporter may file such a request with the Secretary-Director of the Commission setting forth all facts pertinent to such exception. The application shall include a history of the average factors previously obtained, both tabulated and plotted on a graph of factors versus time, showing that the particular installation has experienced no erratic drift. The applicant shall also furnish evidence that the other interested party has agreed to such exception. The Secretary-Director may then set the frequency for determination of the system's accuracy at the interval which he deems prudent."

Now, in there you will notice that either the producer or the transporter can ask for the exception. If the producer asks for the exception, then he has got to furnish evidence to the transporter and show that the transporter is satisfied with it and vice versa.

All that is left is number 5.

"5. Failure to operate an automatic custody transfer system in compliance with this rule shall subject the approval thereof to revocation by the Commission.

I think that's self explanatory.

Q Before we go into the proposed form C-106, let me ask you how you think this proposed Rule 309-A will operate in conjunction with Rule 309-B.

A This will in no way affect the operation of 309-B. There is one provision in paragraph (b) that is moot, however. That's the provision where it permits the Secretary-Director of the Commission to authorize the commingling of oil from two separate leases under certain conditions. Section 3 prohibits any of these commingling batteries from having more than 16 units producing into it. Now we take away the 16 unit limitation from the ACT system and 309-A, then, that portion of (b) is moot. If you have a standard tank battery, then (b) is identically the same in effect and operation.

Q So, you are proposing no change in 309-B at the present time?

A No, sir, only to recognize that the 16 unit portion is not applicable to ACT commingling installations.

Q Mr. Nutter, let's mark for identification the rule that you went through Commission's Exhibit No. 1.

(Thereupon, Commission's Exhibit No. 1 was marked for identification).

Q Do I understand, Mr. Nutter, that you will wish to offer these API bulletins as exhibits?

A Yes, sir. I wish to thank Al Carpenter of Humble.

MR. MORRIS: We will mark API Bulletin 1101 as Commission's Exhibit No. 3, API Bulletin 2509-A as Commission's Exhibit No. 5.

(Thereupon, Commission's Exhibits

No. 3, No. 4 and No. 5 were marked for identification).

Q If you will refer to what we have marked as Commission's Exhibit No. 2, that being your proposed form C-106 as refered to in your proposed Rule 309-A. Would you go through that form and explain where you feel necessary any particular part of it?

A Yes, sir. 106 is the number that we have had sitting there. They haven't been able to use it for a long time. In the upper right hand corner it has the ACT permit number and a blank space. We thought that it would probably in the interest of smoother operation if we'd number each of these permits and then set up a file for it and then the meter tests as they come in would be filed in that permit number file. That's the reason for the permit number there.

Next we have the operator's name and field in which the installation is located, the address and the county. It has the spaces for the names of the lease or leases to be served by this ACT unit; the name of the pool or pools to be served by the ACT unit and the location of the ACT unit by the unit, section, township and range. It also has space for the operator to furnish the order number authorizing commingling between the leases if more than one lease is to be served by this system, and the date; it also has a space for order number authorizing commingling between pools if more than one pool is to be served by this system; the name of the authorized transporter of oil from the system and his

address to be provided on the form. It has a space for the maximum expected daily through-put for the system in barrels per day to be inserted on the form. Then there is a space for the operator to check one of two boxes indicating the type of fail safe feature that would be utilized "if system fails to transfer oil due to malfunction or otherwise, waste by overflow will be averted by either A or B."

A reads "Automatic shut-down facilities as required by Section (4) h-1 of Rule 309-A." I want to correct that. It should be corrected to 3 (h)-1.

Just across from that is alternative B. I wish also to correct that. It should be Alternative (3) h-2 rather than (4) h-2 and it provides adequate available capacity to receive production during maximum unattended time of lease operation.

"If A above is checked, will flowing well be shut-in at the header manifold or at the well-head?" You insert which ever it is and then fill in the maximum well-head shut-in pressure.

Then it says if B above is checked, how much storage capacity is available above the normal high working level of the surge tank in barrels. Now that includes the capacity open and available in an extra overflow storage tank; that's all that provides. Then in the next paragraph it says "What is the normal maximum attended time" - - there's an error there; it should be unattended time of lease operation rather than attended time - - "in hours". The next paragraph is; "What device will be used for

measuring oil in this "C" Unit and it says to check one: either positive displacement meter, weir-type measuring vessel, positive volume metering chamber, and the space for some other type. And then below that there is a space for remarks. And the certification reads; "I hereby certify that the information given above is true and complete to the best of my knowledge and that the subject ACT system will be installed and operated in accordance with Rule 309-A. This is signed by the individual, his title and date and there is a space for approval by the representative of the Commission, his title and date of approval.

And then finally "Approval of Form C-106 does not eliminate the necessity of an approved C-110 prior to running any oil or gas from this system."

Q I thought that only the operator need sign the form C-106, that the signature or approval of the pipe line is not required on the form.

A That's correct. It is contemplated that the producer will in all cases make application for the ACT system. He will send in a plat of the lease and a letter from the transporter agreeing to it.

Q Mr. Nutter, this rule change with the accompanying form that you are proposing spells out quite a bit more detail, does it not, the requirements that an ACT system will have to meet before it's eligible for administrative approval?

A This goes into some detail as to the basic re-

quirements of the system, correct.

Q Do you feel that the requirements of the rule and details of the form will be an undue burden upon any operator that desires to obtain an administrative approval for his system?

A No, I think these are the minimum requirements that should be gone into and approved prior to the use of a system. I think that everything in here is either information that has been submitted in the rule or form or basic requirements of the rule; it is the same information that has been a requirement when an operator has come in for a hearing on one of these installations and I think that the information is the same information, the basic requirements are the same requirements that are contemplated by Mr. Hoover in the proposed rule of Gulf Oil. However, Gulf has not gone into the detail that we have. Some of these would be incorporated into the orders and certainly a lot of this information would have to be incorporated into this application. We have attempted to spell it out in the rule and application so the system would comply.

Q Your proposal is also different from that proposed by Mr. Hoover in that he has proposed a rule requiring administrative approval whereas your proposal really doesn't require administrative approval other than approval of a form submitted by the operator, is that correct?

A That's correct. Now, we also contemplate on some of these systems where the District Office of the Commission is

familiar with the package unit that can be installed and is being installed by an operator or operators using the same type of package or ACT unit. It is contemplated that the District Office would be able to approve this thing without even going out to look at it. In other cases we have contemplated an inspection before approval, but essentially these are all basic requirements.

Q Mr. Nutter, do you have any further comments that you would like to offer on your rule change or proposed form?

A No, sir. I didn't finish what I was saying. As I said, some of these are going to have - - we feel if it's authorized in the District Office of the Commission, the thing can be speeded up rather than being handled through the Santa Fe office. That's one of the points, that a field inspection, plus the approval in the district, will expedite handling.

Q There is no requirement relative to a waiting period or a waiver from off set operators?

A No, sir.

Q And that will speed up the process?

A Yes, sir.

Q Did you prepare Exhibits Nos. 1 and 2 and were Exhibits Nos. 3, 4 and 5 supplied to you by the API?

A I prepared 1 and 2, and 3, 4, and 5 came to me from API through various channels.

MR. MORRIS: At this time, Mr. Commissioner, I would like to offer Commission's Exhibits Nos. 1 through 5 into evidence.

MR. PORTER: Are there any objections to the admission of these Exhibits? They may be so admitted.

(Thereupon Exhibits Nos. 1 through 5 were admitted into the record).

CROSS EXAMINATION

BY MR. KASTLER:

Q Did you indicate that a hearing would be held for the approval of any proposed ACT transfer equipments?

A Yes, there would be if an operator did not meet the basic requirements of the rules.

MR. KASTLER: That's all.

MR. PORTER: Does anyone else have a question?

EXAMINATION

BY MR. PAYNE:

Q Mr. Nutter, I noticed that your proposed rule has no provisions for notice to or objection by royalty owners. Do you feel there may be any good reason why royalty owners should have this right?

A No, not under normal operation.

Q In an ordinary case the installation of ACT would actually cut down on leakage?

A Yes, one of the features of the ACT is that royalty owners stand to benefit by prudent operation of the ACT unit.

Q I think that the rule requires that a measuring and recording device be checked for accuracy at least once a month.

A Yes, sir.

Q When this test is taken and you get your factors, is that to be incorporated each month also?

A Yes, sir.

Q In other words, you don't just take the test and keep using the old factors?

A No, sir.

Q Some operators have been doing that in the past.

A We have known of cases like that, yes.

Q Do you feel that the requirement that flow lines be tested once each year in the event they use h-l is an undue burden?

A No, sir, I don't think so.

Q Do you think flow lines deteriorate like casing?

A Probably more so.

MR. PAYNE: Thank you.

MR. PORTER: Does anyone have a question of Mr. Nutter? You may be excused.

(Witness excused)

Does anyone desire to present testimony in this case?

MR. BURK: Sinclair has one witness.

R. M. ANDERSON

called as a witness, having been first duly sworn, testified as follows:

DIRECT EXAMINATION

BY MR. BURK:

Q Will you state your name and employment.

A R. M. Anderson, Engineer, Sinclair Oil and Gas Company in the Midland Division Office.

Q Have you previously offered testimony before the Commission in your capacity as an Engineer?

A I have.

Q Have you previously testified before the Commission regarding the ACT units installed in New Mexico on Sinclair leases?

A I have.

Q How many such units has Sinclair installed in New Mexico?

A A total of four units in operation.

Q These units which Sinclair has, are they similar or dissimilar to the units described by the Gulf witness and shown on the diagrammatic exhibit introduced in their case?

A They are dissimilar.

Q Is the unit or system which Sinclair has installed - - is this a unit that is more or less standard within the Sinclair Company?

A Yes, it is. It is a shop-fabricated unit that was designed by Sinclair personnel, built in Sinclair shops and is used company-wide.

Q It is used in other places than New Mexico?

A Yes, sir.

Q Under the rule proposed by Gulf for administrative approval, could the Sinclair unit receive administrative approval?

A No, sir.

Q I would like to ask you to explain in what substantial way the Sinclair unit would differ from the unit described by Gulf.

A The main thing that I would like to point out in this testimony is certainly not the superiority of the Sinclair units over any other unit that may be in operation. The point I would like to make is that there is more than one way to skin the cat and we have come up with a way which we consider to be the best way in so far as our operations are concerned. We have a system which essentially complies with all the matter that has been pointed out here with one exception, but I would like to comment briefly on some of the many ways that our system grossly varies from the Gulf system just to show that approved systems do vary. I am doing this in an effort so that no standard unit will be adopted as a result of the hearing here. I would like to see the Commission leave here with sufficient flexibility as indicated by Mr. Nutter's proposed rule to permit the approval of both Sinclair type units and Gulf type units and other type units that may be proposed to the Commission. Practically all aspects of the Gulf sketch, which they have I believe identified as Exhibit 2, vary in some respects to Sinclair units. For instance, starting with the surge tank where the oil starts into the LACT system, they have both a high

and low level switch to stop and start the pump. Sinclair does not have either high or a low level switch in its surge tanks to control the pump. Our pump is started by a clock mechanism and the pumper sets the number of starts a day that best suits his operation in the lease up to 96 starts a day. As for the stop level switch, we have two. The pressure is controled by Murphy switches installed in the LACT units. It's not on this surge tank and one switch will stop the delivery from the surge tank at 30 inches above the outlet and the other will stop it at 24 inches above the outlet, so the surge tank is not controlled by float level switches. There is a high level emergency switch shutting the lease in case of full storage. We do have an emergency shut-in switch at the top of the tank which does shut-in the facility if the surge tank fills up. The next item in which we have differed is that we don't install the air-eliminating device. We have in its place a feature where we have a 3-way valve and when our timer turns on the unit, the unit initially circulated for some 15 minutes out of the surge tank to the LACT system and back in the surge tank and that 15 minute cycle enables the meter, the temperature bulb on our meter, to come up to temperature. It purges the line of air and gas and it flushes out any sediment that might have occurred during the shut down period and transfer. Therefore, the air eliminator is not a necessary device on our unit, we feel. The next item is the meter itself and they specify a safety shut down switch and we do not incorporate that on the meter. We get around

that facility by having two basic designs which we use alternatively. In case of low production where the lease is being mostly produced by low capacity wells, where we have small amounts of production, we set just one temperature component meter on our LACT unit and we feel by having the pumper personnel on the lease producing his wells we have not gone to automation out here on these installations. We have personnel on the lease, they are inspecting these meters several times a day, they actually record the meter readings every morning and check them several times throughout the day, and we feel in the event the meters were to fail to function properly, the personnel would be aware of it in a matter of hours. In low productivity wells, we feel that it would be a very simple matter to estimate within a few barrels exactly the production that passed the meter and was not metered and we have worked this feature out with several pipe lines and under those conditions, they have connected and have been agreeable to them. It is what we consider a reasonable feature in the event we are riding a considerable amount of oil. We place no meters in the LACT unit. One is checking the other and in the event one were to fail, we would have the other meter as a check.

Now, a more common failure of it besides a breakdown that could cause the meter not to measure oil would be a shaft shearing in the meter or some major thing which is very unusual, it does not happen frequently at all. A major meter failure, we believe, is a failure of the temperature calibration and if it's

no longer operating, it throws a slight amount of air into the oil going through the meter which you assume is being corrected for temperature, and that failure in one meter installation, such as Gulf proposes, is not detectable until the next calibration, once a month, which has been mentioned. However, in the case of large volumes of oil where we have the two meters in the line, we have one meter to check against the other at all times and each has a separate temperature compensating device and therefore we feel that when the meters are not agreeing a calibration is immediately called for. The incorrect meter is determined and we have a accurate measurement of oil from the other meter so that's how we get around in not installing the safety shut down switch. We don't consider it necessary, considering the other way we do it.

Q Have you completed your answer to that question?

A I believe I have with the one exception that this sketch does show a master meter prover connection system. We use alternative methods like prover tanks.

Q The Sinclair unit is substantially different from the Gulf, I assume. Probably other companies may have units still different from Sinclair units?

A That's correct.

Q All of them have possibly received approval by the Commission at hearings in the past?

A Yes, sir.

Q Mr. Nutter has proposed a rule which would in-

corporate a minimum standard for approval of these units by administrative action without a hearing. I will ask you to state whether you're in agreement with the rules proposed by him and if you are not in agreement point out in which respects and your reasons as to whether any of these minimum requirements may be dropped?

A I am in agreement with Mr. Nutter's rule completely except for one or two items. On his paragraph 3, section (g), I am not in agreement with that provision insofar as it applies to what I have just been talking about. I believe I have explained that point sufficiently. One other provision that I am not in agreement with is that paragraph (d) of that same paragraph 3, subparagraph (d) where he has required that set-stop counters be installed to stop the flow of oil through the system at the time the allowable has been run. I believe that this is a step towards automation rather than transfer provision. I believe if you are going to have an automatic fleet that you would certainly need that automatic feature in your LACT system. However, it is my opinion that you do not need an automatic shut off device on your meter if you haven't put in an automatic lease because you will have personnel on the lease - - I know Sinclair does - - operating the lease, flowing the wells, producing the well, and at the same time keeping up with their production through reading the meters or gauging the tanks; so we have been successful in something over 20 installations in the southwest. Now, we have been successful

in shutting off the leases at the end of the month at the proper time and not producing to an extent that it becomes any kind of a problem. It is not an undue hardship to manually close the lease in when you are using an LACT system. So I do not concur with paragraph (d).

Q What would be your recommendation, then, as to the adoption of this provision of Rule 309-A?

A I would recommend that it just be deleted from this provision.

Q You favor the remainder of the proposed revision?

A Yes.

Q Do you have anything further to add?

A No, sir.

MR. PORTER: Does anyone have a question of Mr. Anderson?

CROSS EXAMINATION

BY MR. PAYNE:

Q Mr. Anderson, is it your understanding that most pipe lines require the set stop counters to stop the flow of oil through the system when the allowable has been run?

A No, sir, it's not my belief. We are connected to three different pipe lines in the Midland Division and none of them requires this allowable feature to shut-in the LACT unit. None of them have it.

Q If this were a requirement, then none of your units would have been eligible for approval by the District Supervisor?

A By the Commission, yes, that is correct.

Q None of yours would have been eligible?

A That's right.

Q That is solely because of paragraph (d) or is it also because of paragraph (g)?

A It's certainly because of paragraph (d). With regard to paragraph (g), it says "adequate fail-safe features." Now, whether doing it in the manner I explained is an adequate fail-safe feature - - if it were to be decided to be such and it undoubtedly has by the Commission when they approve these for installation in New Mexico - - I would say that it's only with regard to paragraph (d) that our installation would fail to qualify.

CROSS EXAMINATION

BY MR. MORRIS:

Q Mr. Anderson, how much expense is involved putting one of these automatic cut off equipment on as set forth in paragraph (d) on your system?

A I don't know, but I would estimate somewhat in the neighborhood of $100. I do not know the cost of that item.

Q If it were made a requirement by the Commission, would you feel that it was prohibitive in cost?

A I believe that it would certainly be one point. We have personnel on our leases, pumpers serving our leases who are paid to do that and to put this added feature on there we feel would be undesirable from several standpoints. It might promote

subconscious laxity. I would not recommend that we install it.

Q Other than where you have pointed out that you disagree with this proposal, I take it you are supporting the Commission's proposed rule, is that correct?

A Yes, sir.

MR. MORRIS: Thank you.

(Questions by Mr. Porter): Mr. Anderson, explain a little bit further the feature that you have which prevents oil from passing through the pipe line in the event the meter fails.

A It's been our experience whenever we have a failure where oil has gone through the pipe line - - and I understand that this is a very rare situation, its very infrequent because it is a matter of negotiation based upon past history, past, recent history. Now, in the event of a power failure where all of the oil is being discharged by a delinquent pump the valve returns to the closed position automatically so in case of power failure there is no trouble. The only way that oil can be delivered that is not being measured is in the meter itself, if a shaft were to shear off the meter, which again is a most uncommon occurrance. You can't say it is impossible because sometimes it's known to happen but that's the only way. In case of large capacity leases we do have the two meters checking one against the other. In the case of small capacity leases, why, we have them all on 24 hours a day. Their allowable is all they can take. We know just about what those wells are making and we feel we can receive fair treatment from

these pipe lines in that unlikely event that it happens. It doesn't happen often enough to justify incorporating the automatic shut down switch on the meter.

Q You wouldn't know despite the fact that it's API recommended practice?

A They're written by groups of operators from many companies with that idea and they represent a negotiated set of standards that they all can subscribe to and they give and take all of the way through the instrument. The instrument, too, is designed to be all inclusive and handle every sort of situation, whereas the specific installation - - I think if the operator is interested in saving money and economizing and producing his oil in the most economical way, he will devote a little personal attention to each installation and he will find that some things that would be required in one field would not be required in another; due to the difference in crude, the difference in volume production and depth. API standards, in my opinion, can't hope to be the only way you can do it. This is an excellent guide to cover the general case, but I believe that in this respect if the API is requiring something like this, I do not concur with them with regard to this one recommendation.

Q Now, disregarding the cost of these features to provide assurance against mismeasurement in the case of a power failure would you say it is more desirable to have that fail safe feature than to not have it?

A In the case of our LACT unit where we are handling large volumes, it is not desirable to have it in my opinion, - - unless I am overlooking something here - - in that we have two meters in series one checking against the other both of which are kept in perfect operation, so therefore it is not desirable to have some additional mechanical device hung on these meters that may tend to fail itself. When those fail safe devices in the meter stop registering and so forth, they do not protect against a failure in the temperature compensating device and that does fail occasionally on these things and we feel our meter is superior in that we have two meters, two compensating devices, one to check against the other. In that case I would say it would be better not to have the fail safe device to shut the lease in in case a meter fails because the other meter is used as a check.

Q Well now, you say that in the event of a power failure it is automatically taken care of anyway, is that correct?

A Yes.

Q Failure on the part of a meter in the case of a severed shaft where you have two meters would probably be an assurance against mismeasurement of oil?

A Yes.

Q What is the breaking point at which you decide to put two in series or just one?

A We have been breaking at about 5 to 6 hundred barrels per day.

Q And you have no assurance on a lease producing 5 or 6 hundred barrels per day or less that you wouldn't mismeasure oil in the event of a failure, is that correct?

A We have this assurance; we don't anticipate any such failure as closly as we watch and calibrate and with the personnel on the lease. We don't anticipate that we will have very many failures, and further, we don't anticipate that we will have a failure for very long; it would be a matter of hours.

Q I realize your assurance that you wouldn't mismeasure oil, that you don't anticipate it. What happens if you did have a failure?

A It's only a matter of hours until it's corrected.

Q But the same oil has been passed through the system that has not been metered.

A Because it's a low-capacity system.

Q It could be up in the 5 or 6 hundred barrels?

A Yes.

MR. PORTER: Does anyone have any question of the witness?

CROSS EXAMINATION

BY MR. PAYNE:

Q Would you delete all of paragraph (d) or just the first sentence?

A I have no objection to the second sentence.

MR. PAYNE: Thank you.

MR. PORTER: Are there any further questions? The

witness may be excused.

(Witness excused)

MR. PORTER: Does anyone wish to present any further testimony in this case? Would anyone like to make a statement?

MR. KASTLER: I have a statement I would like to make for the record.

MR. PORTER: You may proceed.

MR. KASTLER: Gulf did not and does not now advocate the typical type of LACT unit that would be adopted as the only approvable LACT unit without necessitating a hearing. We provided in paragraph 3 of our proposed rule change that application for administrative approval merely state as a fact the proposed installation is basically similar in design and operation to one previously approved by the Commission.

We proposed our amendment as a subjective approach to the problem believing it would provide the utmost simplicity and flexibility. We deliberately intended to exclude from this case the reporting of facts which were in our opinion concerned with producing equipment rather than delivery equipment. We also assumed as a given fact that the oil in the surge tank would have been already purged of all unsoluble impurities for the reason that this involves, in Gulf's system at least, the producer's facility located at and operated in conjunction with the heater treaters.

Finally, I wish to state that Gulf is primarily seeking relief from what we consider unnecessary hearings and that we

appreciate the effort of Mr. Nutter and the Commission staff both in calling this hearing and in their constructive proposals; and, therefore, have no serious objection to the adoption of the Commission's proposed rule and form C-106 in lieu of that proposed by Gulf.

MR. PORTER: Does anyone have anything else to say?

MR. BUELL: I am Guy Buell for Pan American Petroleum Corporation. Pan Am is in agreement with the objectives of both the Gulf proposal as well as Mr. Nutter's proposal. We would not object if either one were adopted. We do lean to Mr. Nutter's proposal because of the more detailed requirements set out in the Nutter proposal.

MR. BRATTON: Humble Oil is in support of the alteration of Rule 309-A as proposed by Mr. Nutter and the Commission staff. Installations are proposed which qualify according to the basic requirements and reduce additional work loads which would be imposed upon the Commission. Repetitious hearings are not warranted. We would suggest and recommend, however, that further consideration be given to the provision in section 3 (h) - 1 proposed by Mr. Nutter relative to the annual flow lines where adequate precautions are exercised to maintain the flow lines in satisfactory condition. It is believed that recurring tests are not warranted and are an unnecessary burden on the producer. In addition to the expense incurred, loss of production would likely ensue since a number of operators probably use cold water or such tests for maximum safety.

It is Humble's theory and we honestly suggest a more flexible provision be drafted, that it be drafted and adopted.

MR. ROBINSON: I am Ed Robinson of Texaco Incorporated. Texaco concurs in the objections proposed by both Gulf and Mr. Nutter. However, Texaco also strives to eliminate any administrative burden regardless of how small it is if we feel that perhaps it is unwarranted. The requirements to get a letter from the pipe line authorizing agreement with the proposed LACT unit is what we feel to be an administrative burden in that even though they do give a letter concurring with your application, before the unit is complete you still have to satisfy the pipe line with your installation and they may require some minor change on it even though previously they had approved your recommendation and we feel that this requirement, even though small, can often result in a delay. It's kind of like writing to an operator requesting a waiver. He wants to do the work first before he gets around to giving you this waiver and often times there is a 10-day period before you get the letter.

This might happen with the pipe line. Maybe the man that handles it is on vacation and we might happen to be delayed maybe 30 days and regardless of the installation we are still held responsible to the pipe line company in that we have to get their final okay on it and we request that that part be eliminated.

MR. PORTER: Would anyone else like to make a statement?

MR. Mc GANNON: I am R. L. Mc Gannon, Standard of Texas.

We are in agreement with the rule change but believe consideration should be given as set forth by the operators.

MR. PORTER: Does that conclude the statements?

If there is nothing further, the Commission will take the case under advisement.

We will have a short recess at this time.

(Whereupon recess was taken at 2:50 p.m.)

STATE OF NEW MEXICO)
) ss
COUNTY OF BERNALILLO)

I, Thomas F. Horne, Court Reporter, in and for the County of Bernalillo, State of New Mexico, do hereby certify that the foregoing and attached Transcript of Proceedings before the New Mexico Oil Conservation Commission was reported by me in machine shorthand and reduced to typwritten transcript under my personal supervision, and that the same is a true and correct record to the best of my knowledge, skill and ability.

Thomas F. Horne
Court Reporter

My Commission Expires:

_____

Gulf Oil Corporation

ROSWELL PRODUCTION DISTRICT

W. A. Shellshear
F. O. Mortlock
M. I. Taylor
H. C. Vivian

P. O. Drawer 669
Roswell, New Mexico

February 6, 1961

Oil Conservation Commission
State of New Mexico
Santa Fe, New Mexico

Re: Application for Hearing to Revise Statewide Rule 309 to Establish a Procedure for Administrative Approval for Automatic Custody Transfer Systems

Gentlemen:

Gulf Oil Corporation respectfully requests that the Commission set for hearing this application to consider the revision of Statewide Rule 309 to establish a procedure for administrative approval of automatic custody transfer systems where equipment of a type previously approved by the Commission is proposed.

In support of this application, Gulf submits the following:

(1) Sufficient evidence in Gulf's opinion is available to prove that an ACT system is an accurate and efficient method of accounting for production and delivering to the pipe line.

(2) Present rules require a separate hearing for each installation of ACT equipment even though the identical ACT equipment has consistently been approved on other locations.

(3) Gulf is of the opinion that all ACT systems approved by the Commission have been basically similar in design utilizing safety equipment to shut in the lease in the event of full storage or in the alternative provide for sufficient storage for handling the production during the unattended hours.

(4) In the event conditions should be encountered which might tend to involve waste or to impair correlative rights, the administrative approval could be withheld and the applicant notified that a hearing will be required or the Commission may upon its own motion institute proceedings for a hearing.

GULF

It is requested that this matter be set for hearing at an early date.

Respectfully submitted,

GULF OIL CORPORATION

By W. A. Shellshear
District Manager

JHH:sz

cc: Oil Conservation Commission
Post Office Box 2045
Hobbs, New Mexico

No. 11-61

DOCKET: REGULAR HEARING - THURSDAY, APRIL 13, 1961

OIL CONSERVATION COMMISSION - 9 A.M. - HIGH SCHOOL CAFETERIA 1300 EAST SCHARBAUER, HOBBS, NEW MEXICO

ALLOWABLE: (1) Consideration of the oil allowable for May, 1961.

(2) Consideration of the allowable production of gas for May, 1961, from nine prorated pools in Lea County, New Mexico, also consideration of the allowable production of gas from nine prorated pools in San Juan, Rio Arriba and Sandoval Counties, New Mexico, for May, 1961.

CASE 2241: Application of Potash Company of America for an extension of the potash-oil area. Applicant, in the above-styled cause, seeks an extension of the potash-oil area as set forth in Order R-111-A, and amendments thereto, to include the following-described acreage: Township 20 South, Range 29 East, NMPM, Eddy County, New Mexico

Section 13: SW/4 NW/4 and NW/4 SW/4
Section 14: SE/4 NE/4 and NE/4 SE/4

CASE 2242: Application of the Oil Conservation Commission on its own motion to consider certain changes in the definition section of its Rules and certain changes in the definitions in Rule 107, and to consider amending Rule 112 to provide, among other things, for administrative approval for multiple slim-hole completions.

CASE 2243: Application of Gulf Oil Corporation for an amendment of Rule 309 (a). Applicant, in the above-styled cause, seeks an amendment of Rule 309 (a) to permit the installation of lease automatic custody transfer equipment without the necessity of notice and hearing.

CASE 2244: Southeastern New Mexico nomenclature case calling for an order creating new pools and extending existing pools in Chaves, Eddy, Lea and Roosevelt Counties, New Mexico, and for an order defining the vertical limits of a certain Pool:

(a) Create a new oil pool, the vertical limits to be the Abo formation. This pool is to be designated as the Allison-Abo Pool and described as:

TOWNSHIP 9 SOUTH, RANGE 36 EAST, NMPM
SECTION 11: NW/4

BEFORE THE OIL CONSERVATION COMMISSION

OF

STATE OF NEW MEXICO

IN THE MATTER OF THE APPLICATION OF GULF OIL CORPORATION FOR ADOPTION OF RULES FOR ADMINISTRATIVE APPROVAL OF AUTOMATIC CUSTODY TRANSFER SYSTEMS.

Case No. 7243

ENTRY OF APPEARANCE

Come now Kellahin & Fox, P. O. Box 1713, Santa Fe, New Mexico, and enter their appearance in the above captioned case in behalf of Amerada Petroleum Corporation in association with Mr. H. D. Bushnell, a member of the Oklahoma Bar.

By Jason W. Kellahin

CONTINENTAL OIL COMPANY

LEGAL DEPARTMENT — DENVER 2, COLORADO

A. T. SMITH
GENERAL ATTORNEY
C. R. HAMPTON
F. E. RADLOFF
W. M. GRIFFITH
G. H. MAYBERRY
R. A. HOLLERN
ATTORNEYS

April 11, 1961

Oil & Gas Conservation Commission
State Land Building
Santa Fe, New Mexico

Re: Case No. 2243

Dear Sir:

Reference is made to the subject case and the application of Gulf Oil Company to amend Rule 309 (a) to permit the installation of lease automatic custody transfer equipment without the necessity of notice and hearing. Continental Oil Company would like to join Gulf Oil Company in its application for amendment of Rule 309 (a), and respectfully requests the commission to approve this amendment.

Very truly yours,

William M. Griffith

William M. Griffith

bv
cc: John Tynan
Ralph Vertrees
M. A. MacLennan

CASE 2243 RULE CHANGE PROPOSED BY OIL CONSERVATION COMMISSION STAFF

RULE 309-A. CENTRAL TANK BATTERIES

Oil shall not be transported from a lease until it has been received and measured in (a facility of an approved design) located on the lease. Such facilities shall permit the testing of each well at reasonable intervals and may be comprised of (manually gauged closed stock tanks for which proper strapping tables have been prepared, with a maximum of sixteen proration units producing into said tanks, or of) automatic custody transfer (ACT) equipment. The use of such automatic custody transfer equipment shall be permitted only after compliance with the following:

1. The operator shall file with the Commission Form C-106, Notice of Intention to Utilize Automatic Custody Transfer Equipment, and shall receive approval thereof prior to transferring oil through the ACT system. The carrier shall not accept delivery of oil through the ACT system until Form C-106 has been approved.

2. Form C-106 shall be submitted in quadruplicate to the appropriate District Office of the Commission and shall be accompanied (in quadruplicate) by the following:

(a) Plat of the lease showing thereon all wells which will be produced into the ACT system.

(b) Schematic diagram of the ACT equipment, showing thereon all major components such as surge tanks and their capacity, extra storage tanks and their capacity, transfer pumps, monitors, reroute valves, treaters, samplers, strainers, air and gas eliminators, back pressure valves, metering device (indicating type and capacity, i.e., whether automatic measuring tank, positive volume metering chamber, weir-type measuring vessel, or positive displacement meter). Schematic diagram shall also show means employed to prove accuracy of measuring device.

(c) Letter from transporter agreeing to utilization of ACT system as shown on schematic diagram.

3. Form C-106 will not be approved by the Commission unless the ACT system is to be installed and operated in compliance with the following:

(a) Provision must be made for accurate determination and recording of uncorrected volume and applicable temperature, or of temperature corrected volume. The overall accuracy of the system shall equal or surpass manual methods.

(b) Provision must be made for representative sampling of the oil transferred for determination of API gravity and BS&W content.

(c) Provision must be made if required by either the producer or the transporter of the oil to give adequate assurance that only merchantable oil is run by the ACT system.

(d) Provision must be made for set-stop counters to stop the flow of oil through the ACT system at or prior to the time the allowable has been run. All counters shall provide non-reset totalizers which shall be visible for inspection at all times.

(e) All necessary controls and equipment must be enclosed and sealed, or otherwise be so arranged as to provide assurance against, or evidence of, accidental or purposeful mismeasurement resulting from tampering.

(f) All components of the ACT system shall be properly sized to ensure operation within the range of their established ratings. All components of the system which require periodic calibration and/or inspection for proof of continued accuracy must be readily accessible. The frequency and methods of such calibration and/or inspection shall be as set forth in Rule 309-A, 4-c.

(g) The control and recording system must include adequate fail-safe features which will provide assurance against mismeasurement in the event of power failure, or the failure of the ACT system's component parts.

(h) 1. The ACT system and allied facilities shall include such fail-safe equipment as may be necessary, including high level switches in the surge tank or overflow storage tank which, in the event of power failure or malfunction of the ACT or other equipment, will shut down all artifically lifted wells connected to the ACT system and will shut-in all flowing wells at the well-head or at the header manifold, in which latter case all flowlines shall be pressure tested to at least 1½ times the maximum well-head shut-in pressure prior to initial use of the ACT system and once each year thereafter.

2. As an alternative to the requirements of paragraph (h) 1 above, the producer shall provide and shall at all times maintain a minimum of available storage capacity above the normal high working level of the surge tank to receive and hold the amount of oil which may be produced during maximum unattended time of lease operation.

4. (a) In all ACT systems employing automatic measuring tanks, weir-type measuring vessels, positive volume metering chambers, or any other volume measuring container, the container and allied components shall be properly calibrated prior to initial use and shall be operated, maintained, and inspected as necessary to ensure against incrustation, changes in clingage factors, valve leakage or other leakage, and improper action of floats, level detectors, etc.

(b) In all ACT systems employing positive displacement meters, the meter(s) and allied components shall be properly calibrated prior to initial use and shall be operated, maintained, and inspected as necessary to ensure against mismeasurement of oil.

(c) The measuring and recording devices of all ACT systems shall be checked for accuracy at least once each month unless exception to such determination has been obtained from the Secretary-Director of the Commission. API Standard 1101, "Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter," shall be used where applicable. Determinations may be made against Master Meters, Portable Prover Tanks, or Prover Tanks permanently installed on the lease. If permanently installed Prover Tanks are used, the distance between the opening and closing levels and the provision for determining the opening and closing readings shall be sufficient to detect variations of .05%. Reports of determinations shall be filed on the Commission Form entitled "Meter Test Report," or on another acceptable form and shall be submitted in duplicate to the appropriate District Office of the Commission.

(d) To obtain exception to the requirement of paragraph (c) above that all measuring and recording devices be checked for accuracy once each month, either the producer or transporter may file such a request with the Secretary-Director of the Commission setting forth all facts pertinent to such exception. The application shall include a history of the average factors previously obtained, both tabulated and plotted on a graph of factors versus time, showing that the particular installation has experienced no erratic drift. The applicant shall also furnish evidence that the other interested party has agreed to such exception. The Secretary-Director may then set the frequency for determination of the system's accuracy at the interval which he deems prudent.

5. Failure to operate an automatic custody transfer system in compliance with this rule shall subject the approval thereof to revocation by the Commission.

FORM C-106 ACT Permit No.____

NOTICE OF INTENTION

TO UTILIZE AUTOMATIC CUSTODY TRANSFER EQUIPMENT

Operator_____ Field_____

Address_____ County_____

Lease(s) to be served by this ACT Unit_____

Pool(s) to be served by this ACT Unit_____

Location of ACT System: Unit_____Sec_____Twp_____Rge_____

Order No. authorizing commingling between leases if more than one lease is to be served by this system_____Date_____

Order No. authorizing commingling between pools if more than one pool is to be served by this system_____Date_____

Authorized transporter of oil from this system_____

Transporter's address_____

Maximum expected daily through-put for this system:_____bbls/day

If system fails to transfer oil due to malfunction or otherwise, waste by overflow will be averted by: (Check One)

A. ☐ Automatic shut-down facilities as required by Section (3) h-1 of Rule 309-A.

B. ☐ Alternative (3) h-2, providing adequate available capacity to receive production during maximum unattended time of lease operation.

If A above is checked, will flowing wells be shut-in at the header manifold or at the well-head?_____Maximum well-head shut-in pressure_____

If B above is checked, how much storage capacity is available above the normal high working level of the surge tank?_____Bbls.

What is the normal maximum attended time of lease operation?_____Hours

What device will be used for measuring oil in this ACT Unit? (Check One)

☐ Positive displacement meter ☐ Weir-type measuring vessel

☐ Positive volume metering chamber ☐ Other; Describe_____

_____

Remarks:_____

_____

I hereby certify that the information given above is true and complete to the best of my knowledge and that the subject ACT system will be installed and operated in accordance with Rule 309-A.

Approved, Oil Conservation Commission By_____

By_____ Title_____

Title_____Date_____ Date_____

Approval of Form C-106 does not eliminate the necessity of an approved C-110 prior to running any oil or gas from this system.

no change up to approval

Rule 309(A) Oil shall not be transported from a lease until it has been received and measured in a facility of an approved design located on the lease. Such facilities shall provide the testing of each well at reasonable intervals and ~~must~~ comprised of manually gauged closed stock tanks for which proper strapping tables have been prepared, or of automatic custody transfer (ACT) equipment. The use of such automatic custody transfer equipment shall be permitted only after compliance with the following:

1. The operator shall file with ~~the appropriate District~~ Office of the Commission, ~~Santa Fe~~, Form C-106, Notice of Intention to Utilize Automatic Custody Transfer Equipment, and shall receive approval thereof prior to transferring oil through the ACT system. The carrier shall not accept delivery of oil through the ACT system until Form C-106 has been approved.

2. Form C-106 shall be submitted in ~~quadruplicate~~ to the appropriate District Office of the Commission ~~Hobbs~~ and shall be accompanied (in ~~triplicate~~ quadruplicate) by the following:
   (a) Plat of the lease showing thereon all wells which will be produced into the ACT system
   (b) Schematic diagram of the ACT equipment, ~~as well as~~ showing thereon all ~~essential~~ major components such as ~~shown~~ surge tanks and their capacity, extra storage tanks and their capacity, transfer pumps, monitors, ~~sampler~~, re-route valves, samplers, strainers, ~~&~~ air and gas eliminators, back pressure valves, metering device (indicating type and capacity, i.e., whether ~~meter~~

~~tanks~~ automatic measuring tank, positive volume metering chamber, weir-type measuring vessel, or positive displacement ~~meter~~) Schematic diagram shall also show means employed to ~~determine accuracy~~ prove accuracy of ~~metering~~ measuring device.

(d) Letter from transporter agreeing to utilization of ACT system as shown on schematic diagram

3. Form C-106 will not be approved by the Commission ~~unless~~ the ACT system is to be ~~installed and operated in~~ ~~substantial~~ compliance with the following:

(a) Provision must be made for accurate determination and recording of uncorrected volume and applicable temperature, or of temperature corrected volume. The overall accuracy of the system shall equal or surpass manual methods.

(b) Provision must be made for representative sampling of the oil transported for determination of API gravity and the BS&W content.

(c) Provision must be made if required by either the producer or the transporter of the oil to give adequate assurance that only merchantable oil is run by the ACT system.

(d) Provision must be made for set-stop counters to stop the flow of oil through the ACT system at or prior to the time ~~the permitted total~~ has been run. All counters shall provide non-reset totalizers which shall be visible for inspection at all times. ~~The control and recording system~~

(e). All necessary controls and equipment must be enclosed and sealed, or otherwise be so arranged as to provide assurance against, or evidence of, accidental or purposeful mismeasurement ~~shall be free to~~

(f) ~~[redacted]~~ the ACT system shall be properly sized to ensure operation within ~~three tenths of accuracy~~ the range of ~~[redacted]~~ rated rate.

(h) All components of the system which require periodic calibration and/or inspection for proof of continued accuracy must be readily accessible. The frequency and ~~procedure~~ methods of such calibration and/or inspection shall be as set forth in Rule 399(A)4-C ~~automatically agreeable to the producer and the transporter, subject to Commission approval.~~

(g) The control and recording system must include adequate fail-safe features ~~that~~ which will provide assurance against mismeasurement in the event of power failure or the failure of the ACT system's component parts.

(4)

(k)(1) The ACT system and allied facilities shall include such fail-safe equipment as may be necessary, including high level switches in the surge tank ~~and/or~~ or overflow storage tank which, ~~will~~ in the event of power ~~failure~~ failure or malfunction of the ACT or other equipment, will shut down all artificially lifted wells connected to the ACT system and will shut-in all flowing wells at the well-head or at the header manifold, ~~or~~ in which latter case all flowlines shall be pressure tested to at least ~~one~~ 1½ times the maximum well-head shut-in pressure prior to initial use of the ACT system and once each year thereafter.

(k)(2) As an alternative to the requirements of paragraph (k)(1) ~~18(k)~~ above, the producer shall provide and shall maintain at all times a minimum of available storage capacity above the normal high working level of the surge tank to ~~store~~ receive and hold the amount of oil which may be produced during maximum unattended time of lease operation.

4(a) In all ACT systems employing automatic measuring tanks, weir-type measuring vessels, positive volume metering chambers, or any other volumetric measuring ~~measuring~~ container, the container and allied components shall be properly ~~calibrated~~ calibrated prior to initial use and ~~at such subsequent intervals as may be mutually agreeable to the producer and the transporter, subject to Commission approval~~ shall be operated, ~~and~~ maintained, and inspected as necessary to ensure against incrustation, changes in clingage factors, valve leakage or other leakage, improper action of floats, level detectors, etc.

(b) In all ACT systems employing positive displacement meters, the meter(s) and allied components shall be properly calibrated prior to initial use and shall be operated, maintained, and inspected as necessary to insure against misemeasurement of all the measuring and recording devices of all ACT

(c) [redacted] systems shall be checked for accuracy at least once each month unless exception to such determination has been obtained from the Secretary Director of the Commission. API Standard 1101, "Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter" shall be used where applicable. ~~Comparative~~ Determinations ~~may be made~~ and calibration reports shall be

Portable Prover Tanks, or Prover Tanks permanently installed on the lease. If permanently installed Prover Tanks are used, the distance between the opening and closing levels and the provision for determining the opening and closing readings shall be sufficient to detect variations of .05%. Reports of determinations shall be

~~(c)~~ filed on Commission Form 107, Meter Test Report, which shall be submitted ~~in accordance with Rule~~ in duplicate to the appropriate District Office of the Commission.

(d) To obtain exception to the requirement of paragraph (c) above that all measuring and recording devices be ~~inspected~~ checked for accuracy once each month, either the producer or transporter ~~that~~ may file such a request with the Secretary-Director of the Commission setting forth all facts pertinent to such exception including a history of the average factors previously obtained both ~~plotted~~ on a graph tabulated and plotted on a graph, factors versus time, ~~together with evidence that the~~ proving that the particular installation has experienced no erratic drift. The applicant shall also furnish evidence that the other interested party has agreed to such exception. The ~~Secretary~~ Secretary-Director may then set the frequency for determination of the system's accuracy at the interval which he deems prudent.

METER CALIBRATION WORKSHEET

LEASE State "Q" ZONE Tubbs WELL NO. 1 DATE 9-25-59

A) Meter Serial No. M 24-207

B) Meter Reading "END of Test 543

C) Meter Reading "BEGINNING" of Test 471

D) Oil Produced 26 bbls

E) Meter Temperature 78 °F

F) Volume Correction Factor

G) Oil Produced @ 60°F 26 bbls

1) Tank or Master Meter No. 3678

2) Tank Gauge "END" of Test 14 ft. 9-1/8 in. 488.52 bbls

3) Tank Gauge "BEGINNING" 13 ft. 11 in. 460.92 bbls

4) Oil Produced 27.60 bbls

5) API Gravity & Temp. of Oil 37 °API 78 °F

6) API Gravity @ 60°F 35.7 °

7) Volume Correction Factor .9911

8) Oil Produced @ 60°F 27.54 bbls

Ratio Error (G/8) 0.9441

Lease Meter Factor ($\frac{1}{G/8}$) 1.0592

% Error ($\frac{G - 8}{8}$) 5.59 %

Remarks:

Tank strapped June 18, 1937

This meter is used to measure fluids

___ During custody transfer
___ Prior to commingling production from two or more pools
___ Prior to commingling production from two or more leases

Lease(s) and Well(s) _____

Location (Sec, Twp, Rge) _____

TESTING DEVICE

Device:	Meter	Tank	Stock Tank	(Explain)
Make		Mfr. No.	Size	Serial No
Date of Last Calibration			Factor	

LEASE METER

Type of Meter	P. D.	Dump	Other (Explain)
[redacted]			
Date Last Repaired			Last Test
Bbls Metered Since Last Test	Gravity Last Test		Meter Factor Last Test

[redacted] TEST

	Run No.	Run No.	Run No.	Run No.
Final Reading				
Initial Reading				
[redacted] Measured				
[redacted] Corrected to 60°F				
Master Meter Factor				
Net Barrels Measured				

LEASE METER

Final Reading				
Initial Reading				
Gross Barrels Measured				
Gross Barrels Corrected to 60°F				
Meter Factor (Indicate by * the factors used to obtain the average factor below				

Average Meter Factor _____ Meter Factor To Be Used _____

Remarks _____

This meter is used to measure fluids

___ During custody transfer
___ Prior to commingling production from two or more pools
___ Prior to commingling production from two or more leases

Lease(s) and Well(s) _____

Location (Sec, Twp, Rge) _____

TESTING DEVICE

Device:	Meter	Power Tank	Stock Tank	Other (Explain)
Make		Model No.	Size	Orifice No
Date of Last Calibration			Factor	

LEASE METER

Type of Meter	P. D.	Dump	Other (Explain)
Make		Model	Size
Date of Last Calibration			Last Test
Bbls Metered Since Last Test	Gravity Last Test		Meter Factor Last Test

CUSTODY TEST

Testing Device	Run No.	Run No.	Run No.	Run No.
Final Reading				
Initial Reading				
Barrels Measured				
Barrels Corrected to 60°F				
Master Meter Factor				
Net Barrels Measured				

LEASE METER

Final Reading				
Initial Reading				
Gross Barrels Measured				
Gross Barrels Corrected to 60°F				
Meter Factor (Indicate by ✓ the factors used in obtaining the average factor below				

Average Meter Factor _____ Meter Factor To Be Used _____

Remarks _____

Tested by _____ Position _____ Company _____

Witnessed by _____ Position _____ Company _____

I hereby certify that the above data are true and correct to the best of my knowledge

Name _____ Position _____ Company _____

Lease Meter Serial No._____
Test Report No._____

NEW MEXICO
OIL CONSERVATION COMMISSION

METER PROVING REPORT

Company_____ Pool(s)_____
This meter is used to measure fluids

_____ During custody transfer
_____ Prior to commingling production from two or more pools
_____ Prior to commingling production from two or more leases

Lease(s) and Well(s)_____

Location (Sec, Twp, Rge)_____

TESTING DEVICE

Type of Device:	Master Meter	Prover Tank	Stock Tank	Other (Explain)
Make		Model No.	Size	Serial No.
Date of Last Calibration				

LEASE METER

Type of Meter	P.D.	DUMP	OTHER (Explain)	
Make		Model No.	Size	Serial No.
Date Meter Installed or Last Repaired			Date of Last Test	
Bbls Metered Since Last Test		Gravity Last Test		Meter Factor Last Test

CURRENT TEST

Date of Test_____ Gravity_____ Fluid Temp_____

TESTING DEVICE	Run No._____	Run No._____	Run No._____	Run No._____
Final Reading				
Initial Reading				
Gross Barrels Measured				
Gross Barrels Corrected to 60°F				
Master Meter Factor				
Net Barrels Measured				

LEASE METER_____

Final Reading				
Initial Reading				
Gross Barrels Measured				
Gross Barrels Corrected to 60°F				
Meter Factor (Indicate by *the factors used to obtain the average factor below				

Average Meter Factor_____ Meter Factor to be Used_____

REMARKS:_____

Tested by_____ Position_____ Company_____
Witnessed by_____ Position_____ Company_____

I hereby certify that the above data are true and correct to the best of my knowledge.

NAME_____ Position_____ Company_____

CASE 2243 RULE CHANGE PROPOSED BY OCC STAFF

RULE 309-A

Oil shall not be transported from a lease until it has been received and measured in a facility of an approved design located on the lease. Such facilities shall permit the testing of each well at reasonable intervals and may be comprised of manually gauged closed stock tanks for which proper strapping tables have been prepared, with a maximum of sixteen proration units producing into said tanks, or of automatic custody transfer (ACT) equipment. The use of such automatic custody transfer equipment shall be permitted only after compliance with the following:

1. The operator shall file with the Commission Form C-106, Notice of Intention to Utilize Automatic Custody Transfer Equipment, and shall receive approval thereof prior to transferring oil through the ACT system. The carrier shall not accept delivery of oil through the ACT system until Form C-106 has been approved.
2. Form C-106 shall be submitted in quadruplicate to the appropriate District Office of the Commission and shall be accompanied (in quadruplicate) by the following:
   (a) Plat of the lease showing thereon all wells which will be produced into the ACT system.
   (b) Schematic diagram of the ACT equipment, showing thereon all major components such as surge tanks and their capacity, extra storage tanks and their capacity, transfer pumps, monitors, re-route valves, treaters, samplers, strainers, air and gas eliminators, back pressure valves, metering device (indicating type and capacity, i.e., whether automatic measuring tank, positive volume metering chamber, weir-type measuring vessel, or positive displacement meter). Schematic diagram shall also show means employed to prove accuracy of measuring device.
   (c) Letter from transporter agreeing to utilization of ACT system as shown on schematic diagram.
3. Form C-106 will not be approved by the Commission unless the ACT system is to be installed and operated in compliance

with the following:

(a) Provision must be made for accurate determination and recording of uncorrected volume and applicable temperature, or of temperature corrected volume. The overall accuracy of the system shall equal or surpass manual methods.

(b) Provision must be made for representative sampling of the oil transferred for determination of API gravity and the BS&W content.

(c) Provision must be made if required by either the producer or the transporter of the oil to give adequate assurance that only merchantable oil is run by the ACT system.

(d) Provision must be made for set-stop counters to stop the flow of oil through the ACT system at or prior to the time the allowable has been run. All counters shall provide non-reset totalizers which shall be visible for inspection at all times.

(e) All necessary controls and equipment must be enclosed and sealed, or otherwise be so arranged as to provide assurance against, or evidence of, accidental or purposeful mismeasurement resulting from tampering.

(f) All components of the ACT system shall be properly sized to ensure operation within the range of their established ratings. All components of the system which require periodic calibration and/or inspection for proof of continued accuracy must be readily accessible. The frequency and methods of such calibration and/or inspection shall be as set forth in Rule 309-A, 4-c.

(g) The control and recording system must include adequate fail-safe features which will provide assurance against mismeasurement in the event

of power failure, or the failure of the ACT system's component parts.

(h) 1. (1) The ACT system and allied facilities shall include such fail-safe equipment as may be necessary, including high level switches in the surge tank or overflow storage tank which, in the event of power failure or malfunction of the ACT or other equipment, will shut down all artificially lifted wells connected to the ACT system and will shut-in all flowing wells at the well-head or at the header manifold, in which latter case all flow-lines shall be pressure tested to at least 1½ times the maximum well-head shut-in pressure prior to initial use of the ACT system and once each year thereafter.

~~(h)~~ 2. (2) As an alternative to the requirements of paragraph (h) (1) above, the producer shall provide and shall at all times maintain a minimum of available storage capacity above the normal high working level of the surge tank to receive and hold the amount of oil which may be produced during maximum unattended time of lease operation.

4. (a) In all ACT systems employing automatic measuring tanks, weir-type measuring vessels, positive volume metering chambers, or any other volume measuring container, the container and allied components shall be properly calibrated prior to initial use and shall be operated, maintained, and inspected as necessary to ensure against incrustation, changes in clingage factors, valve leakage or other leakage, and improper action of floats, level detectors, etc.

(b) In all ACT systems employing positive displacement meters, the meter(s) and allied components shall be properly calibrated prior to initial use and shall be operated, maintained, and

inspected as necessary to ensure against mis-measurement of oil.

(c) The measuring and recording devices of all ACT systems shall be checked for accuracy at least once each month unless exception to such determination has been obtained from the Secretary-Director of the Commission. API Standard 1101, "Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter," shall be used where applicable. Determinations may be made against Master Meters, Portable Prover Tanks, or Prover Tanks permanently installed on the lease. If permanently installed Prover Tanks are used, the distance between the opening and closing levels and the provision for determining the opening and closing readings shall be sufficient to detect variations of .05%. Reports of determinations shall be filed on the Commission form ~~107~~ entitled "Meter Test Report," or on another acceptable form and ~~which~~ shall be submitted in duplicate to the appropriate District Office of the Commission.

(d) To obtain exception to the requirement of paragraph (c) above that all measuring and recording devices be checked for accuracy once each month, either the producer or transporter may file such a request with the Secretary-Director of the Commission setting forth all facts pertinent to such exception. ~~including a~~ The application shall include a history of the average factors previously obtained, both tabulated and plotted on a graph of factors versus time, showing that the particular installation has experienced no erratic drift. The applicant shall also furnish evidence that the other interested party has agreed to such exception. The Secretary-Director may then set the frequency for determination of the system's accuracy at the interval which he deems prudent.

5. Failure to operate an automatic custody transfer system in compliance with [redacted] this rule shall subject the approval thereof to revocation by the Commission.

C-106 ACT Permit [redacted]

NOTICE OF INTENTION
TO UTILIZE AUTOMATIC CUSTODY TRANSFER EQUIPMENT

Operator _____ Field _____

Address _____ County _____

Lease(s) to be served by this ACT Unit _____

[redacted]

one lease is to be served by this system _____ Date _____

Order No. authorizing commingling between pools if more than one pool is to be served by this system _____ Date _____

Authorized transporter of oil from this system _____

Transporter's address _____

Maximum expected daily through-put for this system: _____ barrels

If system fails to transfer oil, due to malfunction or otherwise, waste by overflow will be averted by:

(Check One:

A. ☐ Automatic shut-down facilities as required by Section (4)h-1 of Rule 309-A

B. ☐ Alternative (4)h-2, providing adequate available capacity to receive production during maximum unattended time of lease operation.

If A above is checked, will flowing wells be shut-in at header manifold or at well-head? _____. Maximum well-head shut-in pressure _____

If B above is checked, how much storage capacity is available above normal high working level of the surge tank? _____ Bbls.

[redacted]

☐ Positive displacement meter ☐ Weir-type measuring vessel

☐ Positive Volume Metering Chamber ☐ Other; Describe _____

Remarks: _____

I hereby certify that the information given above is true and complete to the best of my knowledge and that the subject ACT system will be installed and operated in accordance with Rule 309-A

Approved, Oil Conservation Commission	By _____
By _____	Title _____
Title _____	Date _____
Date _____	

Approval of Form C-106 does not eliminate the necessity of an approved C-110 prior to running any oil or gas from this lease

Gulf Oil Corporation

ROSWELL PRODUCTION DISTRICT

W. A. Shellshear
F. O. Mortlock
M. I. Taylor
H. C. Vivian

February 28, 1961

P. O. Drawer 669
Roswell, New Mexico

Oil Conservation Commission
State of New Mexico
Santa Fe, New Mexico

Attention: Mr. A. L. Porter, Jr.

Gentlemen:

Reference is made to Gulf's application of February 6, 1961, for hearing to revise Statewide Rule 309 to establish a procedure for administrative approval of Automatic Custody Transfer Systems. In compliance with Mr. Dan Nutter's telephone request, attached is Gulf's proposed revision to Rule 309.

It is our understanding that the Commission may desire to call this matter for hearing on its own motion, and if so, we would favor this procedure.

Thank you for your consideration in this matter, and if we can furnish additional information, please advise.

Very truly yours,

W. A. Shellshear

W. A. Shellshear

Attachment
JHH:dd

GULF

PROPOSED RULES TO ESTABLISH A PROCEDURE FOR
ADMINISTRATIVE APPROVAL OF AUTOMATIC CUSTODY TRANSFER SYSTEMS

RULE 309 - CENTRAL TANK BATTERIES

(c) The Secretary-Director of the Commission shall have authority to grant exceptions to Rule 309 (a), to permit the use of automatic custody transfer equipment without notice or hearing, provided application for administrative approval has been filed in due form and such application contains the following:

(1) Lease plat.

(2) Schematic sketch of the proposed automatic custody transfer system indicating the function of each of the various components.

(3) Application states that the proposed installation is basically similar in design and operation to one previously approved by the Commission, giving case, order number and date of approval for the installation. If one not previously approved, complete description of the installation should be included.

(4) Application evidences that the pipe line purchaser has approved the installation.

(5) Installation would incorporate the use of safety shut down devices to shut-in the lease in the event of full storage; or in the alternative, provide sufficient storage to handle the production during the unattended hours.

(6) Automatic custody transfer equipment shall incorporate a safety shut down device to prevent the delivery of unmetered oil.

(7) Installation shall have a set-stop counter to stop the delivery of oil when all legal allowable for the month has been run.

The Secretary-Director may, upon his own motion, after receipt of the application, set the matter for hearing if, in his opinion, conditions should be encountered which will tend to involve waste or impair correlative rights.

GOVERNOR
EDWIN L. MECHEM
CHAIRMAN

State of New Mexico
Oil Conservation Commission

LAND COMMISSIONER
E. S. JOHNNY WALKER
MEMBER

STATE GEOLOGIST
A. L. PORTER, JR.
SECRETARY - DIRECTOR

P. O. BOX 871
SANTA FE

April 28, 1961

Mr. M. I. Taylor
Gulf Oil Corporation
P. O. Box 669
Roswell, New Mexico

Re: Case No. 2243
Order No. R-1959
Applicant:
Gulf Oil Corporation

Dear Sir:

Enclosed herewith are two copies of the above-referenced Commission order recently entered in the subject case.

Very truly yours,

A. L. PORTER, Jr.
Secretary-Director

ir/

Carbon copy of order also sent to:

Hobbs OCC x
Artesia OCC x
Aztec OCC x

OTHER _____

This order will also be sent to the following persons when the order is printed.

Guy Buell
H. D. Bushnell
R. M. Anderson
J. E. Robinson
R. L. McGannon
Howard Bratton
Bill Kastler

CASE 2243 RULE CHANGE PROPOSED BY OIL CONSERVATION COMMISSION STAFF

RULE 309-A. CENTRAL TANK BATTERIES

Oil shall not be transported from a lease until it has been received and measured in a facility of an approved design located on the lease. Such facilities shall permit the testing of each well at reasonable intervals and may be comprised of manually gauged closed stock tanks for which proper strapping tables have been prepared, with a maximum of sixteen proration units producing into said tanks, or of automatic custody transfer (ACT) equipment. The use of such automatic custody transfer equipment shall be permitted only after compliance with the following:

1. The operator shall file with the Commission Form C-106, Notice of Intention to Utilize Automatic Custody Transfer Equipment, and shall receive approval thereof prior to transferring oil through the ACT system. The carrier shall not accept delivery of oil through the ACT system until Form C-106 has been approved.

2. Form C-106 shall be submitted in quadruplicate to the appropriate District Office of the Commission and shall be accompanied (in quadruplicate) by the following:

(a) Plat of the lease showing thereon all wells which will be produced into the ACT system.

(b) Schematic diagram of the ACT equipment, showing thereon all major components such as surge tanks and their capacity, extra storage tanks and their capacity, transfer pumps, monitors, reroute valves, treaters, samplers, strainers, air and gas eliminators, back pressure valves, metering device (indicating type and capacity, i.e., whether automatic measuring tank, positive volume metering chamber, weir-type measuring vessel, or positive displacement meter). Schematic diagram shall also show means employed to prove accuracy of measuring device.

(c) Letter from transporter agreeing to utilization of ACT system as shown on schematic diagram.

3. Form C-106 will not be approved by the Commission unless the ACT system is to be installed and operated in compliance with the following:

(a) Provision must be made for accurate determination and recording of uncorrected volume and applicable temperature, or of temperature corrected volume. The overall accuracy of the system shall equal or surpass manual methods.

(b) Provision must be made for representative sampling of the oil transferred for determination of API gravity and BS&W content.

(c) Provision must be made if required by either the producer or the transporter of the oil to give adequate assurance that only merchantable oil is run by the ACT system.

(d) Provision must be made for set-stop counters to stop the flow of oil through the ACT system at or prior to the time the allowable has been run. All counters shall provide non-reset totalizers which shall be visible for inspection at all times.

(e) All necessary controls and equipment must be enclosed and sealed, or otherwise be so arranged as to provide assurance against, or evidence of, accidental or purposeful mismeasurement resulting from tampering.

(f) All components of the ACT system shall be properly sized to ensure operation within the range of their established ratings. All components of the system which require periodic calibration and/or inspection for proof of continued accuracy must be readily accessible. The frequency and methods of such calibration and/or inspection shall be as set forth in Rule 309-A, 4-c.

(g) The control and recording system must include adequate fail-safe features which will provide assurance against mismeasurement in the event of power failure, or the failure of the ACT system's component parts.

(h) 1. The ACT system and allied facilities shall include such fail-safe equipment as may be necessary, including high level switches in the surge tank or overflow storage tank which, in the event of power failure or malfunction of the ACT or other equipment, will shut down all artifically lifted wells connected to the ACT system and will shut-in all flowing wells at the well-head or at the header manifold, in which latter case all flowlines shall be pressure tested to at least 1½ times the maximum well-head shut-in pressure prior to initial use of the ACT system and once each year thereafter.

2. As an alternative to the requirements of paragraph (h) 1 above, the producer shall provide and shall at all times maintain a minimum of available storage capacity above the normal high working level of the surge tank to receive and hold the amount of oil which may be produced during maximum unattended time of lease operation.

4. (a) In all ACT systems employing automatic measuring tanks, weir-type measuring vessels, positive volume metering chambers, or any other volume measuring container, the container and allied components shall be properly calibrated prior to initial use and shall be operated, maintained, and inspected as necessary to ensure against incrustation, changes in slippage factors, valve leakage or other leakage, and improper action of floats, level detectors, etc.

(b) In all ACT systems employing positive displacement meters, the meter(s) and allied components shall be properly calibrated prior to initial use and shall be operated, maintained, and inspected as necessary to ensure against mismeasurement of oil.

(c) The measuring and recording devices of all ACT systems shall be checked for accuracy at least once each month unless exception to such determination has been obtained from the Secretary-Director of the Commission. API Standard 1101, "Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter," shall be used where applicable. Determinations may be made against Master Meters, Portable Prover Tanks, or Prover Tanks permanently installed on the lease. If permanently installed Prover Tanks are used, the distance between the opening and closing levels and the provision for determining the opening and closing readings shall be sufficient to detect variations of .05%. Reports of determinations shall be filed on the Commission Form entitled "Meter Test Report," or on another acceptable form and shall be submitted in duplicate to the appropriate District Office of the Commission.

(d) To obtain exception to the requirement of paragraph (c) above that all measuring and recording devices be checked for accuracy once each month, either the producer or transporter may file such a request with the Secretary-Director of the Commission setting forth all facts pertinent to such exception. The application shall include a history of the average factors previously obtained, both tabulated and plotted on a graph of factors versus time, showing that the particular installation has experienced no erratic drift. The applicant shall also furnish evidence that the other interested party has agreed to such exception. The Secretary-Director may then set the frequency for determination of the system's accuracy at the interval which he deems prudent.

5. Failure to operate an automatic custody transfer system in compliance with this rule shall subject the approval thereof to revocation by the Commission.

FORM C-106 Effective No. _____

NOTICE OF INTENTION

TO UTILIZE AUTOMATIC CUSTODY TRANSFER EQUIPMENT

Operator _____ Field _____

Address _____ County _____

Lease(s) to be served by this ACT Unit _____

Pool(s) to be served by this ACT Unit _____

Location of ACT System: Unit _____ Sec _____ Twp _____ Rge _____

Order No. authorizing commingling between leases if more than one lease is to be served by this system _____ Date _____

Order No. authorizing commingling between pools if more than one pool is to be served by this system _____ Date _____

Authorized transporter of oil from this system _____

Transporter's address _____

Maximum expected daily through-put for this system: _____ bbls/day

If system fails to transfer oil due to malfunction or otherwise, waste by overflow will be averted by: (Check One)

A. ☐ Automatic shut-down facilities as required by Section (4) h-1 of Rule 309-A.

B. ☐ Alternative (4) h-2, providing adequate available capacity to receive production during maximum unattended time of lease operation.

If A above is checked, will flowing wells be shut-in at the header manifold or at the well-head? _____ Maximum well-head shut-in pressure _____

If B above is checked, how much storage capacity is available above the normal high working level of the surge tank? _____ Bbls.

What is the normal maximum attended time of lease operation? _____ Hours

What device will be used for measuring oil in this ACT Unit? (Check One)

☐ Positive displacement meter ☐ Weir-type measuring vessel

☐ Positive volume metering chamber ☐ Other; Describe _____

Remarks: _____

I hereby certify that the information given above is true and complete to the best of my knowledge and that the subject ACT system will be installed and operated in accordance with Rule 309-A.

Approved, Oil Conservation Commission

By _____

Title _____ Date _____

By _____

Title _____

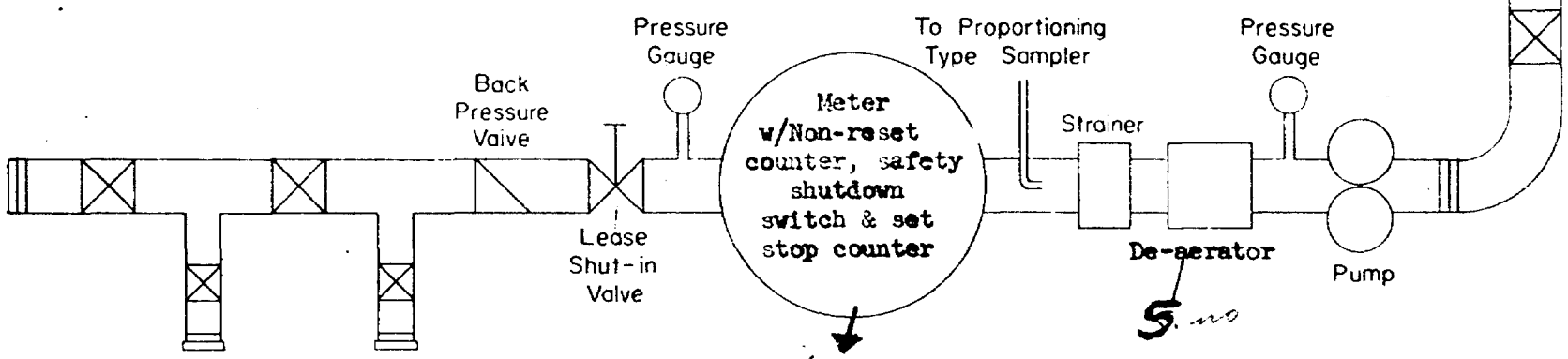
Date _____

Approval of Form C-106 does not eliminate the necessity of an approved C-110 prior to running any oil or gas from this system.

CENTRAL BATTERY LACT UNIT

Storage tank

w/high and low level switches to start and stop pump. High level emergency switch to shut in lease in event of full storage or in alternative overflow to additional storage tank.



2 meter runs.
Sp. S.D. Kw.
$7000.00
more
2 meters

Case No. 2243
Exhibit No. 1

AUTOMATIC CUSTODY TRANSFER SYSTEM

Gulf Oil Corporation — April 13, 1961

PROPOSED RULES TO ESTABLISH A PROCEDURE FOR
ADMINISTRATIVE APPROVAL OF AUTOMATIC CUSTODY TRANSFER SYSTEMS

RULE 309 - CENTRAL TANK BATTERIES

(c) The Secretary-Director of the Commission shall have authority to grant exceptions to Rule 309 (a), to permit the use of automatic custody transfer equipment without notice or hearing, provided application for administrative approval has been filed in due form and such application contains the following:

(1) Lease plat.

(2) Schematic sketch of the proposed automatic custody transfer system indicating the function of each of the various components.

(3) Application states that the proposed installation is basically similar in design and operation to one previously approved by the Commission, giving case, order number and date of approval for the installation. If one not previously approved, complete description of the installation should be included.

(4) Application evidences that the pipe line purchaser has approved the installation.

(5) Installation would incorporate the use of safety shut down devices to shut-in the lease in the event of full storage; or in the alternative, provide sufficient storage to handle the production during the unattended hours.

(6) Automatic custody transfer equipment shall incorporate a safety shut down device to prevent the delivery of unmetered oil.

(7) Installation shall have a set-stop counter to stop the delivery of oil when all legal allowable for the month has been run.

The Secretary-Director may, upon his own motion, after receipt of the application, set the matter for hearing if, in his opinion, conditions should be encountered which will tend to involve waste or impair correlative rights.

Case No. 2243

Exhibit No. 2

THE ATLANTIC REFINING COMPANY
P. O. Box 520 Casper, Wyoming

Positive Displacement Meter Proving Test Report

Date of Calibration 2-5-60 Field Horseshoe-Gallup

Lease Navajo Location Horseshoe Canyon

Meter Make H.O. Smith Model S-24 Serial Number 96884

Meter #2	Test No. 1		Test No. 2		Test No. 3		Test No. 4	
	Master Meter Column A	Line Meter Column B	Master Meter Column A	Line Meter Column B	Master Meter Column A	Line Meter Column B	Master Meter Column A	Line Meter Column B
1. Closing Meter Reading	4549.764	301481.681	4655.411	301589.632				
2. Opening Reading	4510.536	301441.576	4616.274	301549.639				
3. Registration (1-2)	39.228	40.105	39.137	39.993				
4. Temperature Readings	48 48 48 48 48		49 49 49 49 49					
5. Average Temperature	48°		49°					
6. Average Gravity API	42°		42°					
7. Temperature Coefficient	1.0060		1.0055					
8. Master Meter Factor	.99892		.99892					
9. Net Oil @ 60° F (7Ax3Ax8A)	39.421		39.310					
10. Line Meter Factor (9A ÷ 3B)		.98294		.98292				

Average Line Meter Factor .9829

Test Made By: L. Calloway

Test Witnessed By: _____

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.

CONTENTS

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.

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

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 [illegible] 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

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).

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

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.

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.

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,

* 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.

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

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.

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

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

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.

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.
ΔV = volume change attributable to pressure
$= V_w - (V_a + V_w)\,(P_p - P_a)\,(F)$.

Where:

V_w = volume withdrawn from prover as pressure is decreased from P_t to P_a.
P_a = starting pressure (atmospheric) in prover tank, in pounds per square inch absolute.
P_t = 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 pressscale 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.

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

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

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-

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.

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.

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:

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

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_{ts} = 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:

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.

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.

Or, solving for V_h,

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

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_t) 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:

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

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.
$W_{tV}\,60\,F$ = 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_{tV}) 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

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_{PV}), 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_{PV}), to be used in the calculation of the volume measured in the prover, is obtained as follows:

W_{PV} = 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.

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.

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:

41 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:

$$\text{Volume at 90 F and 149 psig } (V_e) = \frac{\text{Volume at 90 F and 300 psig } (V_h)}{1-(P_h-P_e)\,F}$$ (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
$= 16.6 \div [1-(300-149)\ 0.0000486]$
$= 16.7227$ 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,

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

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 bbl

b. Correct volume from 100 F and 500 psig (V_b) to 100 F and 172 psig (V_c):

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

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

(10,039) (0.9308) = 9,344 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_b) to 20 F and 41 psig (V_c) is as follows:

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

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.

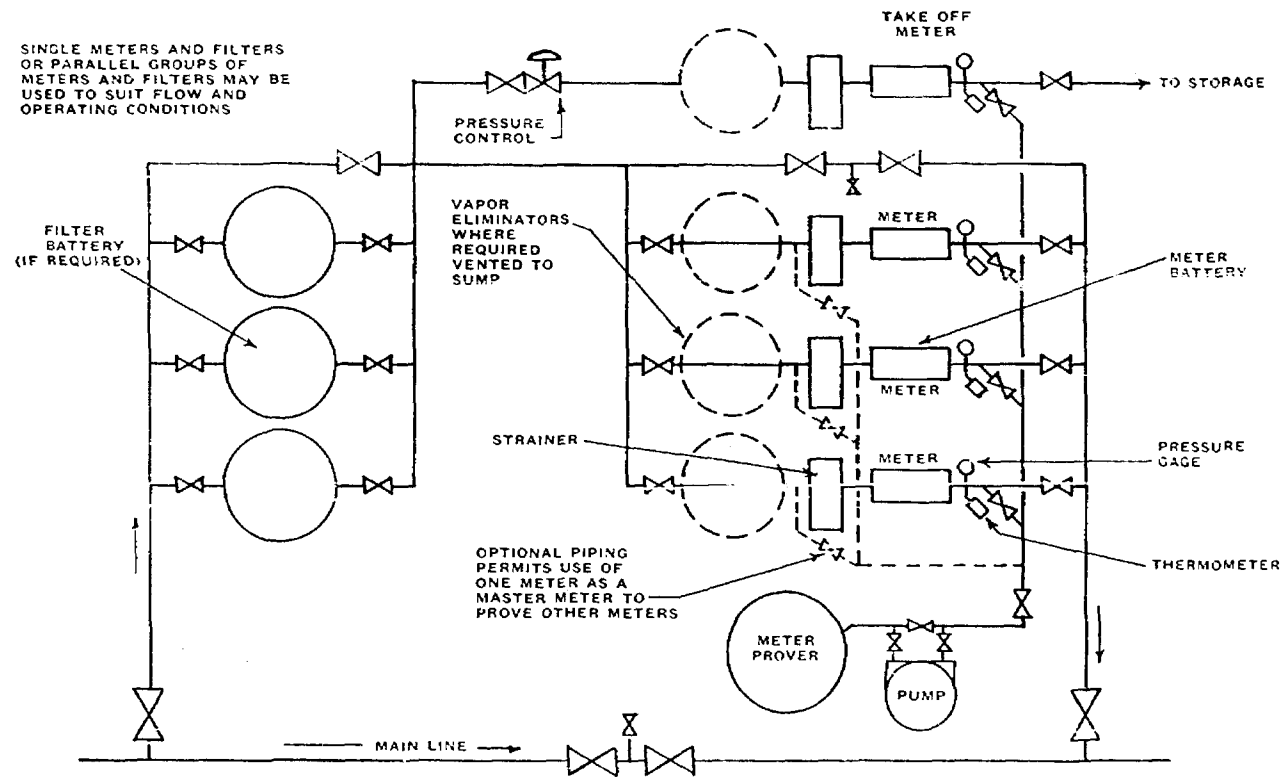
5006 Meters should be maintained in accordance with the manufacturers' instructions. A definite maintenance schedule should be established to provide adequate servicing of the meter and auxiliary equipment. Meters should always be proved after servicing. Meters stored for a long period should be kept 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.

APPENDIX A



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.

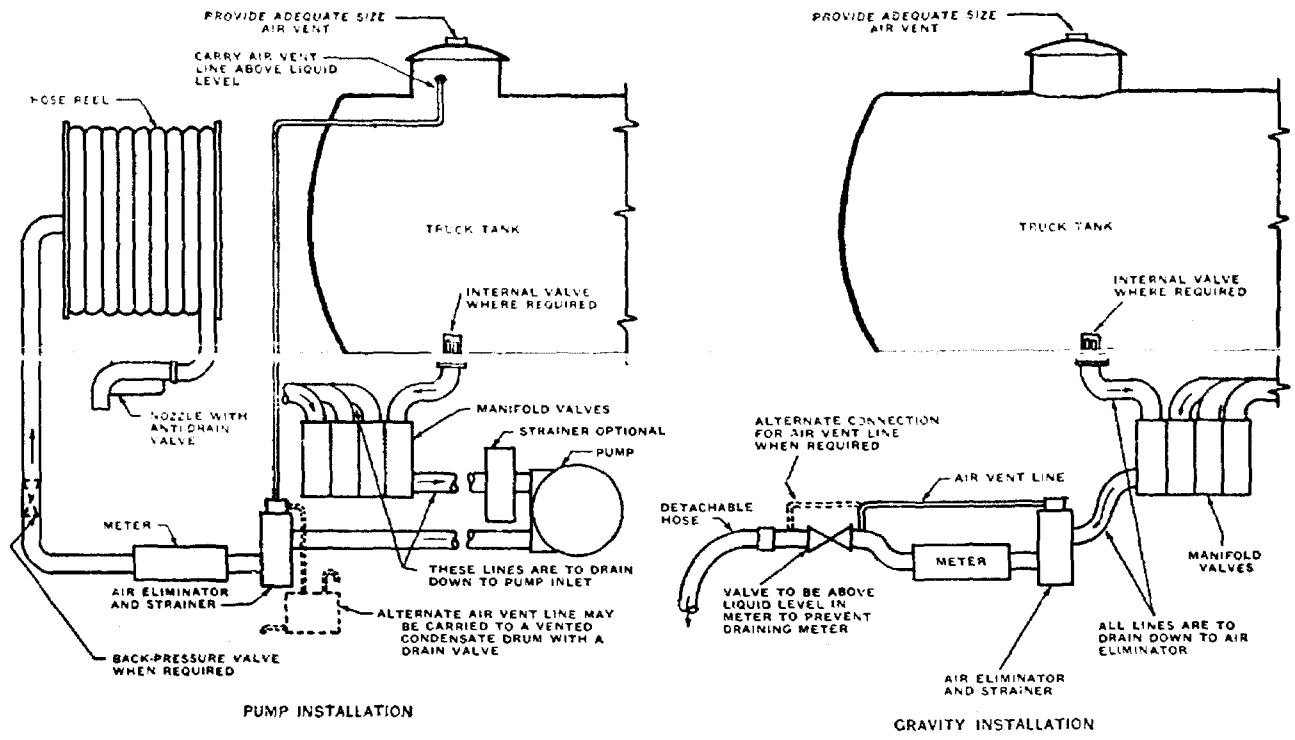


FIG. 2—Installation Diagram—Tank Truck Metering Equipment (Excluding LPG).

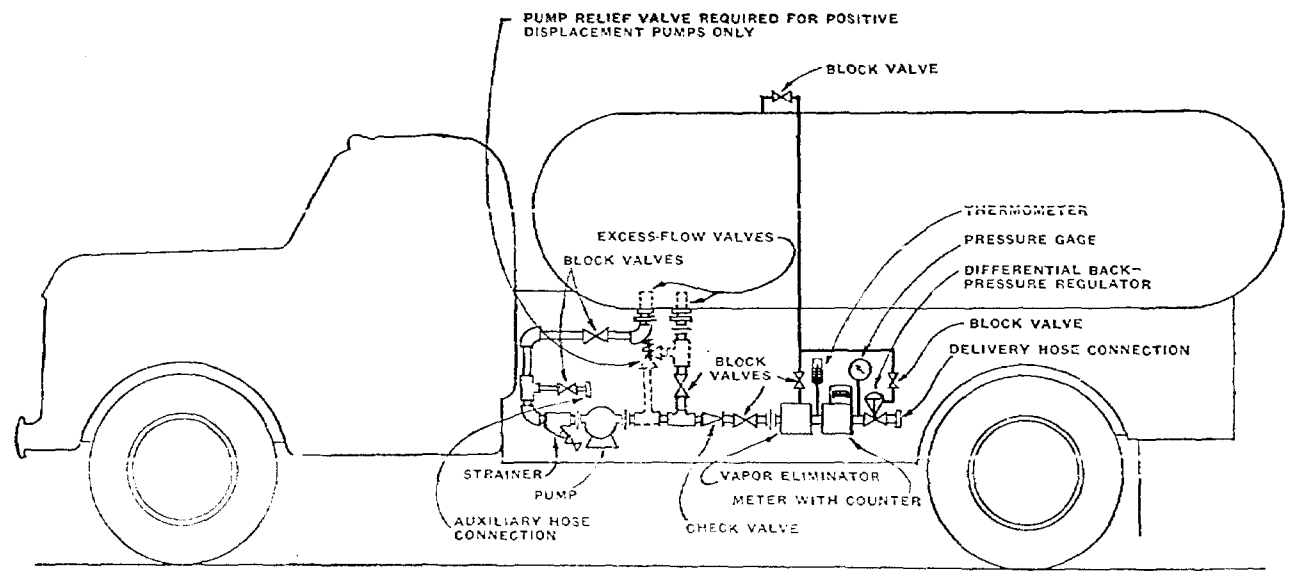
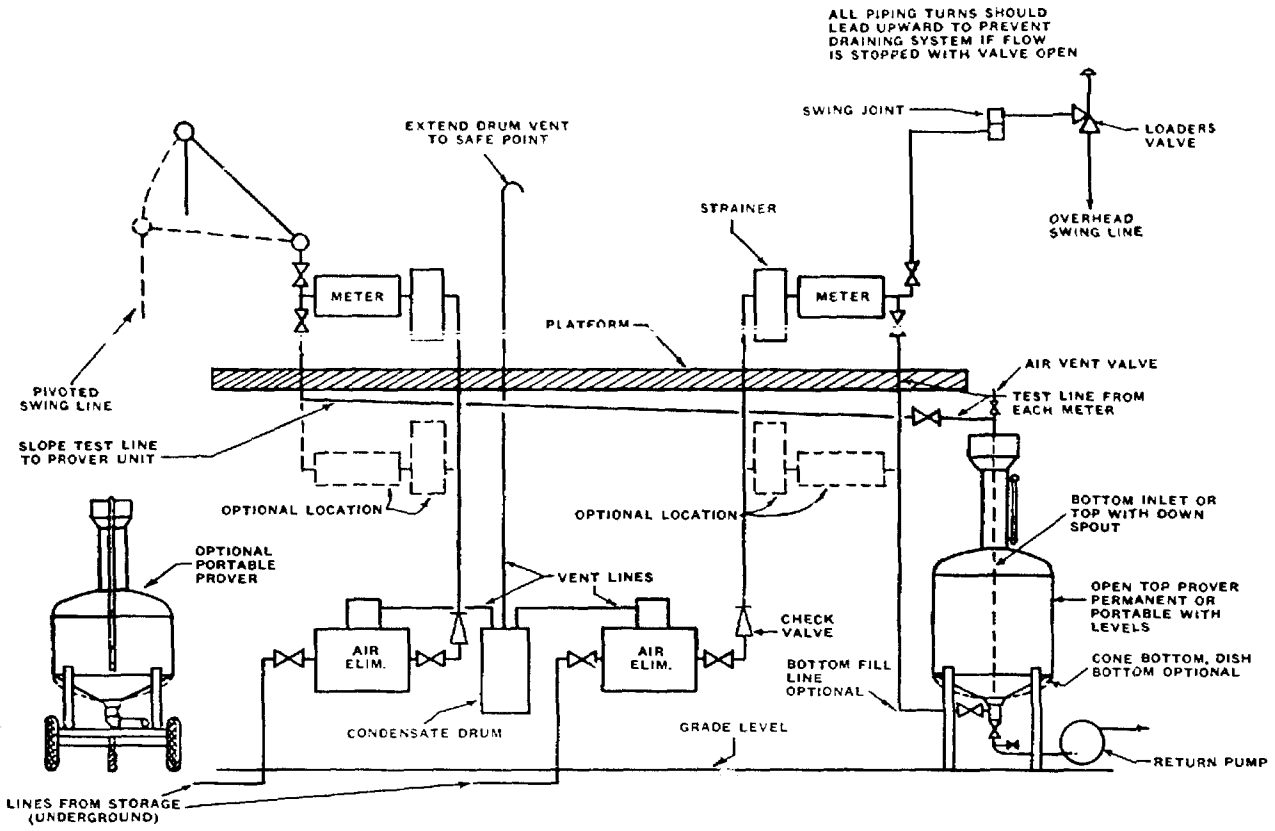


FIG. 3—Typical LPG Truck Meter Installation.



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.

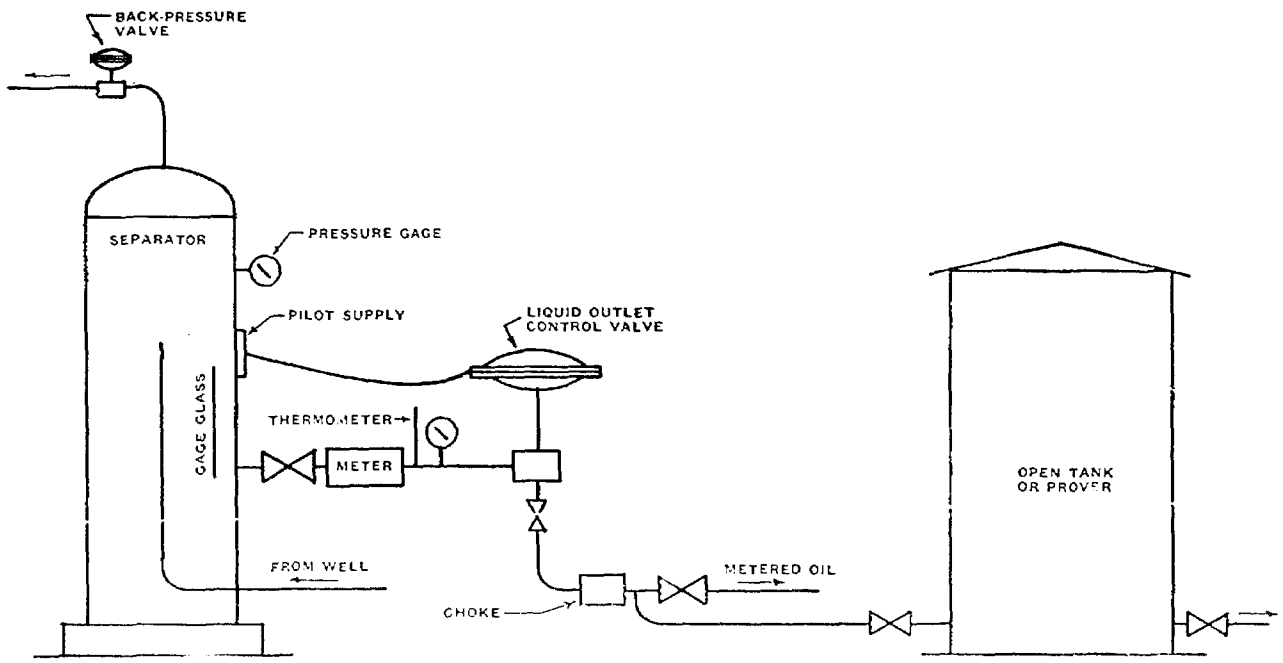


FIG. 5—Schematic Operating Diagram of Oil Well Production Meter Installation Using Stock Tank or Open Prove

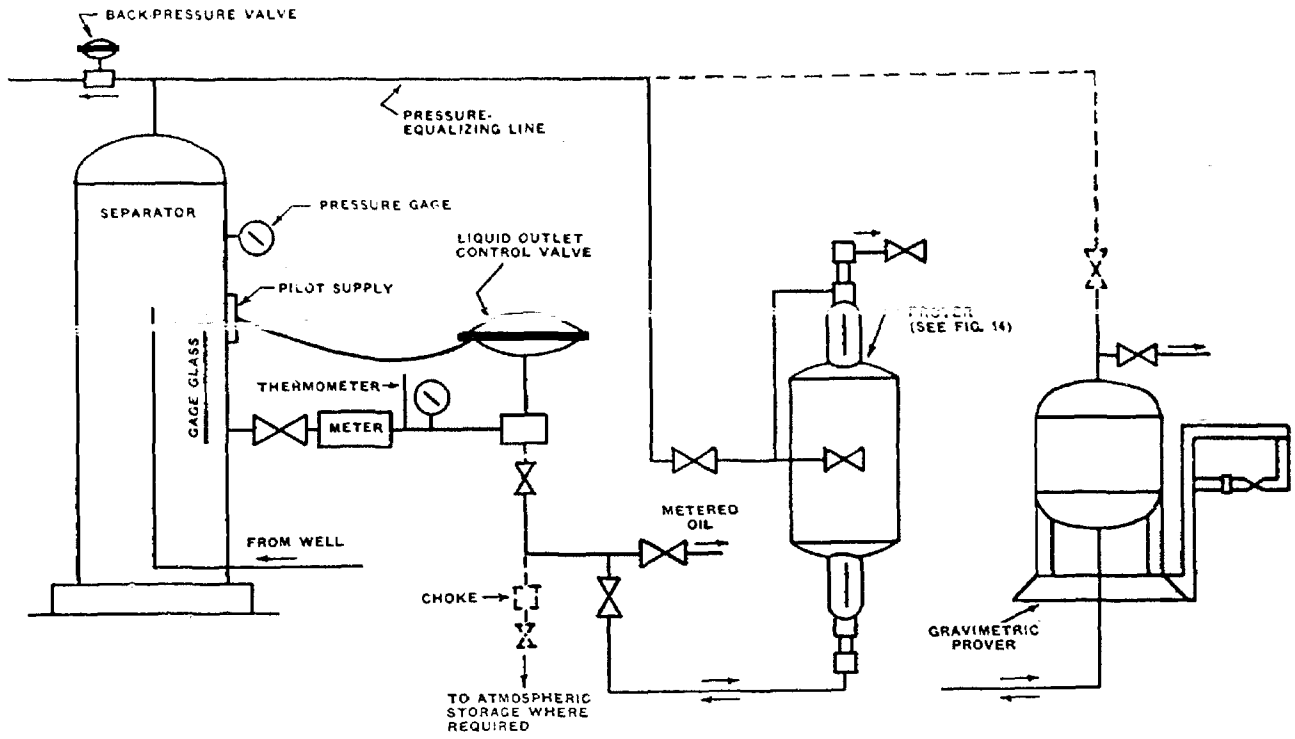


FIG. 6—Schematic Operating Diagram of Oil Well Production Meter Installation Using Gas Displacement or Gravimetric Prover.

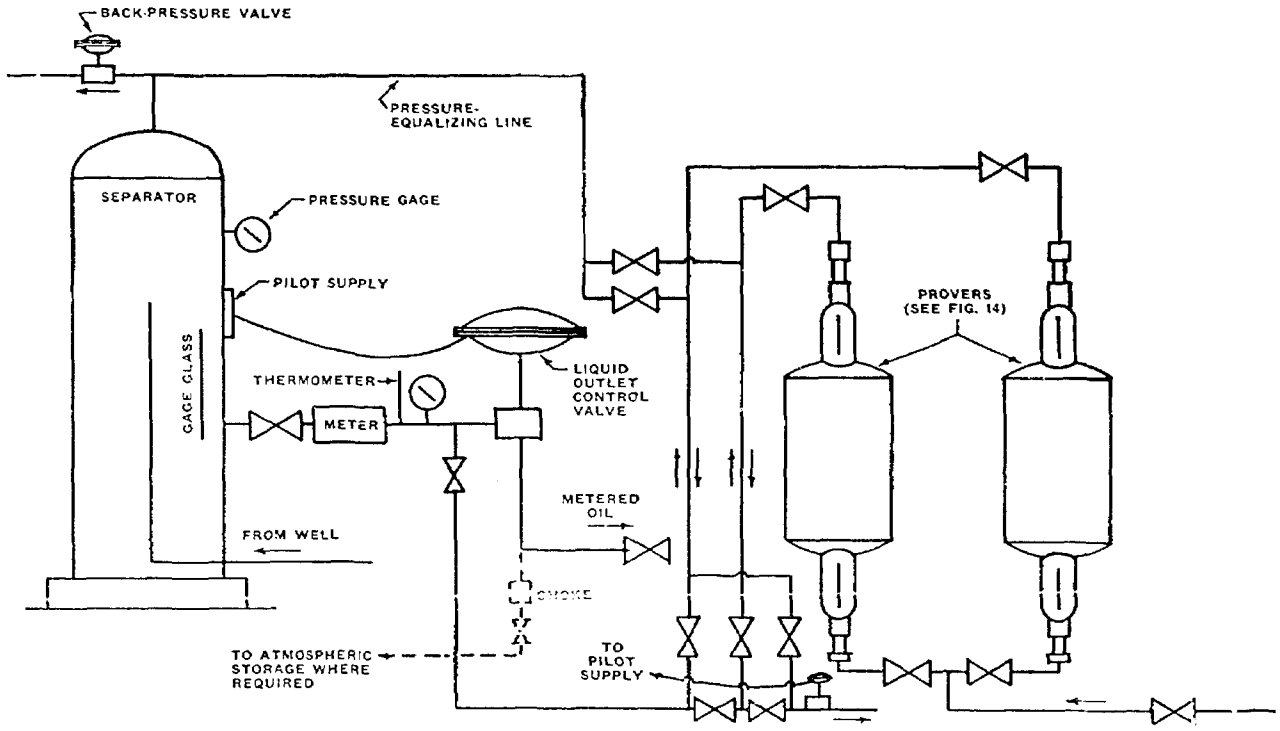


FIG. 7—Schematic Operating Diagram of Oil Well Production Meter Installation Using Dual-Tank Water Displacement Prover.

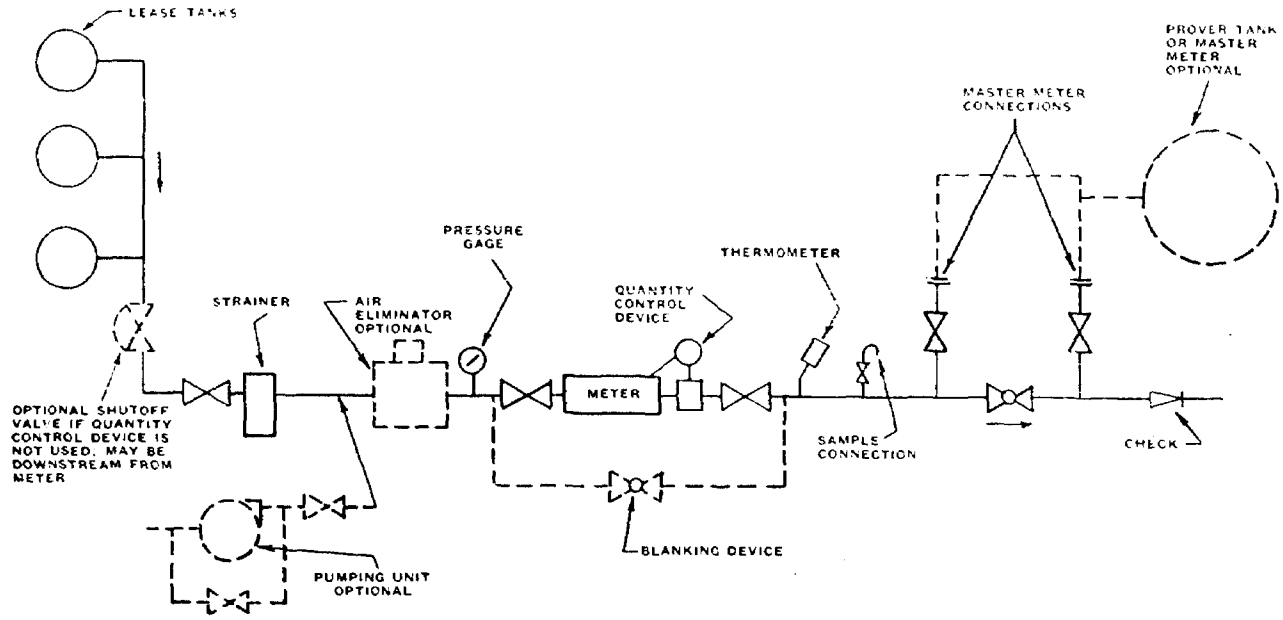


FIG. 8—Schematic Operating Diagram of Metered Pipeline Gathering System—Flow by Pump or Gravity.

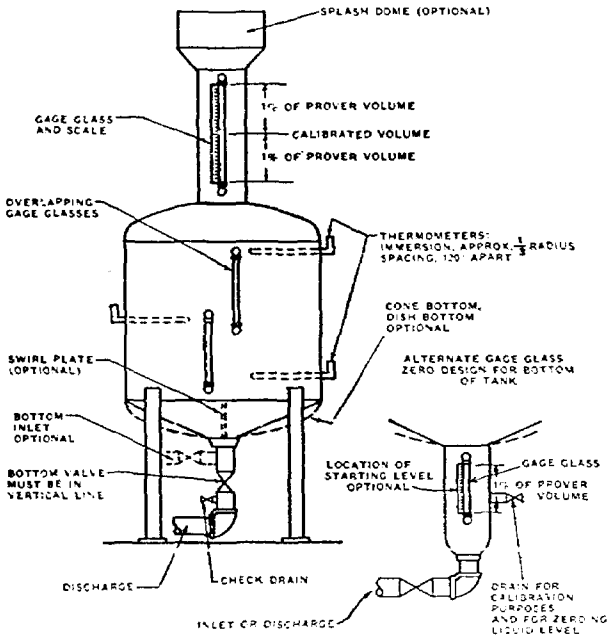


FIG. 9—Open Stationary Prover Tank—Drain to Zero or *Bottom Gage Glass Type.*

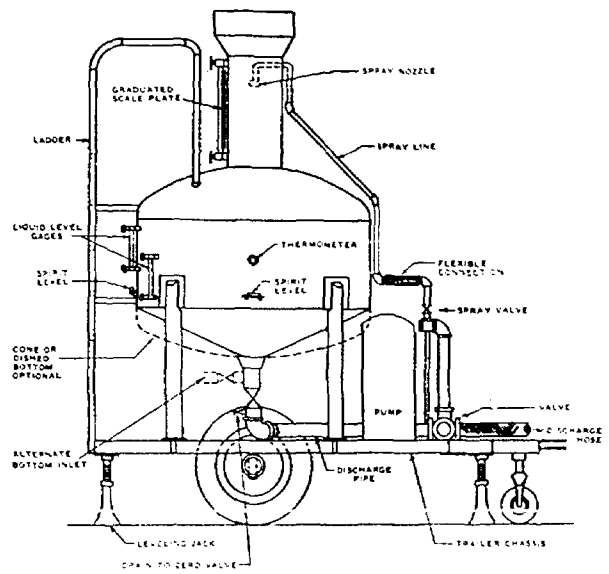
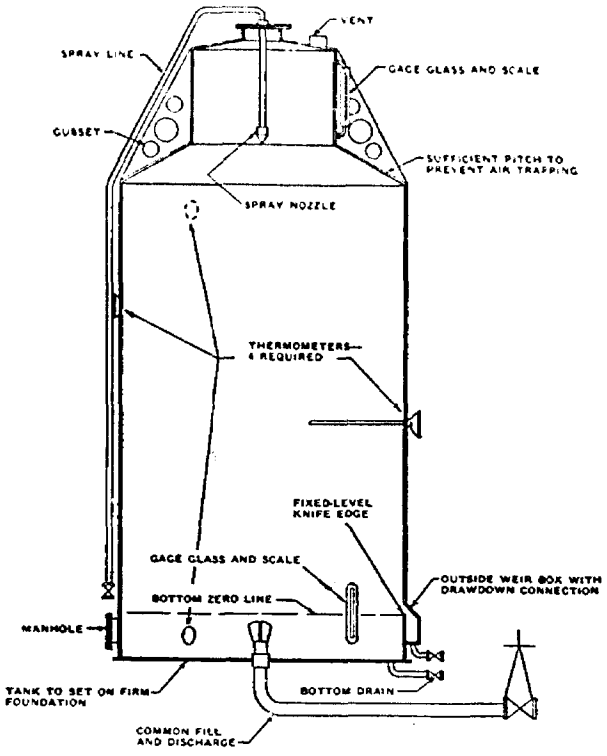


FIG. 10—Open Portable Prover Tank.



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

FIG. 11—Open Single-Weir Prover Tank.

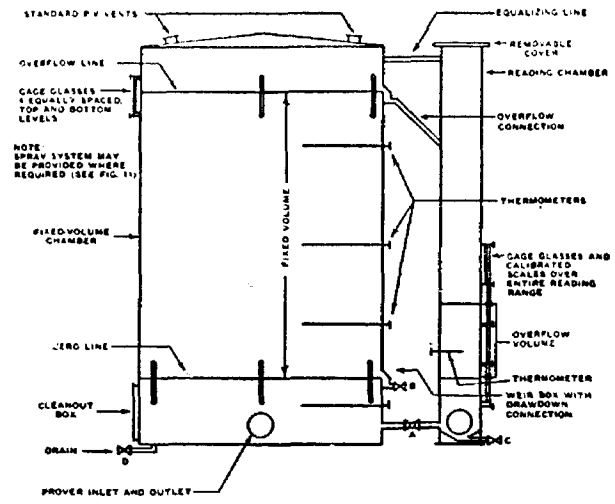


FIG. 12—Double-Weir Prover Tank. Measured Volume = Fixed Volume + Overflow Volume.

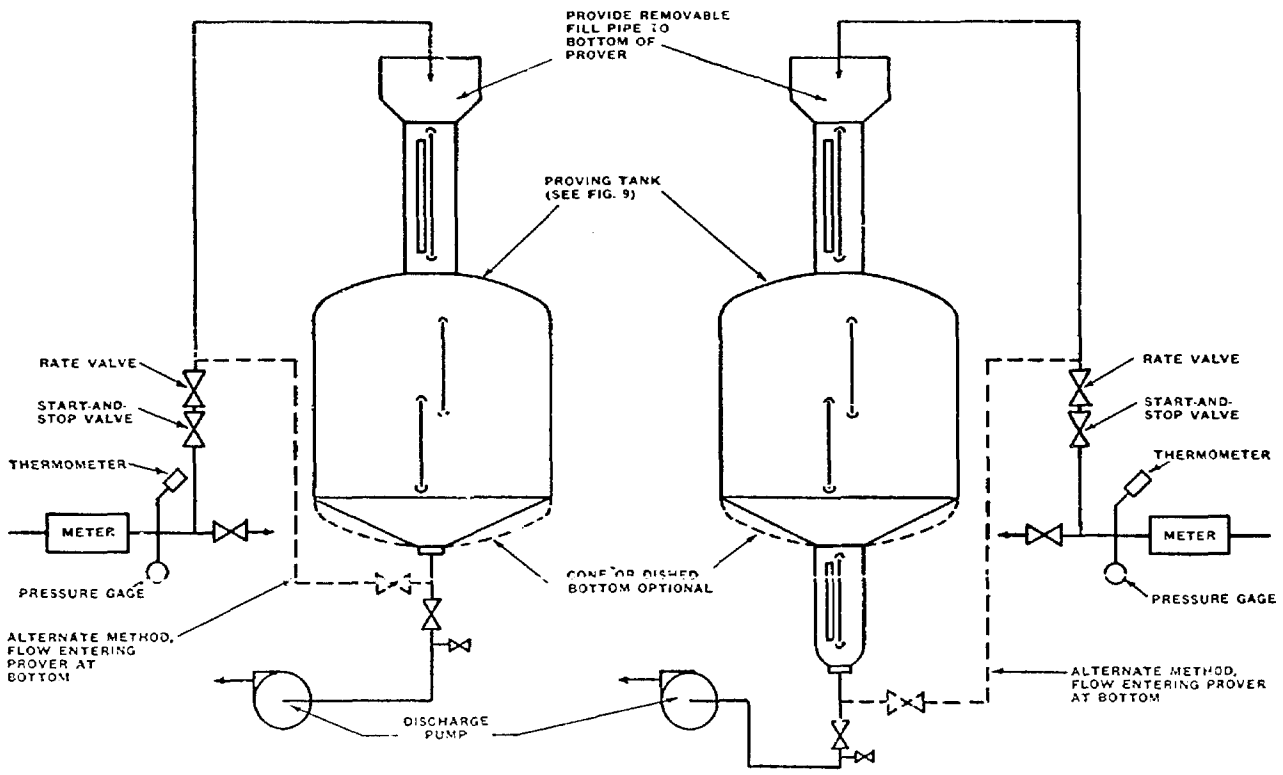


FIG. 13—Schematic Operating Diagram—Four Methods for Using Open Volumetric Provers.

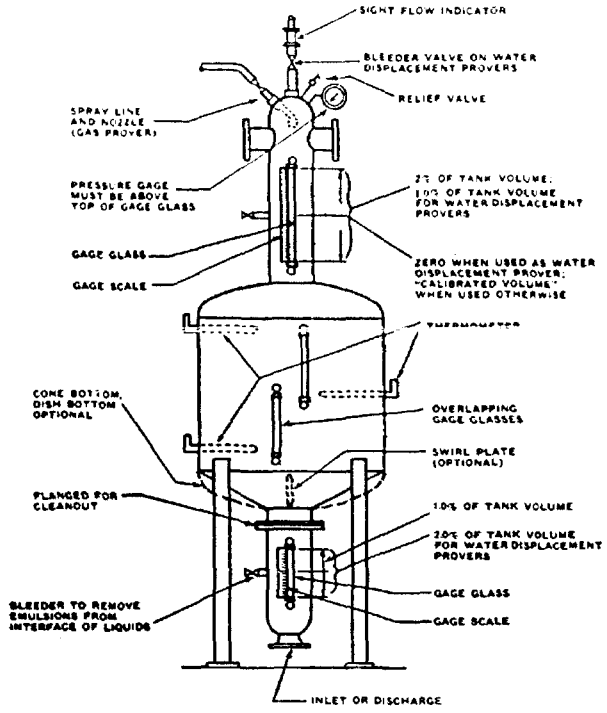


FIG. 14—Closed Stationary Prover Tank.

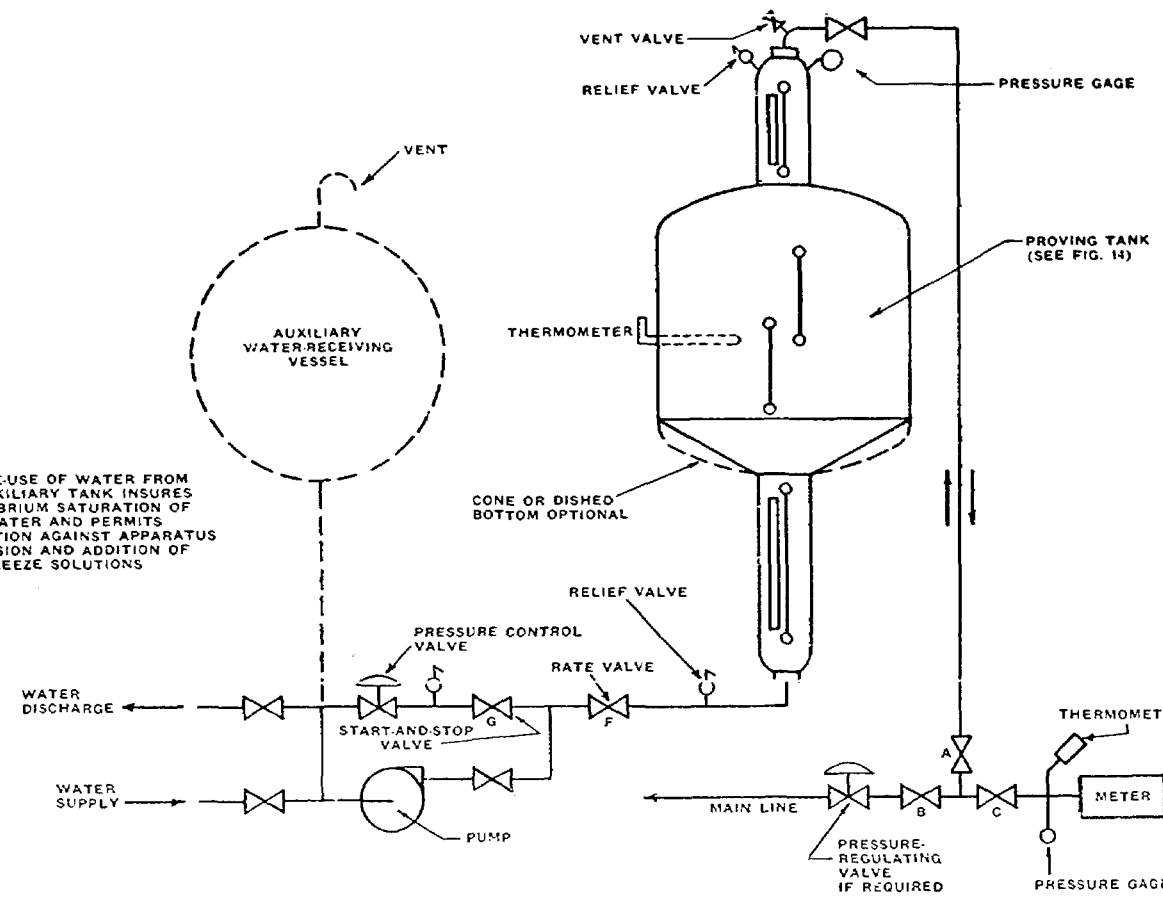


FIG. 15—Schematic Operating Diagram of Single-Tank Water Displacement Prover.

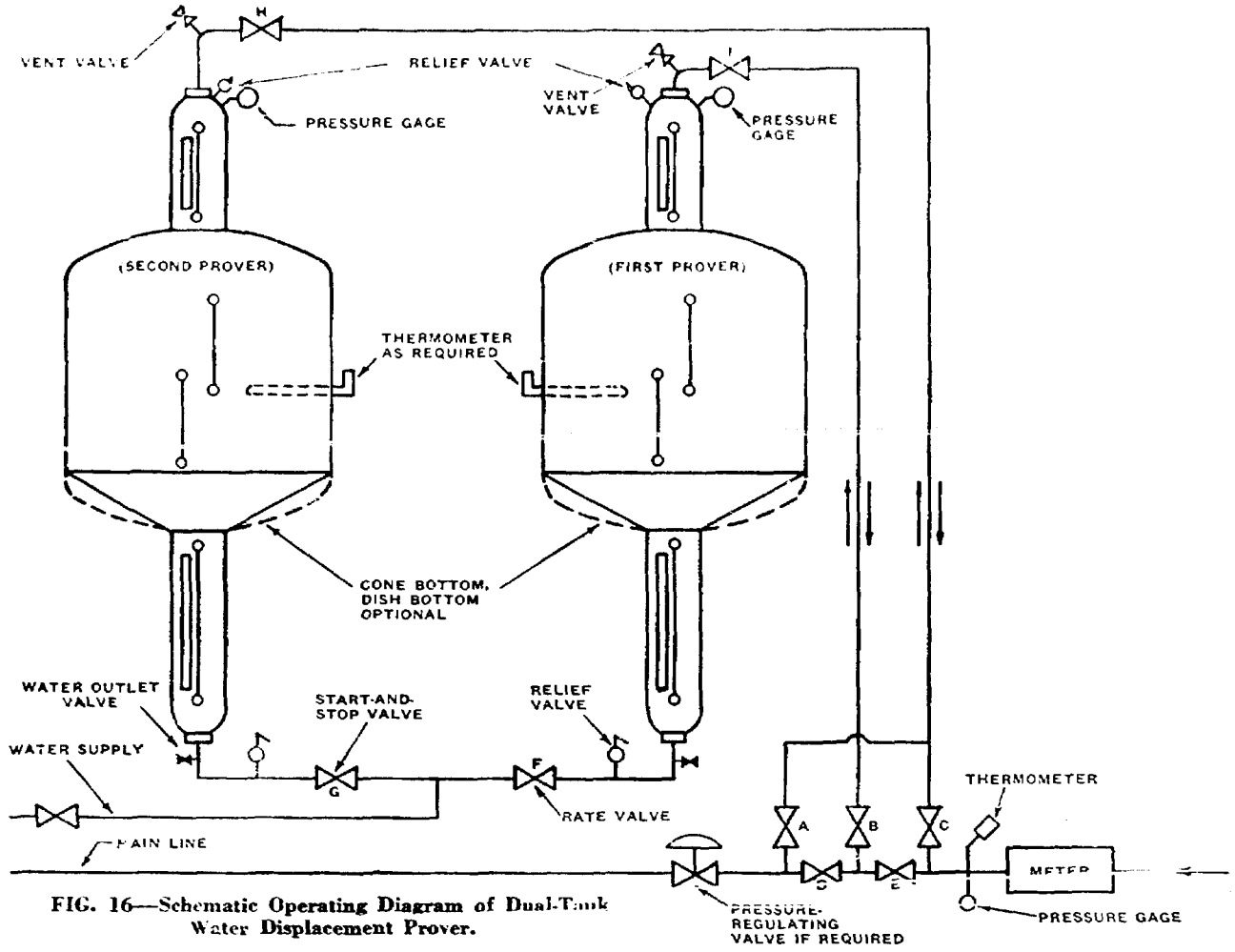


FIG. 16—Schematic Operating Diagram of Dual-Tank Water Displacement Prover.

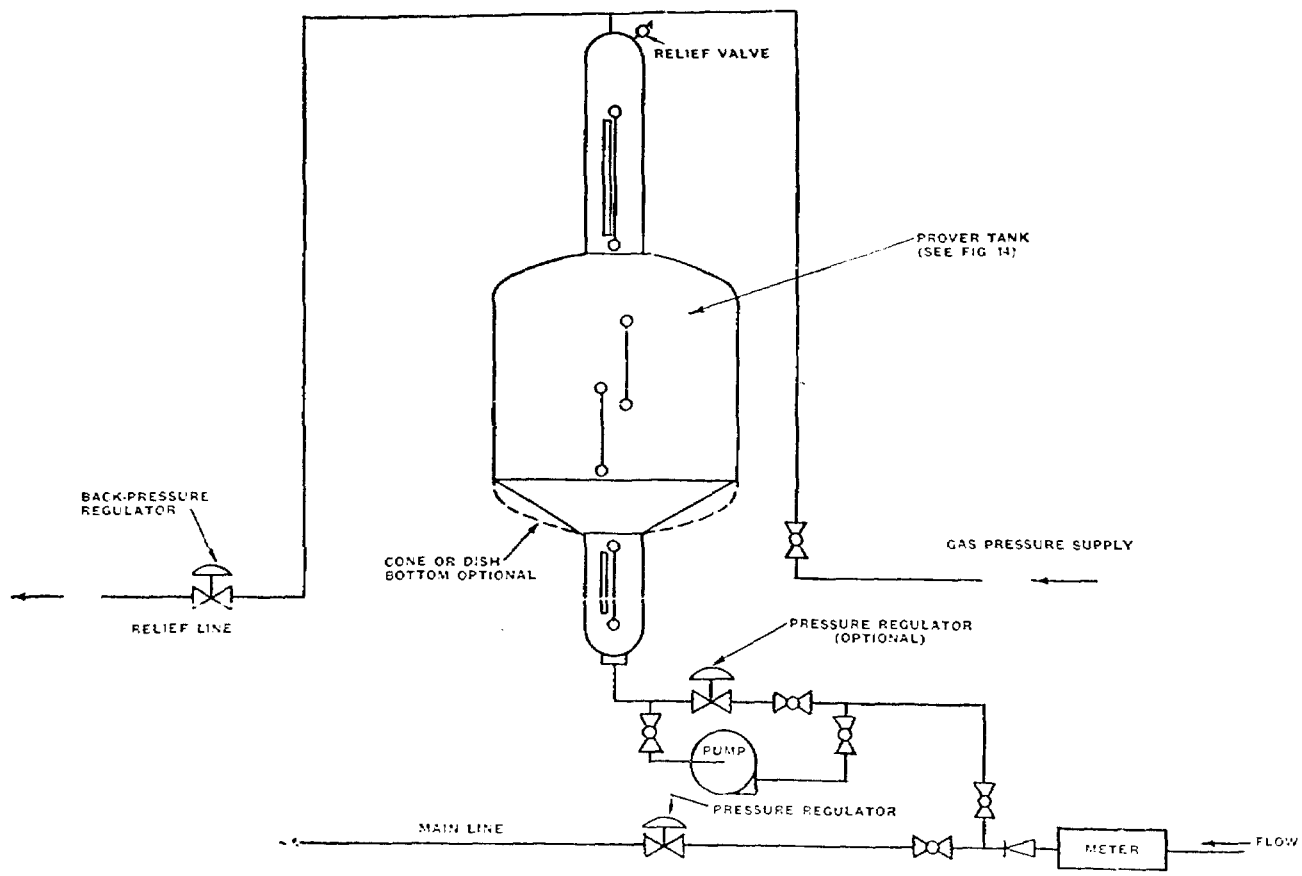


FIG. 17—Schematic Operating Diagram of Prover for Gas Displacement.

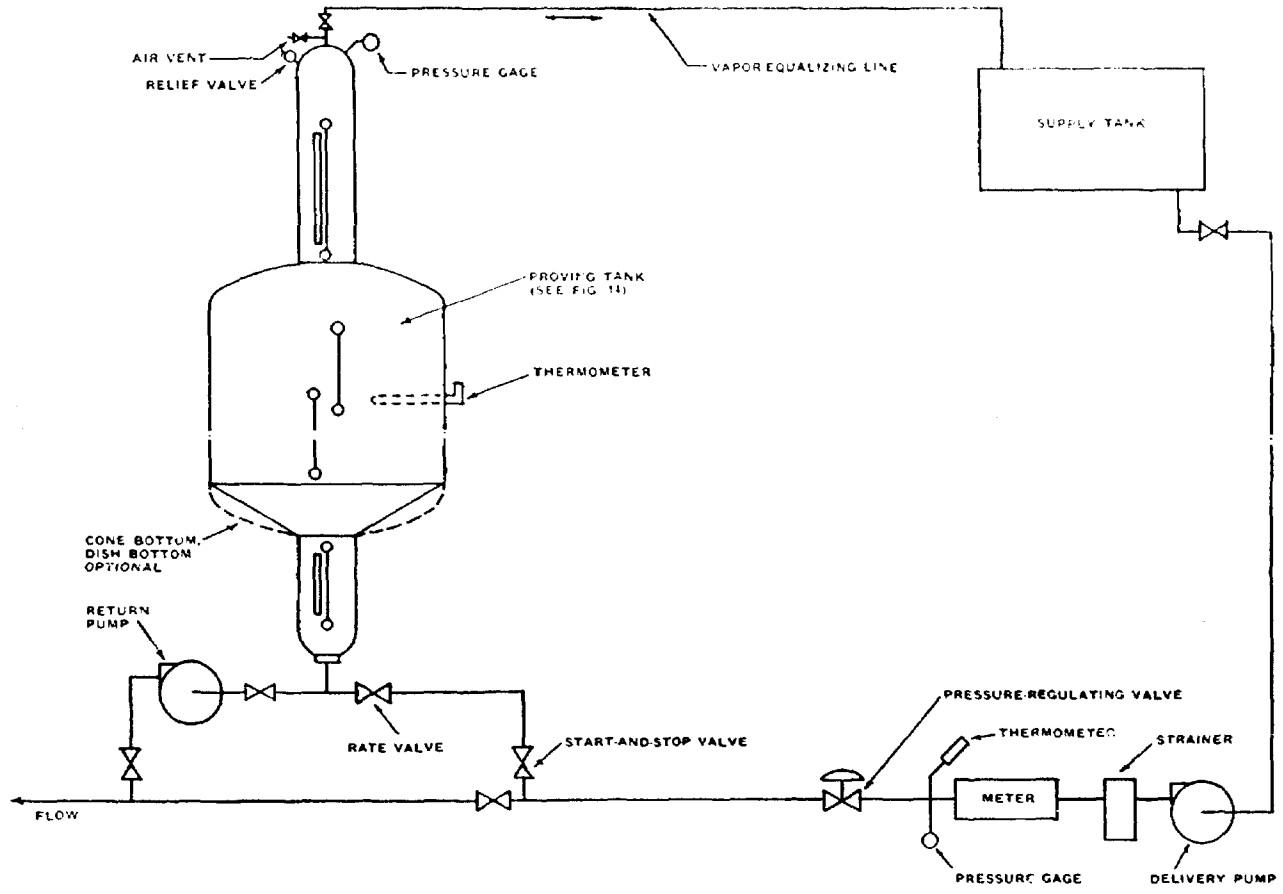


FIG. 18—Schematic Operating Diagram of Volumetric Prover for Vapor Displacement.

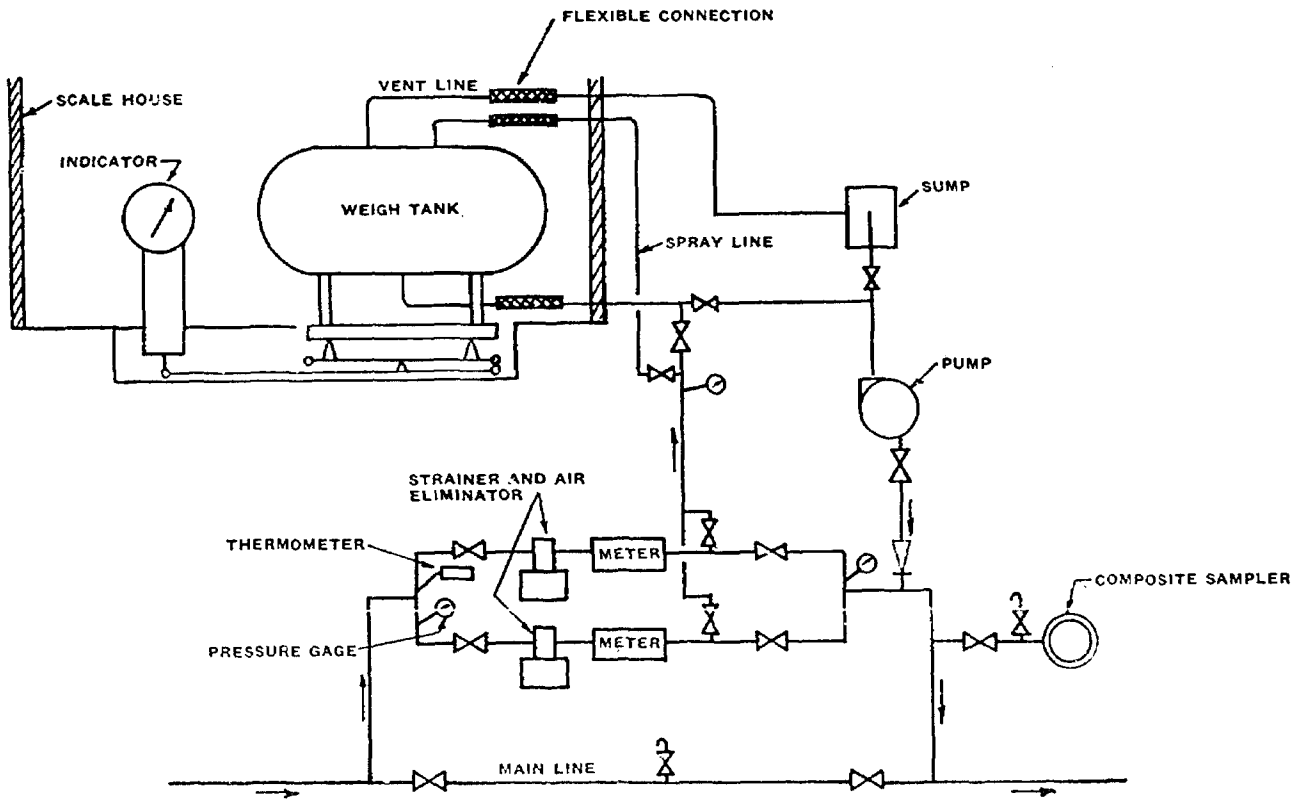


FIG. 19—Schematic Operating Diagram of Open Gravimetric System.

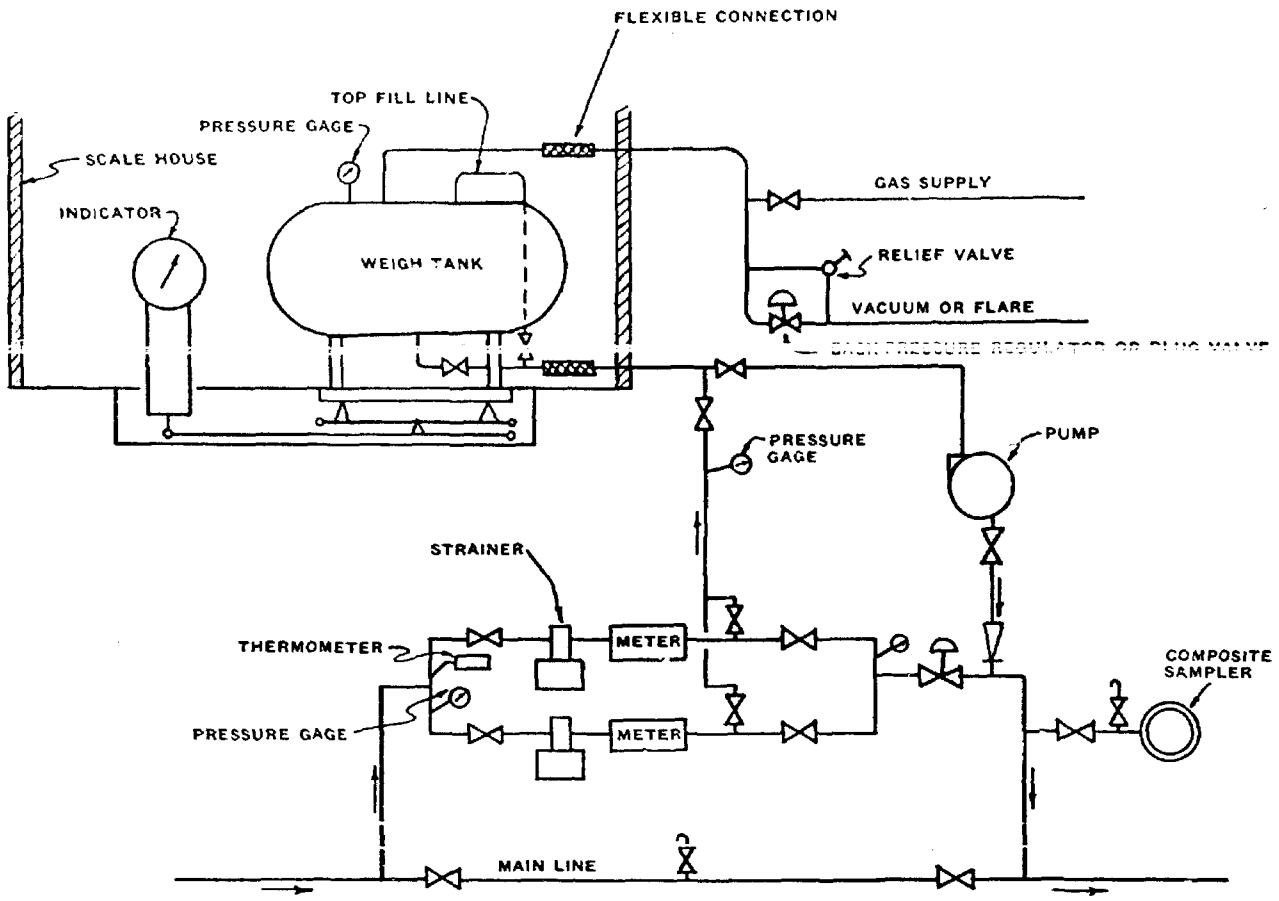


FIG. 20—Schematic Operating Diagram of Closed Gravimetric System.

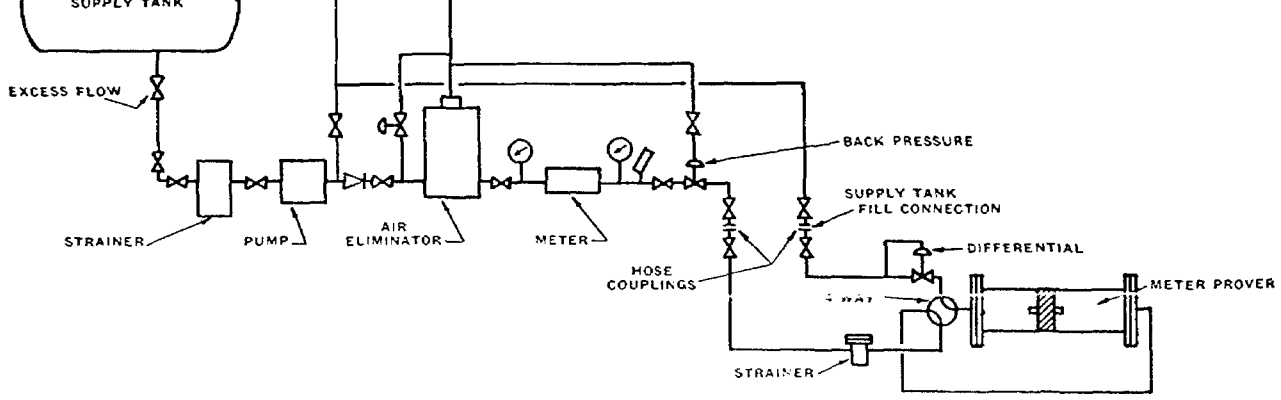


FIG. 21—Schematic Operating Diagram of Bidirectional Piston Displacement Prover System.

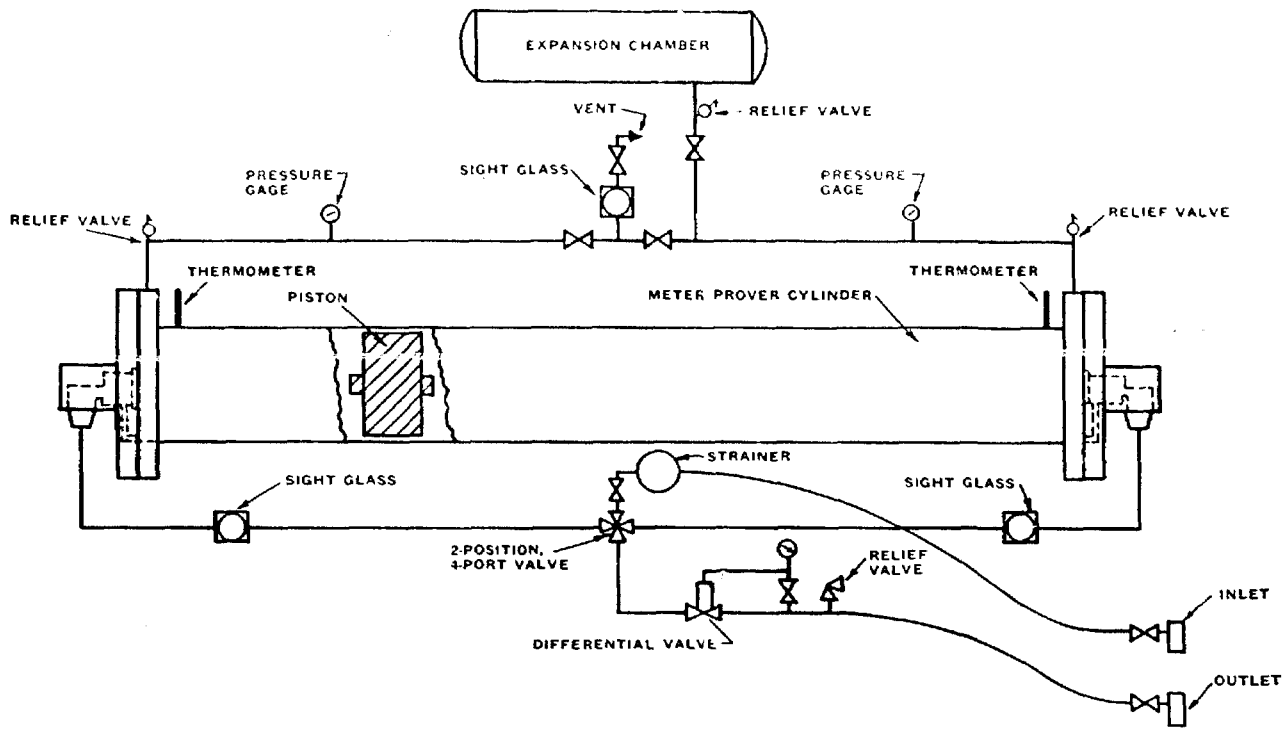
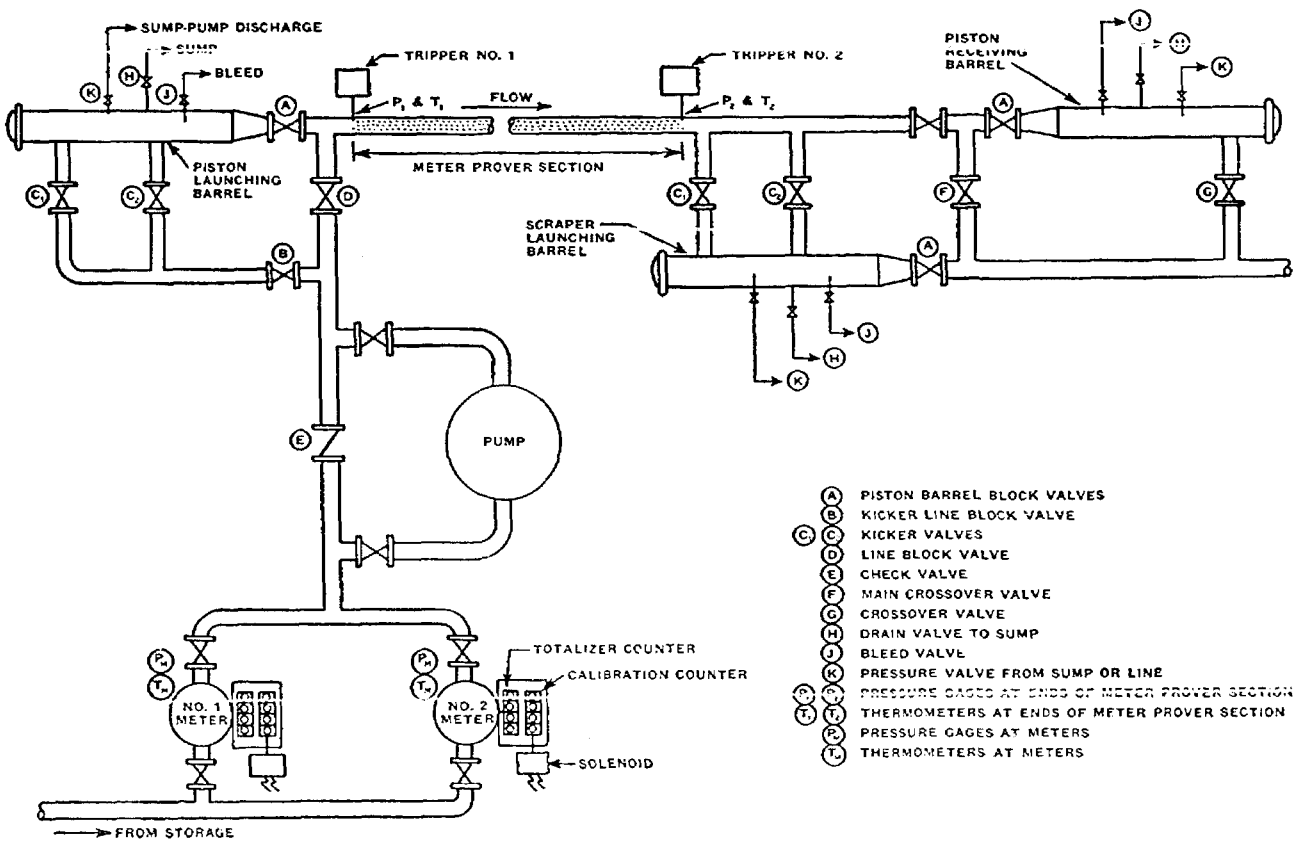
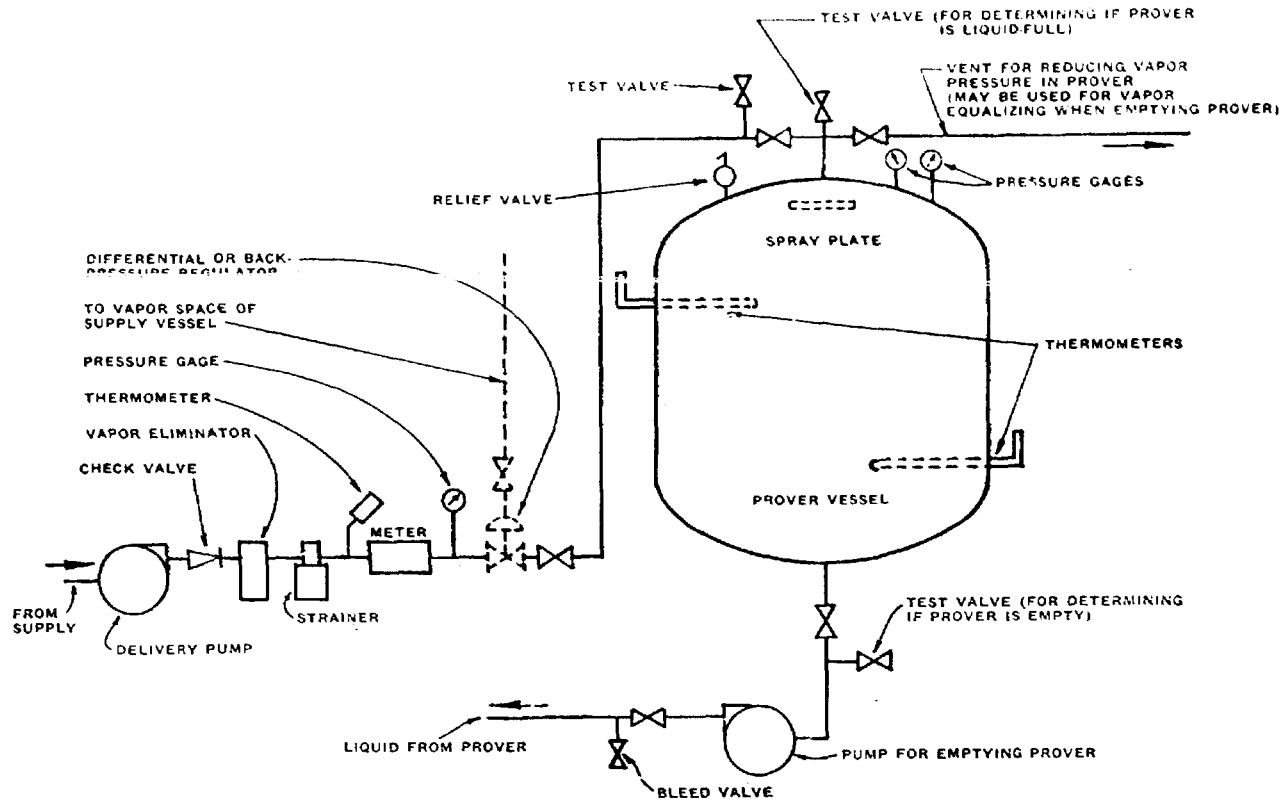


FIG. 22—Schematic Operating Diagram of Bidirectional Piston Displacement Prover.



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

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



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.

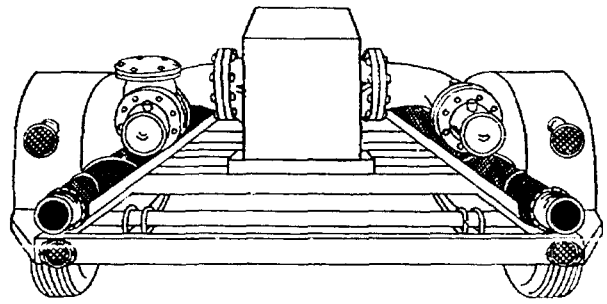


FIG. 25—Portable Master Meter.

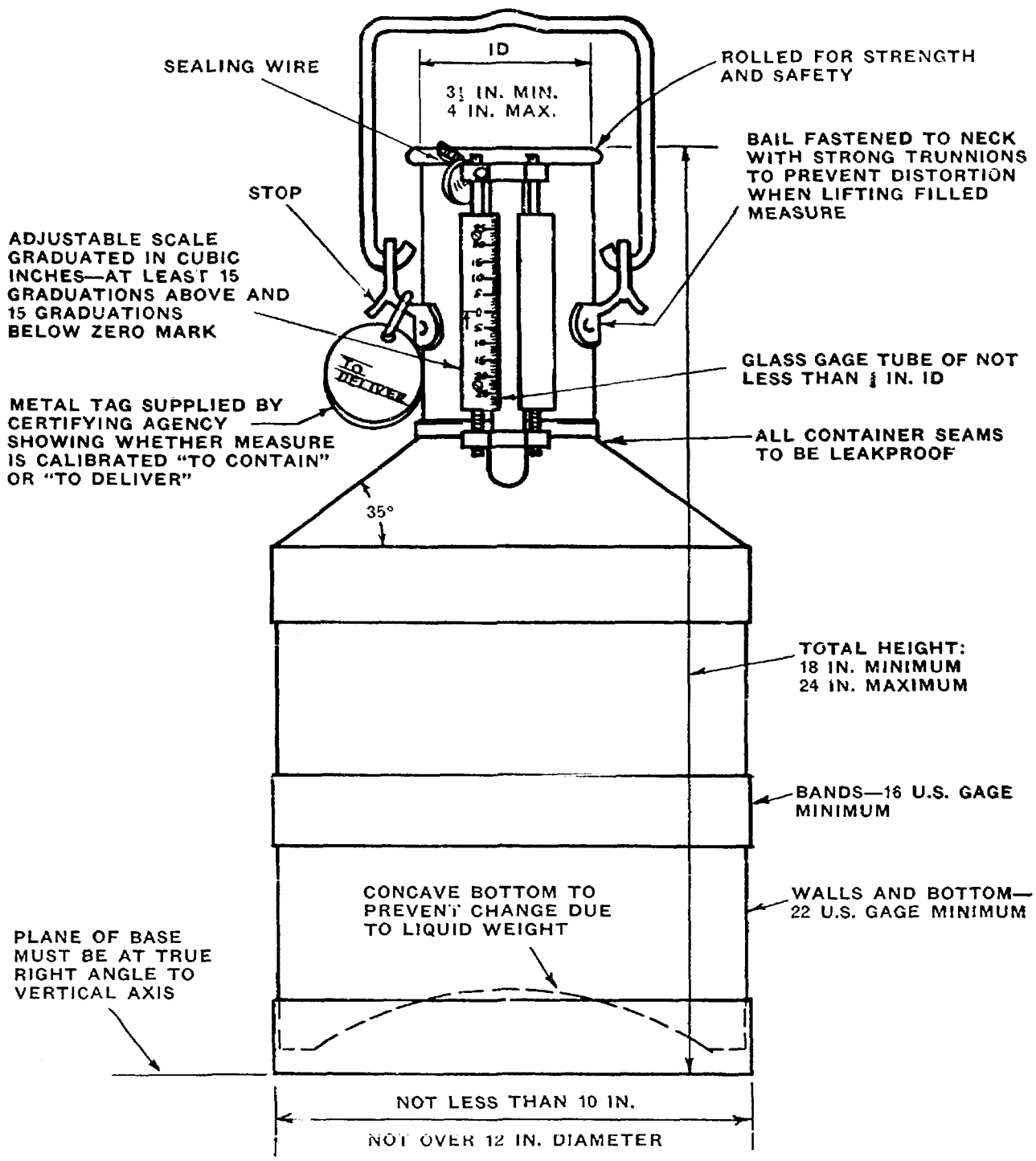
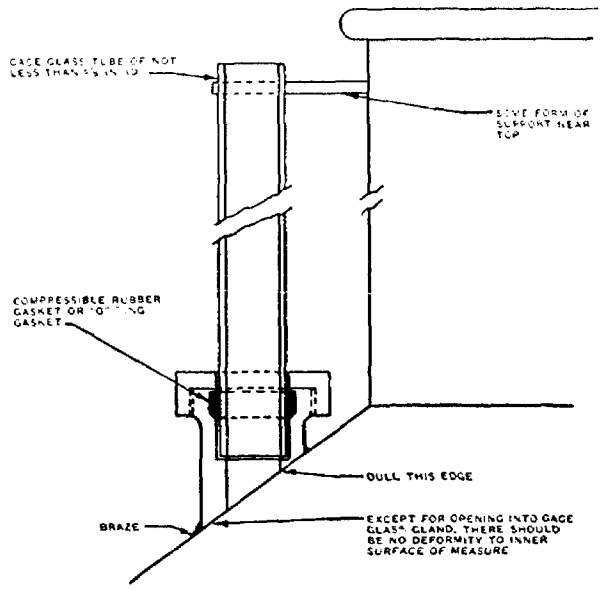


FIG. 26—Typical 5-Gal Test Measure (See Alternate Gage Glass Design, Fig. 27).



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

FIG. 27—Alternate Gage Glass Design.

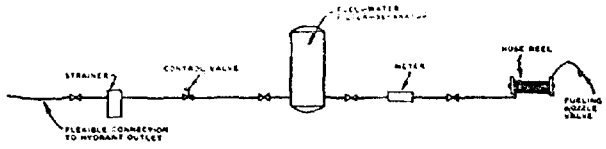


FIG. 28—Schematic Operating Diagram of Hydrant Fueling Vehicle.

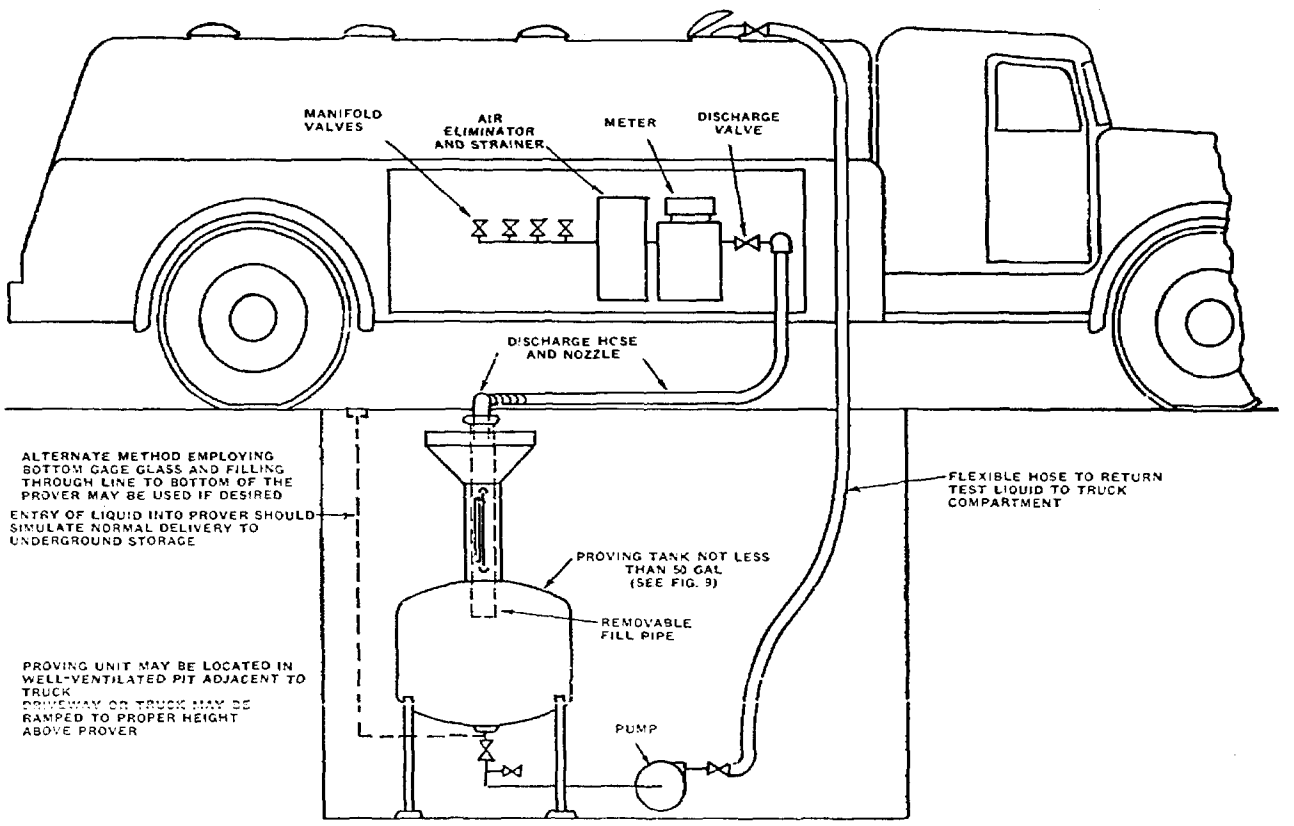


FIG. 29—Schematic Operating Diagram—Gravity Tank Truck Meter Prover.

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.

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

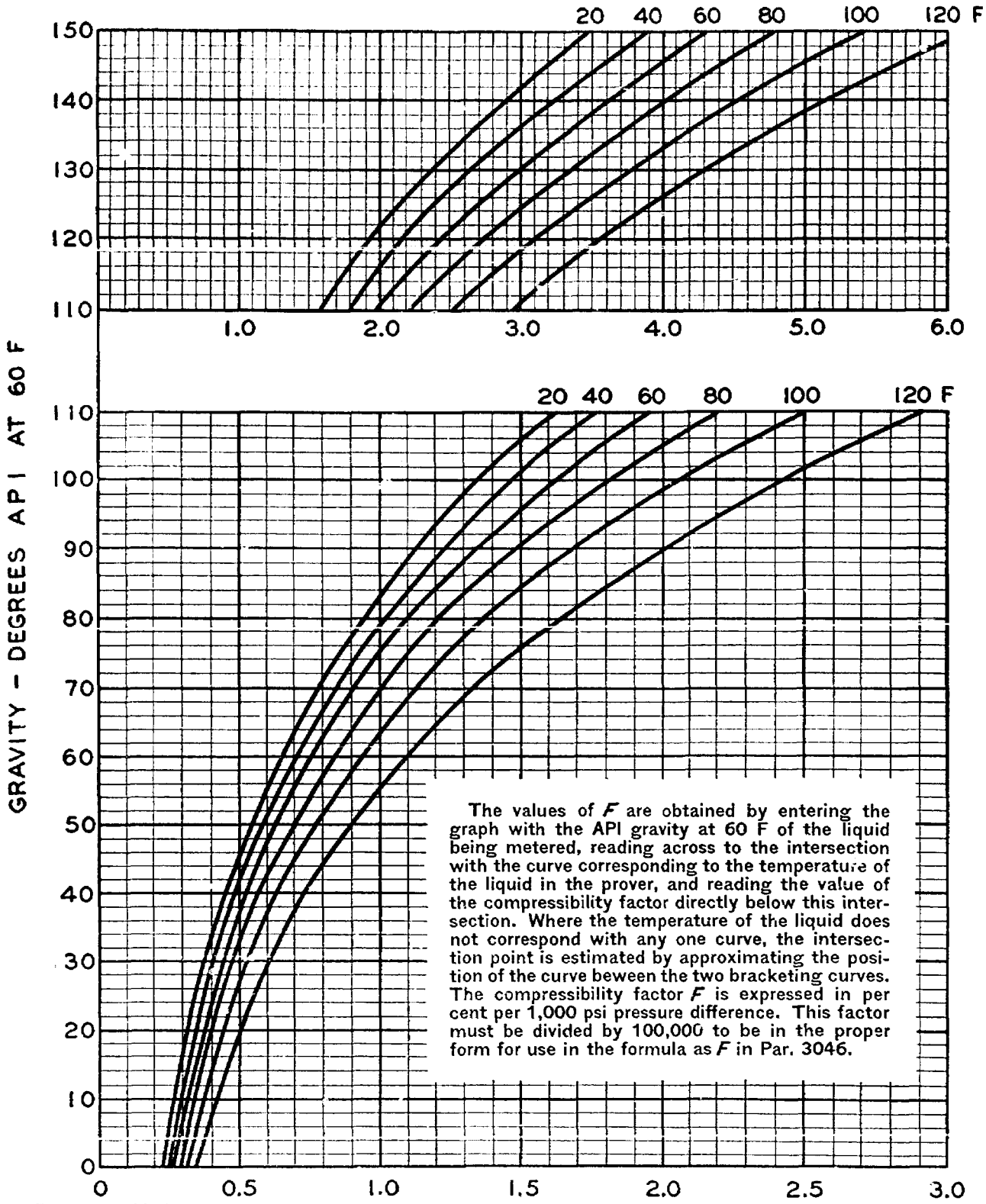
contains 0.9992 gallon at 60° F

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.

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		SIZE	REGISTER NO.	PRESSURE ON PROVER TANK				
	☐ 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*				

REMARKS: _____

19. Average meter factor _____

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.

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.

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.

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		AVERAGE METER FACTOR	
BARRELS METERED SINCE LAST RUN		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_____

DESCRIPTION OF QUANTITIES	RUN NO. 1				RUN NO. 2				RUN NO. 3			
	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: 7 = (hr × 60) + min + (sec ÷ 60)

15 = 11 [1.00 + (14 — 13)(F)], where F is from Table 11, Appendix B

19 = 12 × 16 × 18

25 = 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.

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 $\frac{\text{contain}^*}{\text{deliver}}$ 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 $\frac{\text{were}^*}{\text{were not}}$ 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

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	0.99966	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.

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	[illegible]	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

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 (Observed Values Fahrenheit)	API Gravity 60°F/60°F																			
	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

TABLE II (Continued)

Temperature (Degrees Fahrenheit)	API Gravity 60°/60°F																			
	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

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																			
	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 60°F/60°F																			
	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

TABLE II (Continued)

Temperature (Degrees Fahrenheit)	API Gravity 60°/60°F																			
	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

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	155	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 60° 60°																			
	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	319	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	35'	348	344
52	423	419	414	409	404	400	395	391	387	383	379	376	372	369	365	361	357	35.	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

TABLE II (Continued)

Temperature (Degrees Fahrenheit)	Specific Gravity 60°F/60°F																			
	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

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 Deg. Degrees Fahren.	Specific Gravity 60°F/60°F																			
	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	242
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

TABLE II (Continued)

Temperature (Degrees Fahrenheit)	Specific Gravity 60°F/60°F																			
	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	382	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

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

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

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.

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.

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.

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 determine[illegible] 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:

$$\text{Actual throughput} = (\text{meter registration})\ (\text{meter factor})$$

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.

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. Over-registration 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.

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	2045	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

D R A F T C O P Y - FOR COMMITTEE USE ONLY

API Bulletin 2502

API

RECOMMENDED PRACTICES

for

LEASE AUTOMATIC CUSTODY TRANSFER

AMERICAN PETROLEUM INSTITUTE

New York, N. Y.

#4

API RECOMMENDED PRACTICE FOR LEASE AUTOMATIC CUSTODY TRANSFER

Foreword

a. This Recommended Practice, prepared under the sponsorship of the API Committee on Crude-Oil Measurements, summarizes information that has been gained from a study of the experimental and operating systems devised by various companies for automatic custody transfer of crude oil from producing leases. "Lease automatic custody transfer" (LACT) consists of the measurement and running of oil from the producers' tanks to the connected pipeline on an automatic or unattended basis. This Recommended Practice is issued for the purpose of describing currently acceptable methods for LACT. The practices recommended are considered sound and reliable, but it should be expected that improvements will be made.

b. Throughout this Recommended Practice, references are made to API Standard 2500: "Measuring, Sampling, and Testing Crude Oil"; API Standard 2501: "Crude-Oil Tank Measurement and Calibration"; and API Standard 1101: "Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter." It is intended that these standards be used in all cases where they are applicable, in order to form a sound basis for accomplishing satisfactory automatic custody transfer.

c. Until a few years ago, all crude oil run from producers' tanks was measured, sampled, and tested by the use of hand tools. For about 30 years the American Petroleum Institute has continuously studied and improved these methods to make them as practical and accurate as possible. In 1954 the Institute approved the use of automatic indicating gauges and thermometers on a mutual-agreement basis, and industry is finding them to be accurate and preferable

to hand tools in many instances. In recent years, producers have installed automatic devices at lease tank batteries in quite a few fields to eliminate certain repetitious and time-consuming operations.

d. In many fields it has become apparent that lease automatic custody transfer offers the potential advantages of:

1. Reduction in required lease storage (which could also mean less evaporation losses and less investment in stored oil).
2. Improvement of measurement accuracy.
3. Reduction of the possibility of error in measurement or in quantity computation.
4. Simplification of computation and accounting procedures.
5. Reduction of time required by pumpers and gaugers in making measurements.
6. Improved scheduling of runs on a predetermined basis.
7. Allowing maximum use of other automatic equipment installed primarily for the production operations.
8. Increased operating efficiency and control.

e. The apparent disadvantages are:

1. Lease equipment needs more precise design, engineering, and maintenance.
2. A more complex system is required.

f. Early standardization of industry practice relating to methods and equipment used in lease automatic custody transfer is very desirable for three principal reasons:

1. To facilitate establishment of mutual agreement between parties concerned in automatic custody transfer.
2. To reduce the amount of engineering time required in design of automatic custody transfer installations.
3. To facilitate the periodic inspection of automatic custody transfer installations for insuring satisfactory performance.

It is hoped that the information contained in the Recommended Practice will be of assistance in establishing mutual agreement between parties interested in installation of systems operating in lease automatic custody transfer.

g. The material contained herein does not constitute an official code or standard of the American Petroleum Institute; nor is it intended that this material should become part of API Standard 2500 until such time as industry practice may have become established and the principles outlined in this Recommended Practice and other principles which may develop in practice have been more generally proved.

h. 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, nothing contained in this Recommended Practice grants any right, by implication or otherwise, for the 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 Recommended Practice may be used by anyone desiring to do so, but the sponsor 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.

SECTION I - GENERAL

INTRODUCTION

1. This Recommended Practice is intended to form a basis for mutual agreement between parties concerned in automatic custody transfer of crude oil from producing leases to the connected pipeline. It recommends practices which should provide accurate and reliable measurement and suitable protection against mismeasurement or otherwise faulty operation. LACT, as defined herein, may be used where mutually agreeable to the parties concerned in the transaction and where government or other regulations will permit.

2. These recommendations are not meant in any way to be restrictive or to retard future development of methods found to be either more suitable or more practical.

DEFINITIONS

1. Lease Automatic Custody Transfer. A Lease Automatic Custody Transfer system is defined as an arrangement of equipment designed for the unattended transfer of liquid hydrocarbons from producing leases to the transporting carrier while providing proper means for quality determination, net-volume determination, and fail-safe operation; and while meeting requirements of accuracy and dependability as defined in Recommended Practices for Lease Automatic Custody Transfer.

2. Cycle. Filling and running of one measuring tank.

3. Dump. That volume of oil (corrected or uncorrected for temperature) which is delivered to the pipeline in one complete cycle of the measuring tank, or the running of that volume of oil.

4. Run. A series of dumps or periods of meter measurement, either interrupted or uninterrupted, which are covered by a single-run ticket.

BASIC SYSTEM REQUIREMENTS

1. General. There are a great number of basic alternative arrangements which could be used to accomplish lease automatic custody transfer with satisfactory results. It is the purpose of this section to describe the basic requirements that should be met by all systems. Optional features may be desirable under certain conditions. The basic systems are divided into: (a) measuring tank type systems and (b) positive displacement metering systems.*

2. Requirements for All Types. The following list contains the general requirements of any system for automatic custody transfer. Some features are indicated as optional, or to be used by mutual agreement where conditions warrant; and others are applicable where required by regulations:

a. Stability of Oil. The lease oil handling arrangement must be such that the oil when measured is sufficiently stable and free from volatile fractions to permit accurate measurement and later transportation without abnormal or excessive losses.

b. Volume Correction. Provision must be made for accurate determination and recording of uncorrected volume and applicable temperature, or of temperature-corrected volume. The over-all accuracy of the system must equal or surpass present manual methods.

c. Sampling. Provision must be made for representative sampling of the oil transferred for determination of API gravity and the BS&W (sediment and water) content.**

*Velocity type and mass-flow meters may at some future time be adapted to LACT operations.

**There is some work in progress attempting to perfect new means and techniques of determining the BS&W content of oil that has been run, for use in lieu of conventional sampling and testing.

d. Merchantable Oil. Means must be provided if required by either party to give adequate assurance that the oil is merchantable before it is run.

e. Delivery. If required by either party, control shall be provided over the time of entry of the oil into the carrier's system.

f. Allowable. Where regulations require, control shall be provided to stop the flow of oil into the carrier's system at or prior to the time that the allowable is run.

g. "Fail-Safe" Features. The control and recording system must include "fail-safe features" that will provide adequate assurance against mismeasurement in the event of power failure or the failure of the system's component parts.

h. Tampering. All necessary controls and equipment must be enclosed and sealed, or otherwise be so arranged as to provide assurance against, or evidence of, accidental or purposeful mismeasurement resulting from tampering.

i. Calibration. All components of the system which require periodic calibration and inspection for proof of continued accuracy must be readily accessible. The frequency and procedures to be used should be agreeable mutually to the parties concerned.

j. Floats. If floats are used for level controls, they should be positioned in a manner which protects them from the turbulence of the stream.

k. Standards. All usual codes, regulations, and standards covering measurement of crude oil shall be used where applicable. This specifically includes API Standard 2500, API Standard 2501 and API Standard 1101.

TEMPERATURE MEASUREMENT

1. Temperature Correction. Correct use of devices to indicate, record, or adjust for oil temperatures is highly important where accurate oil volume measurements are to be obtained. In LACT operations two general methods are used to correct volumes for temperatures; i.e., (a) determine the applicable temperature of each run and to correct the run volume to 60°F, or (b) use a temperature compensator to correct continuously the register or counter reading. All temperature measurements or temperature corrections shall be made in accordance with API Standard 2500 or API Standard 1101.

2. Thermometers Check. All thermometers should be checked frequently enough to assure continued accurate indication by comparing them with test thermometers certified by the National Bureau of Standards.

3. Measuring Tank Type Systems. In these systems use of either temperature compensators or temperature recorders is practical. The temperature-sensing bulb in either case must be located where an average temperature of the individual dump is obtainable. The time elements in the cycle of the system must be such that all parts of the temperature-sensing and transmitting device must stabilize with respect to temperature by the time the temperature indication is recorded or is used to adjust the volume counter. This can be checked by comparing the indications with observations of readings from indicating thermometers installed for that purpose.

4. PD Metering Systems. In these systems the use of either temperature compensators or temperature recorders is practical.

5. Temperature-Compensating Devices. These devices should be set and adjusted to the average API gravity of the oil being measured in the specific installation.

SAMPLING

1. Samples. Samples for determination of API gravity and BS&W content shall be obtained by automatic samplers and by procedures as described and set out in Part V of Supplement 1 of API Standard 2500.

2. Measuring-Tank Systems. If mutually agreeable, in measuring tank system it is permissible to take one sample from each dump. Such samples may be commingled and collected for a complete run.

3. Sample Containers. All samples should be collected in closed containers and kept under sufficient pressure to prevent changes in gravity. Mechanical arrangements that allow the determining of the gravity under pressure are permissible, if mutually agreeable.

4. Testing Composite Samples. When samples are transferred from the sample container to testing equipment, every precaution should be taken to insure that the portion of the sample being tested is representative of the sample and of the run.

5. Determining BS&W Content. If mutually agreeable, it is permissible to use devices and procedures that determine the total volume of collected sample and the total volume of BS&W in the sample, and these data can be used to calculate the BS&W content.

6. Recording BS&W Content. If mutually agreeable, it is permissible to use automatic means of measuring and recording BS&W of oil being transferred, provided that such means are periodically calibrated and the results obtained check within a mutually agreed amount with another accepted API Standard method.

PRESENTATION OF MEASURED INFORMATION

1. Procedure. Data from LACT systems include that which automatically is recorded and that which is taken manually at the end of each run. The specific method and procedure for obtaining data and the matter and form for presenting

data shall be determined by mutual agreement and shall comply with any applicable regulations. In general, it is suggested that the procedures be as simple as possible and that they be compatible with the use of conventional run tickets and usual accounting procedures.

2. Preserving Records. In most cases pertinent records and charts, such as calibration reports, need to be stored temporarily for a period of time. The exact procedure should be determined by mutual agreement.

RUN SCHEDULING

1. Scheduling for a Pipeline Load. Pipelines must prorate their capacity among all connected leases. Where LACT operations are contemplated, representatives of the producer and of the receiving carrier should confer in regard to the feasibility of such operations consistent with pipeline load factors. The ultimate in LACT operations is to have continuous delivery from producers' facilities to pipelines. With some types of LACT systems a truly continuous flow is obtainable, while in other types of systems delivery will be a relatively continuous batching operation. Where line load factors are high, careful planning is required. Some considerations are:

a. The periods when line capacity would be available.

b. The producer's ability to have oil ready to deliver.

c. The rates of delivery on an hourly or other time-period basis.

d. In the case of PD metering systems, whether the rate can be maintained within the accurate range of the meters.

e. In the case of measuring tank systems, the time cycle sequences from empty tank to full tank to empty tank.

f. In general, automatic scheduling should improve pipeline load factors.

2. Stopping at Allowables.* Producers as well as receiving carriers are held responsible by regulatory bodies for keeping runs from leases within the allowable where allowables are applicable. Hence, in such cases, provisions must be made to assure that runs from LACT systems do not exceed the lease allowable. In some instances it is feasible to stop delivery manually when or before the allowable has been run and to permit the lease production to accumulate in producers' storage. Mechanical means may also be used to accomplish this end. The system used should meet the following requirements:

a. Tampering. It must be fail-safe, tamperproof, and sealable in such a way that neither the pipeline's representative nor the producer's representative can change the mechanical arrangement without the consent and/or knowledge of the other.

b. Allowable. Any mechanical arrangement used must be capable of being preset for the predetermined volume that will approach but not exceed the lease allowable.

1. Any mechanical arrangement used must prevent any further movement of oil from the lease when the predetermined volume has been reached until it is manually reset.

2. It must be adjustable in order to take care of the allowable changes. Any changes to the mechanical devices must be made only when representatives of both parties are present.

c. Check of Delivery. Registers and counters should be visible so that oil deliveries can be checked at any time.

*Certain current state governmental regulations require that particular attention be paid to this section to avoid losing some of the allowable production.

EQUIPMENT AND INSTALLATION STANDARDS

1. Standards and Approvals. All equipment used in LACT systems should be designed, constructed, calibrated, and operated in accordance with applicable API standards, other standards, and codes, and in compliance with governmental regulations. Currently, it is necessary to obtain approval or to obtain exception to statewide rules from regulatory bodies to use LACT in some states.

2. Types of Controls. Control equipment may be electric, electronic, pneumatic, or hydraulic. Components should be high-quality materials which are resistant to moisture, corrosion, dust, and wear and should be designed for long life with minimum maintenance.

3. Valves. Valves should be of a type that assures tight shutoff; it is preferred that the valve actuators be of a type, or so arranged, that they will permit interruption of the power supply without causing mismeasurement.

4. Counters. The methods selected and used for counting and recording the number of barrels or dumps in a LACT system require particular attention. It is preferable to have at least two independent counters. The counting systems should be designed so that failures of electric or pneumatic power do not cause false counts. A pressure-recording instrument for recording the "head" in a tank and/or a temperature-recorder can be used to advantage in some systems as a check on oil movements.

5. Ratings. Machines, devices, and components of LACT systems should be installed and used in accordance with established ratings. The various components of a system should be compatible with respect to ratings and with systems to which they are connected.

FAIL-SAFE AND MEASUREMENT CHECK FEATURES

1. Protection against Mismeasurement:

   a. Interlocks. Fail-safe features and interlocks should be included in the design of an LACT system to provide reasonable assurance against mismeasurement. The specific devices used in an installation should be decided by mutual agreement. Interlocks or other means should be used on valves, floats, and controls as needed in a system if mechanical failures in the system will interfere with accurate measurements. It is permissible for either party involved to use any means of this type, provided that it does not interfere with accurate measurements or with the satisfactory operation of the system.

   b. Sequence. In measuring tank systems it is suggested that the sequence of operation of the measuring cycle should be retained in event of failure or interruption of electric or pneumatic power.

2. Equipment Enclosures and Security

   a. Control. Control equipment should be housed and locked or sealed, if necessary. Automatic valves shall be of such design and so connected that operation can only be accomplished through locked or sealed control equipment.

   b. Tamperproof Devices. There shall be installed such enclosures and tamperprcof devices as required by the carrier or his agent. The producer may install additional tamperproof devices he considers necessary provided that they do not interfere with the accuracy of measurement.

c. Seals. Any adjustable device that affects measurement must be sealed and/or locked; and the seal shall not be removed without advising and/or without obtaining the consent of the other party.

QUALITY MONITORING

1. General. Where LACT is used, the composite sample of the oil run is tested for BS&W at the end of the run. Hence, it is possible for bad oil or slugs of water to enter a carrier's system unless some means are provided to prevent it. Some pipelines cannot tolerate more than traces of water in oil, while in other cases the maximum allowable amount of water is of less importance. Where LACT operations are contemplated, the parties concerned should mutually agree on (a) the permissible BS&W content of crude, (b) whether some additional means must be provided to insure against bad oil entering the system, and (c) if used, the type of means.

2. Monitor. The only mechanical means used to date to prevent bad oil from LACT units from entering pipelines employs a device for controlling, indicating or recording the BS&W content of the stream. The only satisfactory device developed so far is an instrument that measures capacitance (dielectric constant). When this device is installed in the line to the measuring tank or meter, it can be used to actuate valves so as to divert the stream containing excessive water back to the dehydration facilities and/or stop the flow to the pipeline.

3. Dielectric Constant Monitors

a. Requirements. A dielectric monitor shall consist of a device or instrument designed to measure the dielectric constant of the fluid between the electrodes of a cell mounted in the flowing stream. It shall be calibrated in units of percent BS&W, and shall have a full-scale range not to exceed 0 to 5 percent BS&W. Although the over-all field-calibration checks can be made against

readings of the centrifuge, the instrument should be equipped to allow simple field checking of its internal calibration or operation by switching to one or more self-contained, standardizing, zero-temperature-coefficient capacitors for calibration reference. The instrument shall be of a type which measures true dielectric constant, independent of fluid electrical losses, in order that the effect of salinity of the water content shall not affect the instrument reading. Since the dielectric-constant reading is affected by the temperature* of the measured stream as well as by the percent of BS&W, suitable temperature compensation should be used where stream temperatures are expected to vary appreciably. BS&W monitors should be selected to resist corrosion and fouling by the measured fluid.

b. Effects of Gas. Entrained gas bubbles can cause erroneous measurement. Although this behavior can be used to detect free gas, normally the capacitance cell should be located so as to avoid entrained gas bubbles.

c. Fluid Velocity. The velocity of oil moving through the capacitance cell must be sufficient to prevent drift to a false high reading.

d. Other Factors. Instruments shall not be affected adversely by reasonable or expected variations in supply voltage or frequency or by variations of ambient temperatures.

*Data to date indicate that without compensation a fluid temperature change of 30°F. can be expected to result in a change of calibration equivalent to approximately 0.35 percent of BS&W.

e. Calibration. The initial instrument calibration should be made in conformance with the manufacturer's recommendations and should be based on measurement of the base dielectric constant of a clean, fresh sample of the specific crude to be measured. Adjustment of the zero setting for the initial field calibration (after installation) and for all subsequent field recalibrations may be made on the basis of comparison with the BS&W content of the crude determined by centrifuge methods in accordance with API Standard 2500.

CLINGAGE

1. Definition. Clingage, as used herein, is defined as the amount of oil that adheres to the walls of a measuring tank or a volumetric prover tank after draining or during the "empty" phase of an operating cycle. Not enough data are available to make firm recommendations in regard to taking clingage into account in LACT units; however, it needs consideration in some cases to insure accuracy.

2. Correlation. From data available, it appears that the amount of clingage can be correlated with (a) the viscosity of the oil at operating temperatures, (b) the length of drain time, (c) the ratio of surface area to the volume of the tank, (d) ambient conditions, and (e) the type of coating used and the shape of the tank.

3. Drain Time. Prover tanks customarily are calibrated "to deliver" using water and measures certified by the National Bureau of Standards as described in API Standard 1101. This may not give an accurate calibration of the prover tank "to deliver" or "to contain" crude oil after the tank is in service. When using prover tanks to prove PD meters, adequate drain time must be used to insure an accurate "starting" liquid level.

4. Clingage Factor. The problem of clingage should be considered where measuring tanks are used in LACT. The calibration of tanks or the correction of volume factors applied should take clingage into account on a mutual agreement basis. When tanks are calibrated and a clingage factor is included, the basis of determining the clingage factor should be stated on calibration reports and certificates.

5. Test Results. The following general information may be helpful in dealing with clingage questions. It is based on a relatively small number of carefully conducted tests:

a. Tank Size. The magnitude of differences in volume measurements decreases with increases in tank size. In tanks having capacities above about 50 barrels, clingage appears to be negligible except possibly where oils have very high viscosities.

b. Viscosity. Where oil viscosities are less than about 50 SSU at operating temperatures, clingage appears to be negligible. Where oil viscosities are in the range of 60 to 200 SSU at operating temperatures, the amount of error in volume measurements due to clingage in 5- to 20-barrel tanks is in the order of 0.05 to 0.25 percent.

6. Time Delay. Most LACT systems using measuring tanks incorporate time-delay means to insure proper drainage, thereby minimizing clingage effects.

7. Field Checking. One practical method of calibrating measuring tanks to take clingage into account or to correct water calibration is to compare the volume of oil run from surge or lease stock tanks with the volume as determined by the measuring tanks. (This cannot be used where incrustation is a problem in lease stock tanks.) This requires careful and accurate tank strapping

and accurately measuring the oil in lease tanks (including gauging to the nearest 1/16 inch or closer and making temperature traverses in the lease stock tank in conjunction with the top and bottom gauges). PD meters also can be used to check the calibration of measuring tanks where clingage may be a problem, provided the PD meter is carefully calibrated and operated so as to permit its use as a standard means.

SECTION II - MEASURING TANK LACT SYSTEMS

INTRODUCTION

1. Measuring tank LACT systems are described as those systems which utilize tanks or special vessels as the measuring device in the automatic custody transfer of oil from a lease to a transporting carrier.

2. The system is similar to LACT systems using PD meters as the measuring device in that a means must be provided for production surge and a means must be provided to control the movement of oil through the system. A means must also be provided for determination of both the net quantity and the quality of the oil delivered to the transporting carrier. A device should be provided for control of unmerchantable oil on leases where BS&W production is anticipated.

3. This section is primarily concerned with the classification of tank systems in accordance with the types of measuring as presently used. Other designs will be acceptable when so proven.

TYPES OF MEASURING TANKS

1. Initial Systems. The initial LACT systems were developed around the use of the conventional lease tankage primarily to duplicate as closely as possible the then accepted requirements for custody transfer measurements and secondly to permit the use of LACT with a minimum of additional expense for the great number of lease tanks in existence. These early LACT systems employed floats or weirs to control the fixed volumes to be transferred each dump (see Fig. I and Fig. II). Measuring tanks of this design are still acceptable and sometimes used where conventional stock tanks can be economically converted.

2. Present Systems. From these systems evolved the idea of the present measuring tanks which now find general industry acceptance. The tanks differ

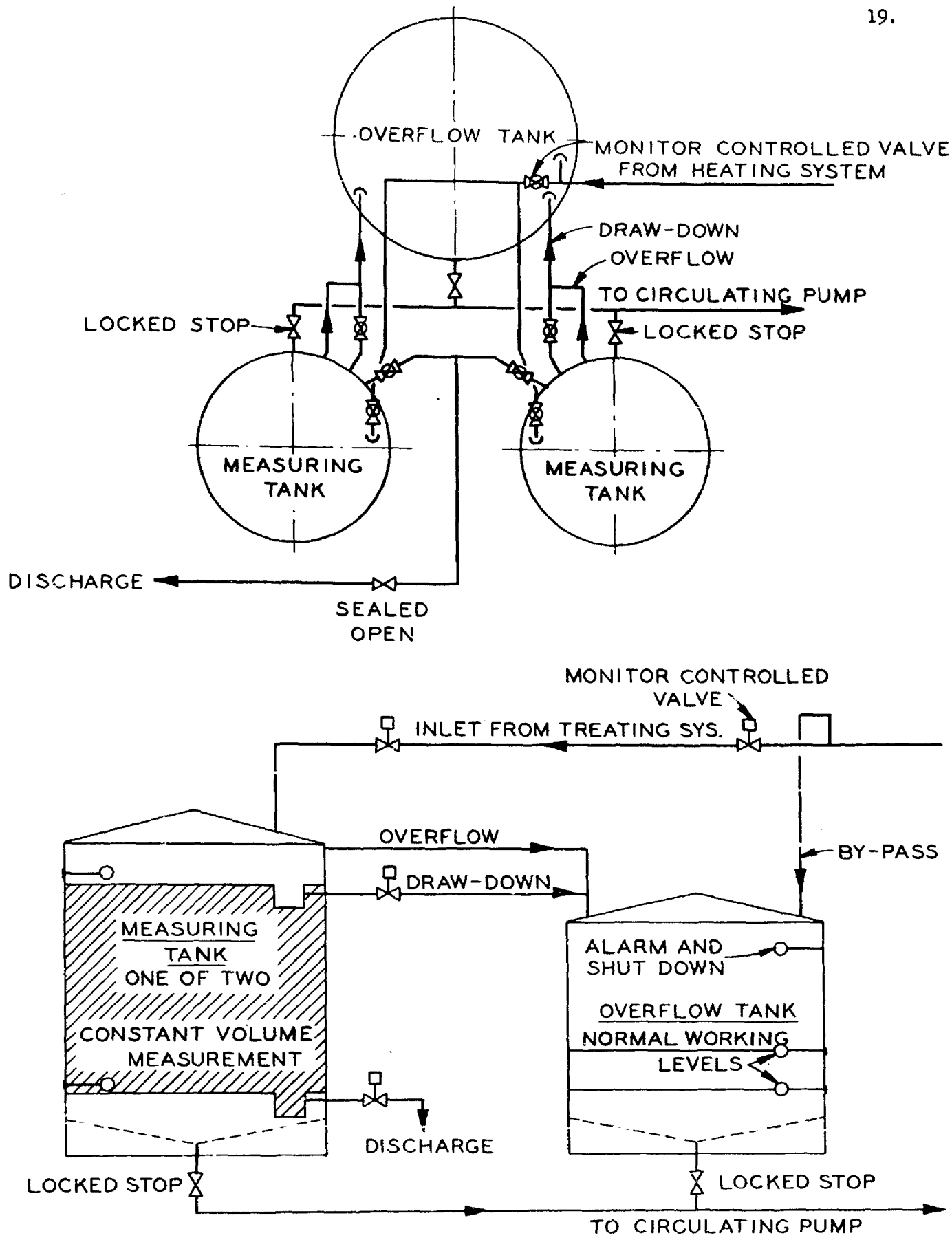


FIGURE I
SCHEMATIC DIAGRAM OF PARALLEL-TANK MEASURING SYSTEM WITH WEIR-CONTROLLED CONSTANT TANK VOLUME

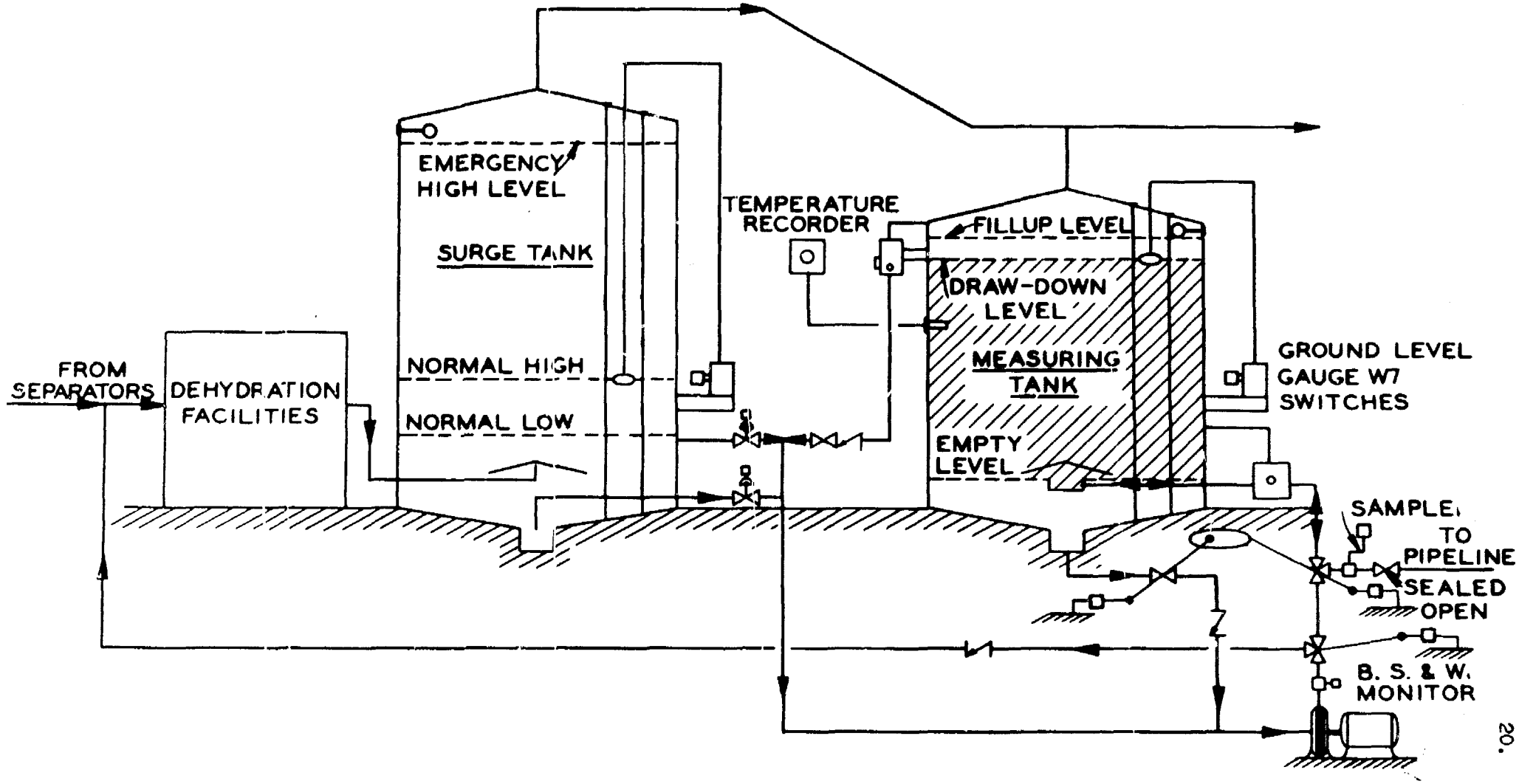


FIGURE II

TANDEM TANK MEASURING SYSTEM WITH WEIR-CONTROLLED CONSTANT TANK VOLUME

from the adaptation of the conventional tank in that control of the lower liquid level is so positioned as to provide complete drainage of the tank each measuring cycle, thus eliminating the possibility of bottom accumulations within the measuring vessel. These tanks are designed in the following three general forms and are available from many manufacturers:

Measuring Vessel Having Top Weir and Bottom Valve (Fig. III)

1. Manner of Operation. This vessel is usually an upright cylindrical vessel with a cone top and cone bottom, a semieliptical head and bottom, or any combination of these two configurations. The top section consists of a weir enclosed by a dome to act as an overflow chamber for the weir. A level detector is located in the overflow section at least an inch below the weir level so that the measuring section must fill with liquid and overflow the weir before the level detector comes into action, stopping the fill cycle. Thus, a full measuring chamber is assured each time. A delivery valve in the lower reduced section establishes the exact point of the lower liquid level of the measured volume and is so positioned as to provide complete drainage of the vessel. A level detector or liquid-sensing device is situated in the lower portion of the measuring chamber and controls the action of the delivery valve so that complete delivery is made each dump. The control system interlocks the upper level-sensing device and the lower level-sensing device so that a constant gross volume of oil is delivered during each cycle. The delivery valve represents the point at which the transfer of custody occurs.

The Totally Contained Volume Chamber (Fig. IV).

1. Manner of Operation. This vessel takes the form of a vertical or horizontal cylindrical tank with top and bottom reduced in cross section. This vessel contains a valve in each reduced section with level-sensing devices external to

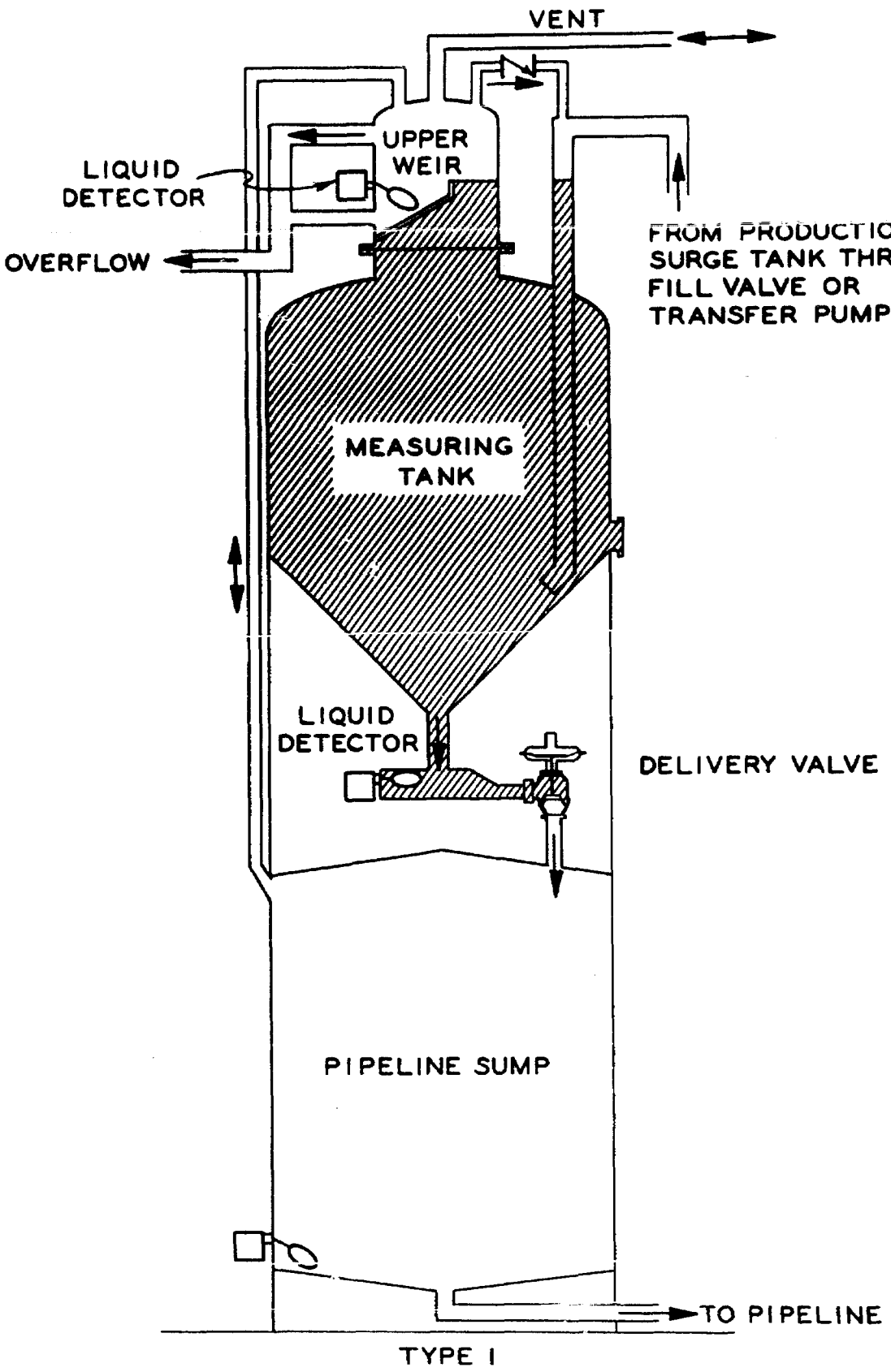


FIGURE III
TOP WEIR, BOTTOM VALVE
MEASURING VESSEL

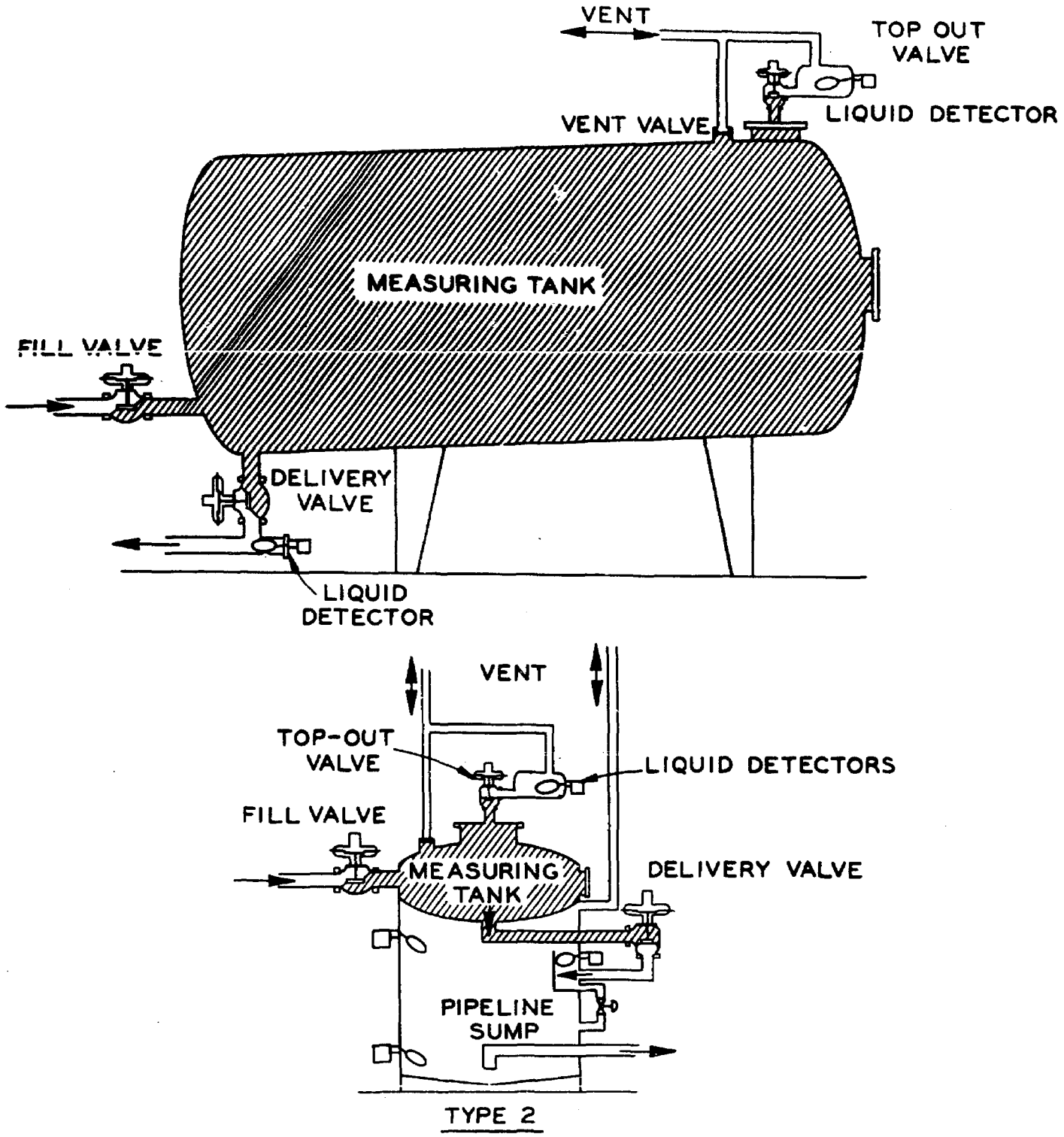


FIGURE IV
TOTALLY CONTAINED
VOLUME CHAMBER

the vessel to control the action of the valves. A valve is also provided in the fill leg. The exact metered volume is contained between the three valves. The delivery valve is the point at which the transfer of custody occurs.

Measuring Vessel Having Level Controls within a Reduced Area (Fig. V)

1. Types. Vessels with reduced-area level control sections are of two general forms:

a. Vertical Vessel Type. Vertical cylindrical vessels with conical top and bottom having a reduced area and level control in the center of the upper cone and a delivery valve in the outlet of the lower section. A float in the bottom section serves only as valve control. The contained volume of this tank is determined by level-sensing device in the top and the face of the delivery valve in the bottom.

The slope of the top deck of the measuring tank should be at least 20° to prevent flexing of the roof and mismeasurement due to the trapping of the gas.

b. Horizontal Vessel. A horizontal cylindrical vessel with reduced-area sections at top and bottom with level controls in each reduced-area section. The horizontal cylindrical vessel is slanted slightly and is constructed with the upper reduced area on the highest end of the vessel while the lower reduced area is located on the lowest end of the vessel. This provides good drainage and prevents any gas trap. Contained volume of this tank is determined entirely by the level-sensing devices. Transfer of custody occurs at the delivery valve in the lower section.

TANK ARRANGEMENTS

1. Classification. Measuring-tank systems may be placed in two general classifications. Class 1 systems (Fig. VI) are intermittent-delivery systems and Class 2 systems (Fig. VII) are continuous-delivery systems, as established

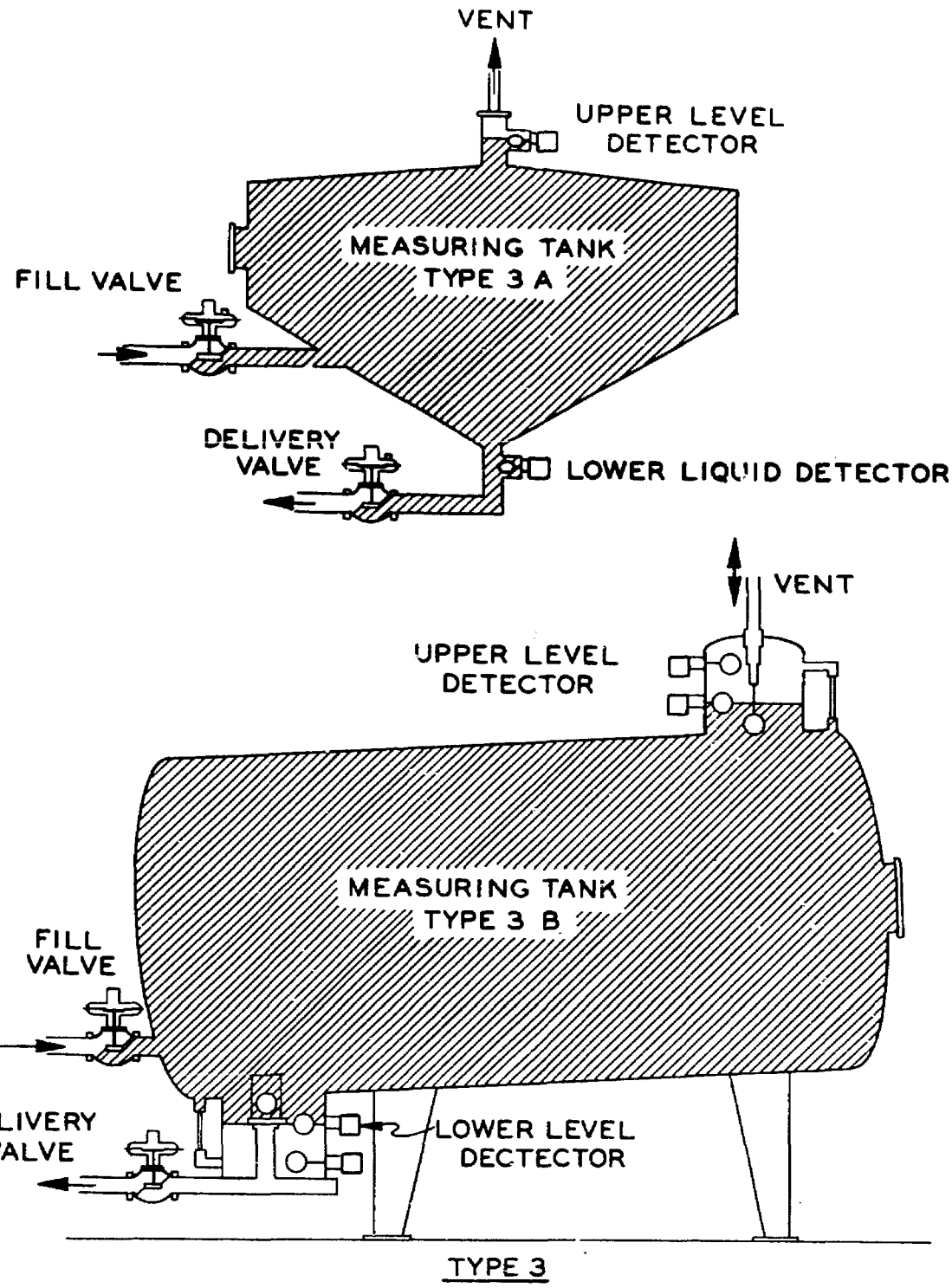
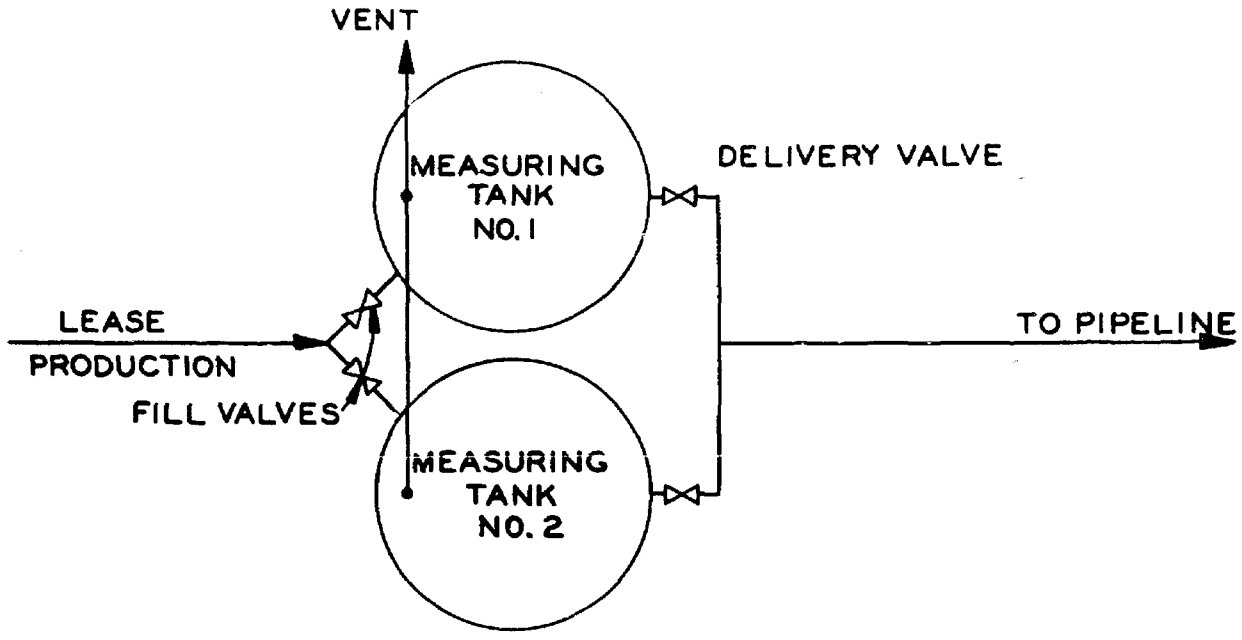
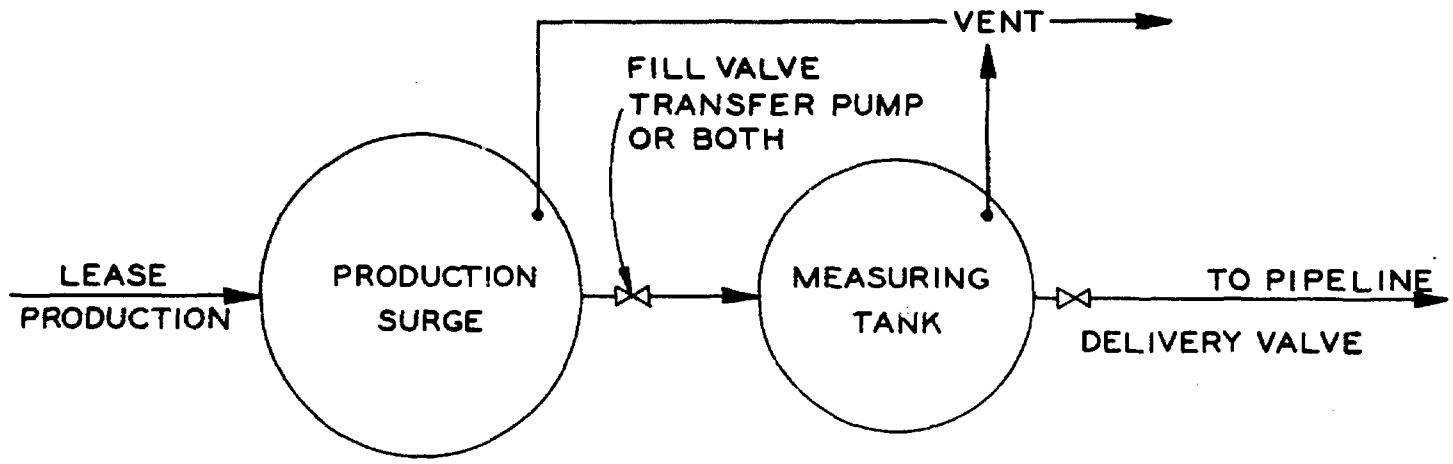


FIGURE V
MEASURING VESSEL WITH
LEVEL DETERMINATION IN REDUCED AREA

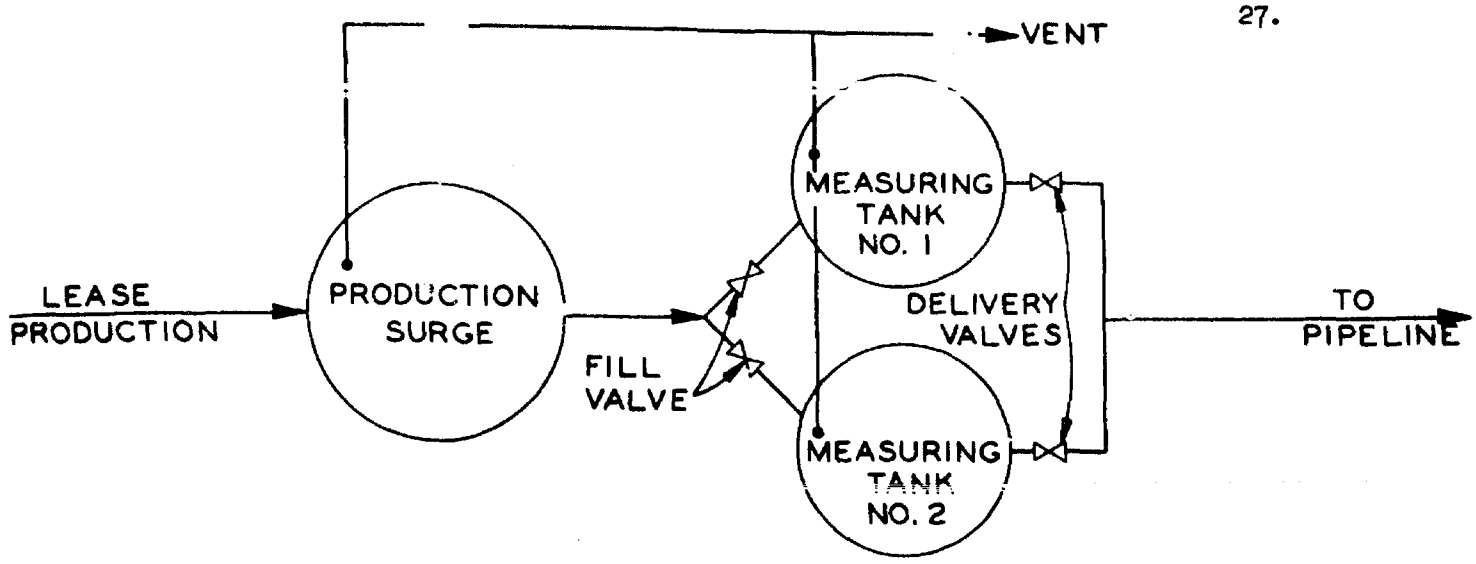


(A) DOUBLE MEASURING TANK-NO SURGE

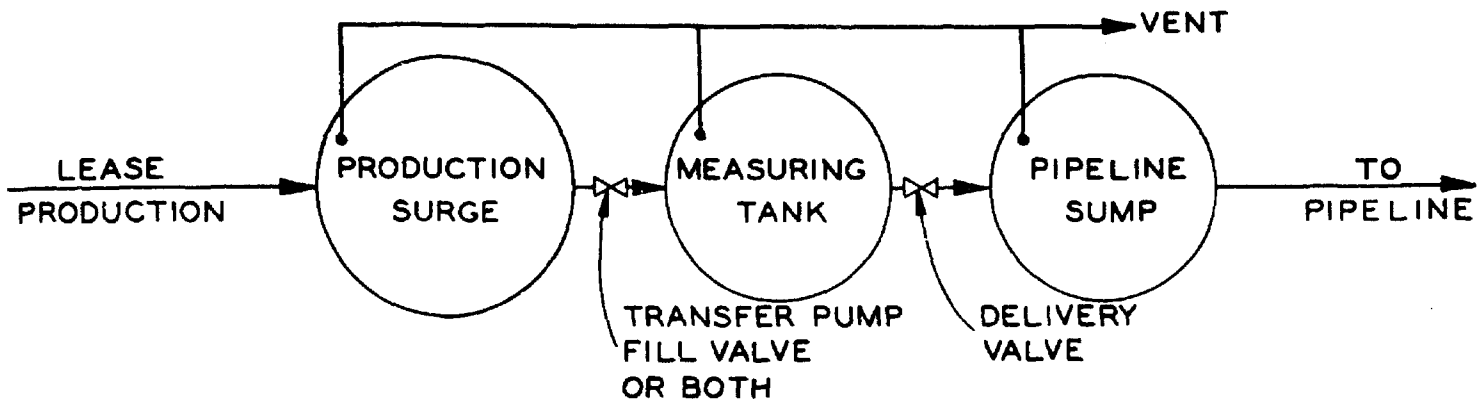


(B) SINGLE SURGE WITH SINGLE MEASURING TANK

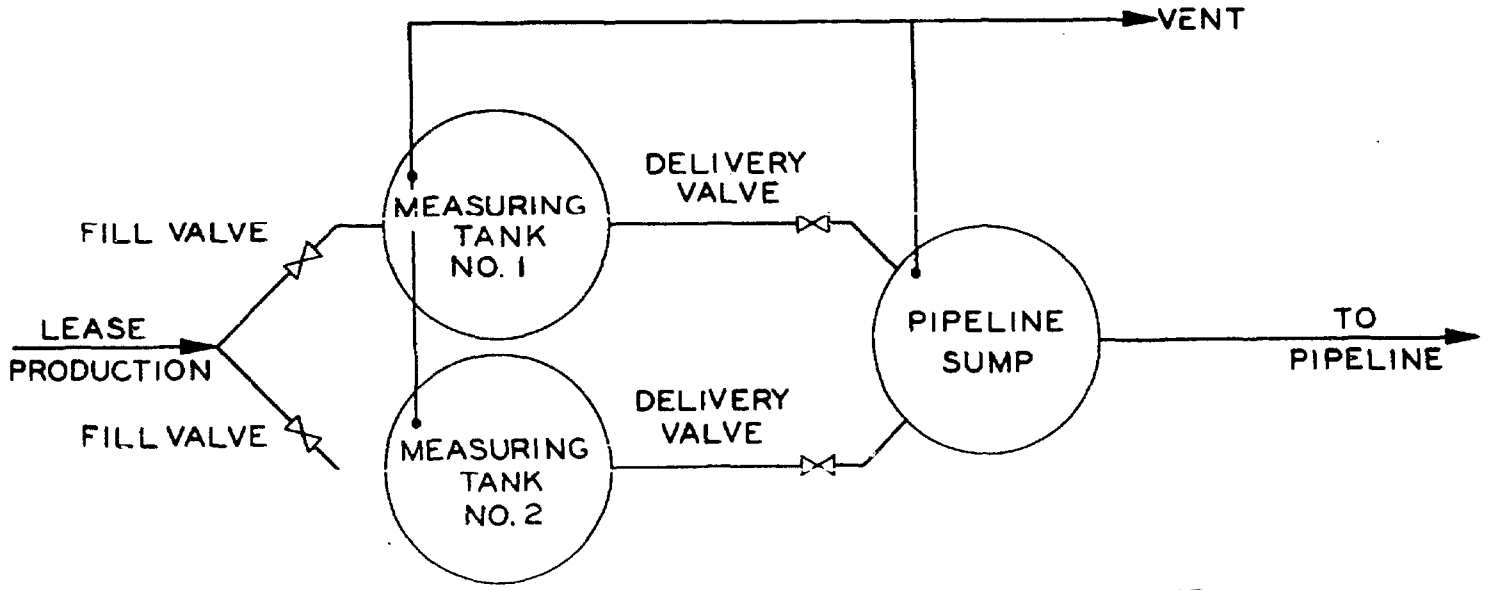
FIGURE VI
CLASS I
TYPICAL SYSTEMS FOR INTERMITTENT
DELIVERY TO PIPELINE



(A) PRODUCTION SURGE WITH TWO MEASURING TANKS



(B) PRODUCTION SURGE WITH MEASURING TANK & PIPELINE SUMP



(C) TWO MEASURING TANKS WITH PIPELINE SUMP

FIGURE VII
CLASS II
TYPICAL SYSTEMS FOR CONTINUOUS DELIVERY TO PIPELINE

by their ability to make either intermittent or continuous delivery to the transporting carrier.

2. Intermittent Delivery. Assuming that all systems will be required to handle production from the lease continuously and intermittent delivery is permissible, a minimum system must include at least two vessels. These vessels may be arranged as two measuring tanks in parallel where the measuring tanks are large enough to provide needed production surge capacity or a production surge vessel and one measuring tank in series (Fig. VI).

3. Continuous Deliveries. In order to minimize the load on a transporting carrier's facility it is recommended that Class 2 systems (Fig. VII) be provided in most instances. Continuous delivery or Class 2 systems require the use of three vessels. These vessels may be arranged as follows:

a. Two Measuring Tanks, No Sump. A production surge tank with two parallel measuring tanks.

b. One Measuring Tank. A production surge tank with one measuring tank and pipeline sump in series.

c. Two Measuring Tanks, No Surge. Two parallel measuring tanks connected to a pipeline sump.

4. Recommended System. Of the three systems shown as Class 2 systems, Figure VII, the single-measuring-tank system is the least complicated from the standpoint of fail-safe interlocks and simplified control components and is recommended.

5. Rate Fluctuation. The systems are designed so that accuracy is not affected by fluctuations in delivery rates up to and including the maximum capacity of the unit.

SPECIAL REQUIREMENTS

1. General. Measuring tanks are emptied with no means provided to wipe the interior surfaces clean. Therefore, volume cannot change due to surface wear. The problem of incrustation and surface clingage must be dealt with in some manner.

2. Incrustation. Incrustation may be controlled and in most cases has been successfully prevented by applying to the interior surface of the measuring tank a baked-on phenolic coating, a catalytically set modified phenolic or epoxy coating, or ceramic coatings. Other materials will be acceptable when so proven.

3. Clingage. The effect of clingage may be determined by actual measurement of the run down volume in a measuring tank after the delivery valve is closed. Measurement should be made at normal operating temperatures and sufficient time allowed to satisfy the parties concerned. Correction for clingage shall be applied to the vessel calibration factor.

4. Valves. Valves used to control liquid to or from a measuring tank must be constructed with soft seats. The valves must be checked periodically to assure that the seat closes bubble tight. All valves which are used to contain the predetermined volume in a measuring tank should be either normally closed or adequately interlocked to prevent mismeasurement in the event of power failure or instrument gas-supply failure. Limit switches or pilot control should be properly applied to these valves in order to provide such interlock control. In the measuring tank described as Type 1, Figure III, which uses a transfer pump to fill, the interlock must be provided between the delivery valve and the transfer pump power circuit.

5. Level Detectors. Level detectors need be only as sensitive as the particular system requires, but in all cases must be reliable. Level detectors which

control multiple circuits in the control and interlock system must be equipped with switches or pilots properly designed so that mismeasurement does not occur, even though maladjustment may develop.

6. Calibrated Volume. All valves which confine a measured volume and all level detectors which are within the measured confines of the vessel should be attached with a type coupling which will allow removal and replacement without altering the calibrated volume of the measuring vessel. Either shop or field calibration is acceptable.

DATA HANDLING

1. General. The ultimate in automatic volume measurement is the adaptation of fully BS&W compensated and temperature-compensated data readout. Temperature-compensated data readout is presently available to all measuring tank systems. Temperature averaging, BS&W averaging and gravity averaging equipment is currently available to measuring tank systems which when applied to a gross volume counter provide complete data readout and may eliminate the need for a proportional mechanical sampler. Many systems currently in operation employ the individual temperature recorded system with a gross dump counter. The latter systems require manually calculated volume-temperature corrections, but may be found adequate in many cases. A pressure-head recorder is very desirable as a gross volume check on the measurement cycle or in the event a mismeasurement occurs.

RECALIBRATION OF VESSELS AND COMPONENTS

1. Inspection and Volume Recalibration. A means of inspection should be provided on each measuring vessel. Vessels should be inspected periodically. Recalibration is not necessary unless inspection indicates that the volume obviously has been changed. Recalibration may be requested by either party.

2. Temperature Instruments Calibration. Temperature instruments shall be recalibrated at mutually agreed intervals using a certified test thermometer to

correlate two or more temperatures within the normal operating range. Correlation should check within 1% of the maximum range of the instrument. This calibration must be performed with the instrument temperature element and the certified test thermometer immersed in a temperature controlled liquid bath. Temperature instruments should be checked for proper adjustment at frequent intervals by simply comparing the recorder temperature reading with that of an approved ASTM or API thermometer during normal operation.

MINIMUM MEASURING TANK VOLUME

1. Maximum Capacity. The maximum capacity of the various measuring tank systems will be governed by the size of the measuring tank or tanks, the speed of response in the temperature system, the time required for proper elimination of entrained gas and adequate draindown. Care should be exercised in sizing the unit so that the time elapsed between the fill and dump cycle is sufficient to obtain a stabilized temperature reading.

2. Delivery Rate. The measuring tank system possesses the inherent ability to deliver at any rate up to the maximum capacity as determined above. This rate may be controlled throughout the capacity range by the ability of the transporting carrier to receive oil.

VENT SYSTEM

1. Vent Lines. Vent lines in the system should be of adequate size to prevent abnormal buildup of pressure or vacuum on any vessel in the system during any sequence in the operating cycle. Adequate protection against liquid movement through the vent system must be provided.

SECTION III - METER SYSTEMS - POSITIVE DISPLACEMENT METERING

INTRODUCTION

1. The purpose of this section is to outline and recommend acceptable and practical methods of obtaining reliable and accurate measurements of lease runs by means of the positive displacement meter system. The PD meter is a part of a system of devices arranged in a manner such that custody transfer of lease runs or other stocks can be automatically and continuously made while unattended.

2. This section discusses procedures and practices for meter selection, installation, operation, maintenance and calibration which are considered essential to accomplish the measuring accuracy and reliability required.

3. It is recommended that API Standard 1101 be used where portions of that standard are applicable. This section is not intended as an independent effort to standardize PD metering of crude oil but more as an adaptation of PD metering as one of the acceptable methods of obtaining the volume measurement for Lease Automatic Custody Transfer Service.

DEFINITION OF TERMS

1. Manner of Operation. Positive displacement meters are meters which measure a fluid by separating the fluid into segments and counting these segments. These meters displace or carry through their measuring elements a fixed quantity plus the slippage for each stroke, revolution or cycle of the moving elements.

2. Standard 1101. The terms pertaining to PD metering which are in common usage within the petroleum industry have been set out in the Introduction of API Standard 1101 and will have the same meaning and significance when used herein.

SELECTION OF POSITIVE DISPLACEMENT METERS

1. Data Needed. Each location and application of meters will require a certain amount of individual consideration. It is recommended that the following pertinent data be defined and analyzed before selecting a meter and planning an installation for a particular service:

a. Range. Range of operating rates of flow.

b. Pressure. Maximum pressure which meter will have to withstand.

c. Liquid Characteristics. Type of liquid or liquids meter will measure including viscosity, corrosiveness, RVP and API gravity.

d. Temperature. Ambient and fluid temperature range under which meter will operate.

e. Temperature Compensation. The applicability of automatic temperature compensation.

f. Abrasive Materials. The amount of abrasive and size of particles and water which will ultimately reach the meter.

g. Register. Type of register or printer desired.

2. Selection. After analysis of the foregoing data, the selection should be in accordance with the manufacturer's recommendations for a meter fulfilling the requirements.

3. Capacities. The meter manufacturers have established recommended flow rates for various sizes of meters of their manufacture and should be consulted for their specific recommendations.

INSTALLATION OF POSITIVE DISPLACEMENT METER SYSTEMS

1. General Arrangement. A recommended arrangement of equipment for automatically measuring lease runs by the positive displacement meter method is shown

in Fig. VIII. The location of each item of equipment should be such that it will properly perform the function for which it is intended depending on existing circumstances.

The schematic arrangement shown will provide satisfactory results under most conditions and is intended to be used only as a guide for meter systems installations. Under certain circumstances the arrangement of equipment should be altered to meet the requirements. For example, the choice of a three-way or a conventional valve to control flow to the pipeline will influence the location and arrangement of other items of equipment. The location of the monitor sensing element which detects nonmerchantable liquid must be such that it will be in the stream regardless of the type control valve selected. The sampler should be located in a position to adequately sample the custody transfer stream without influencing the accuracy of the meter measurement.

2. Specific Requirements. Some important considerations regarding meter installations are as follows:

a. Air Elimination. The installation should be such that air or gases will not be introduced into the system through holes, leaky valves, packing glands of pump shafts or connecting lines. In all installations which are conducive to the passage of air or gas, adequate air elimination equipment should be installed ahead of the meter. Such equipment shall in no case be of smaller rated maximum capacity than that of the pump or feed lines and shall provide complete air elimination, assuring a liquid-filled meter. Vapor outlet lines from air eliminators should be installed for suitable disposal of the vapor.

POSITIVE DISPLACEMENT METER SYSTEM

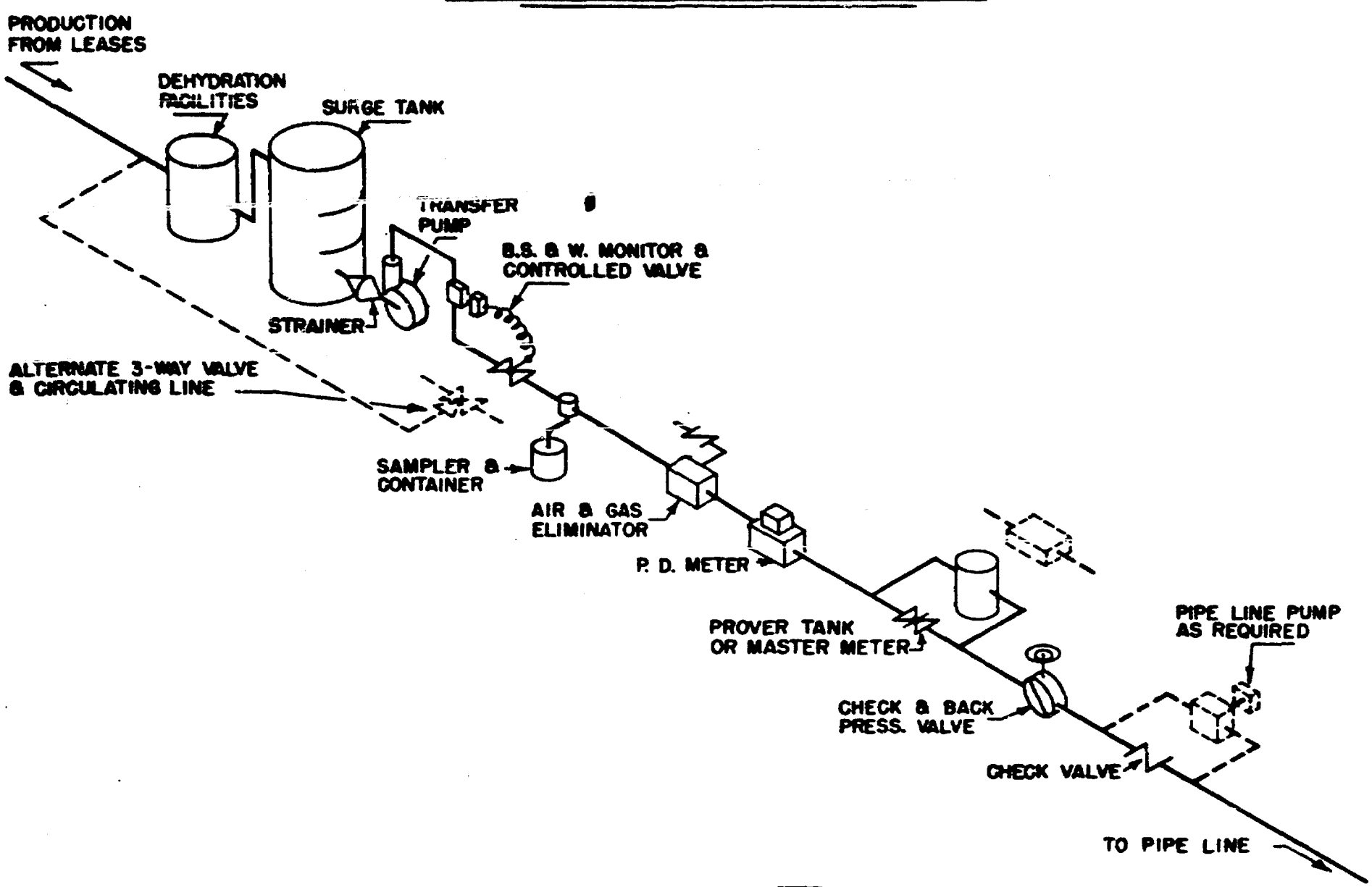


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FIGURE VIII

b. Flow Reversal. The piping system should be arranged to prevent reversal of flow of liquid through the meter.

c. Vaporizing of Stream. Any condition which tends to increase the turbulence of the system should be designed to minimize the possibility of vaporizing the stream.

d. Surges. Meters subjected to pressure pulsation or surges should be adequately protected by surge tanks, expansion chambers or similar devices; and no meter shall be subjected to shock pressures which are greater than its maximum rated working pressure.

e. Proving. Meter installations should be equipped with either manual or automatic means to permit proving at normal operating conditions.

f. Accuracy Range. All meter installations should be designed so that the flow rate through every meter is held between the maximum and minimum limits within which the desired accuracy is obtainable.

g. Bypasses. Any unmetered bypass around a meter or battery of meters shall be provided with a suitable means to prevent undetected flow around the meter.

3. Gross Check. A method should be provided for a gross check on the meter system to make certain that all liquid that passes the meter is indicated on the counter or printer. Some of the methods in use are:

a. Two meters in series.

b. Spot-gauging in tanks or comparison with production testing facilities.

c. Pulse counters on the meter.

d. Use of temperature or pressure recording instruments to detect flow through the meter.

METER PROVING FACILITIES AND PROCEDURES

1. Proving Facilities. Meter accuracy is dependent on the proving facilities provided, and the type of facilities required for accurate proving varies with several factors such as characteristics of the fluid, pressure or static head available, flow rates, and ambient temperature. Once adequate proving facilities are provided, then accurate proving procedures must be adhered to.

2. Methods. Methods of proving meters such as Master Meters, Portable Prover Tanks, or Prover Tanks permanently installed at the LACT installation, as outlined in API Standard 1101, should be used. The Automatic Custody Transfer Installation should provide a test spool or outlet for these alternate methods, should the parties concerned elect to use them.

3. Surge Tank for Proving. A suitable portion of the Surge Tank equipped with sight glasses, graduated scales and thermometers and calibrated by the water displacement method or by precise strapping method outlined in applicable API Standard may be used as a prover tank if agreeable to the parties concerned. The minimum capacity of the calibrated section of such prover should be ten times the maximum volume delivered per minute by the largest meter to be proved. The distance between the opening and closing levels and the provision for determining the opening and closing readings should be sufficient to detect variations of .05%.

4. Proving Frequency. The frequency of calibration should be determined by meter-factor behavior and the degree of accuracy required. It is recommended that PD meters be calibrated at least once per month.

5. Calibration Records. The calibration record for each meter should be kept on file as long as the meter ticket to which it applied. A copy of each official calibration record should be supplied by the meter owner to each party concerned.

c. Meter Factor Record. The ticket on which the metered quantity is reported should have space provided for the meter factor and the number of the calibration record which supports the meter factor on the ticket.

METER SYSTEM OPERATION

1. Procedures. To insure desired accuracy in the metered measurement of liquid hydrocarbons, it is essential that associated meter operating procedures and inter-party understandings and relationships in connection with metered transactions be understood and accepted by all concerned.

2. Degree of Accuracy. The degree of accuracy desired in each installation is the governing factor in determining the extent of operating control. As used in connection with Lease Automatic Custody Transfer Service, the greatest degree of meter accuracy should be sought. For successful meter operation the proving system shall provide complete flexibility, and in all cases the proving of meters should as nearly as possible simulate actual operating conditions.

3. Temperature Determination. The accurate operation of meters necessitates very careful handling of the various phases of metering which are affected by temperature. Obviously, precision temperature measurement is a prerequisite of precision metering, whether the temperature is determined by an independent thermometer or indirectly by means of an automatic temperature compensator. Providing a reliable automatic temperature compensating device can be procured for the meter used, this method of obtaining volumes at the base temperature of 60°F is more desirable than using some temperature indicating or recording device and then mathematically reducing indicated volumes to 60° F. In either case the coefficient of expansion used must be consistent with agreements between the parties concerned.

4. Operation and Maintenance. There are many details in the successful and accurate operation of displacement meters in the field which cannot easily be described in a text or manual but which are essential to good metering. They are items which the meter operator must acquire through training and experience in the field. They include such things as quality meter repair and maintenance work, elimination of human errors, the detection of leaking valves, recognition of air or gas troubles, flow rates, meter reading, temperature reading, etc. Operating practices outlined in API Standard 1101 are recommended as a guide for good metering results.

5. Basic Requirements. Basically, a PD meter system should be designed and operated such that it complies with requirements of paragraph 2, Section I, page 5.

6. Components. A suggested combination of major items of equipment to provide automatic measurement by the positive displacement meter method is shown in Figure VIII. The system, as shown, has no provision for automatically handling nonmerchantable liquid when it reaches the monitor and, therefore, requires manual attention under such circumstances. A system employing a recirculating system including a diverting valve by which nonmerchantable liquid can be treated is acceptable providing it is designed properly.

7. Recommended Sequence of Operation. Recommended sequence of operation will vary slightly depending on the type of pipe line facility connected and the operating schedule of the pipe line. Details should be worked out for each installation; however, the following is recommended as a guide for a system which does not make use of recirculating arrangement. Recommended sequence for:

a. Normal Delivery to a Gravity Flow Pipe Line - Nonscheduled Operation.

1. When the liquid level in the surge tank reaches normal high working level, the transfer pump starts and the controlled valve opens to the pipeline admitting flow through the meter.
2. When the valve reaches its open-to-pipeline position, the automatic sampler is energized and begins sampling.
3. Under normal conditions, delivery to the pipeline continues until the liquid level reaches the normal low level position.
4. Then, the controlled valve closes the pipeline outlet, the transfer pump stops and the automatic sampler is de-energized.

Non-Merchantable Oil Interruption. After the delivery to the pipeline has begun, should nonmerchantable oil flow continuously past the BS&W monitor for a predetermined time interval, the transfer pump is automatically stopped and:

1. The valve closes, stopping flow to the pipeline.
2. The automatic sampler is de-energized.
3. The controls should lock out the transfer equipment until the nonmerchantable liquid has been treated out to meet specifications.

b. Normal Delivery to a Pressurized Pipeline - Nonscheduled Operation.

1. When the liquid level in the surge tank reaches normal high working level, the transfer pump starts, the valve opens to the pipeline admitting flow to the meter.

2. When the valve reaches its open-to-pipeline position, the pipeline pump starts and the automatic sampler is energized.
3. Under normal conditions, delivery to the pipeline continues until the liquid reaches the normal low-level position.
4. Then the valve closes the pipeline outlet and the transfer pump stops.
5. The pipeline pump is shut down and the sampler de-energized.

Non-Merchantable Oil Interruption. After the delivery to the pipeline has begun, should nonmerchantable oil flow continuously for a predetermined time interval past the BS&W monitor, the delivery shall be automatically interrupted;

1. The valve shall close.
2. The pipeline pump is shut down and the sampler is de-energized.
3. The controls should lock out the transfer equipment until the nonmerchantable oil has been treated out to meet specifications.

c. Normal Delivery to a Pipeline - Scheduled Operation. Some pipeline systems are operated on a schedule whereby it is desirable to admit delivery only during a certain interval of time. For this condition the operation sequence should be the same as for nonscheduled delivery except that a time-interval controller shall be added to the circuit which overrides the normal high-working level control.

API Bull. 2509A
August 1956

API BULLETIN

ON

LEASE AUTOMATIC CUSTODY TRANSFER

Prepared by Special Project Group on Lease Automatic Custody Transfer
under the auspices of the American Petroleum Institute's
Committee on Crude-Oil Measurements

For general information only.
This is not an API Standard.

#5

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50 West 50th Street
New York 20, N. Y.

Price $1.00

CONTENTS

FOREWORD

This bulletin, which has been prepared under the sponsorship of the API Committee on Crude-Oil Measurements, summarizes information that has been gained from a study of the experimental and operating systems devised by various companies for automatic custody transfer of crude oil from producing leases. "Automatic custody transfer" consists of the measurement and running of oil from the producers' tanks to the connected pipeline on a completely automatic or unattended basis. To date, the relatively small number of experimental installations do not permit a firm standardization of acceptable practices. This bulletin should therefore be considered as a progress report, issued for the purpose of: 1, advising producing and pipeline companies of what is currently known; and, 2, stimulating further development until generally acceptable methods are in use.

Throughout this bulletin, references are made to *API Standard 2500: "Measuring, Sampling, and Testing Crude Oil"; API Standard 2501: "Crude-Oil Tank Measurement and Calibration"*; and *ASME-API Code 1101: "Code for the Installation, Proving, and Operation of Positive-Displacement Meters in Liquid-Hydrocarbon Service"* (short title: *Petroleum PD Meter Code*). It is intended that these codes be used in all cases where they are applicable, in order to form a sound basis for accomplishing satisfactory automatic custody transfer.

Until a few years ago, all crude oil run from producers' tanks was measured, sampled, and tested by the use of hand tools. For about 30 years the American Petroleum Institute has continuously studied and improved these methods to make them as practical and accurate as possible. In 1954 the Institute approved the use of automatic indicating gages and thermometers on a mutual-agreement basis, and industry is finding them to be accurate and preferable to hand tools in many instances. In recent years, producers have installed automatic devices at lease tank batteries in quite a few fields to eliminate certain monotonous and time-consuming operations. The potential advantages of automatic-custody-transfer systems have led a number of producing and pipeline companies to test the components of which such systems could be made. Also, several companies have constructed and tested full-scale installations of complete automatic-custody-transfer systems.

In many fields it has become apparent that automatic custody transfer offers the potential advantages of:

1. Reduction in required lease storage (which could also mean less evaporation losses and less investment in stored oil).
2. Improvement of measurement accuracy.
3. Reduction of the possibility of error in measurement or in quantity computation.
4. Simplification of computation and accounting procedures.
5. Reduction of time required by pumpers and gagers in making measurements.
6. Improved scheduling of runs on a predetermined basis and made at the most opportune time.
7. Allowing maximum use of other automatic equipment installed primarily for the production operations.

The apparent disadvantages are:

1. Lease equipment needs more precise design and engineering.
2. A more complex system is required.
3. Regular maintenance is required.

The information in this bulletin has been based on evaluation of the experimental automatic-custody-transfer installations which have so far been tested. The practices which it suggests are considered sound and reliable but, since they are based on a limited number of installations, it should be expected that many improvements in these procedures will result from more widespread use of automatic-custody-transfer equipment.

Early standardization of industry practice relating to methods and equipment used in automatic custody transfer is very desirable for three principal reasons: 1, to facilitate establishment of mutual agreement between parties concerned in automatic custody transfer; 2, to reduce the amount of engineering

time required in design of automatic-custody-transfer installations; and, 3, to facilitate the periodic inspection of automatic-custody-transfer installations for assurance of their continued satisfactory performance. It is hoped that the information contained in this bulletin will be of assistance in establishing mutual agreement between parties interested in installation of systems operating in automatic custody transfer, and that in so doing it will be of benefit to the industry by leading toward the early establishment of generally accepted good practice.

The material contained herein does not constitute an official code or standard of the American Petroleum Institute; nor is it intended that this material should become part of *API Standard 2500* until such time as industry practice may have become established, and the principles outlined in this bulletin and other principles which may develop in practice have been more generally proved.

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, nothing contained in this bulletin grants any right, by implication or otherwise, for the 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 bulletin may be used by anyone desiring to do so, but the sponsor 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.

LEASE AUTOMATIC CUSTODY TRANSFER

I—GENERAL

This bulletin is intended to form a basis for mutual agreement between parties concerned in automatic custody transfer of crude oil from producing leases to the connected pipeline. It sets out practices which are intended to provide accurate and reliable measurement and suitable protection against mismeasurement or otherwise faulty operation. Automatic custody transfer, as defined herein, may be used where mutually agreeable to the parties concerned in the transaction and where government or other regulations will permit. This bulletin may also serve as a guide for the installation of equipment to be used in intra-company measurement and in transfer of crude oil on leases or from leases to gathering systems to points of central storage, where regulations permit.

These suggestions are not meant in any way to be restrictive or to retard development of methods found to be either more suitable or more practical than those suggested. Instead, it is hoped that these recommendations will serve as a starting point from which improvements can be made, as developments in equipment and methods warrant.

II—DEFINITIONS

Automatic custody transfer—The automatic determination of quantity and quality* of crude oil in conjunction with the automatic running of that oil into the connected pipeline on an unattended basis and in accordance with any predetermined schedules required.

Cycle—Filling and running of one measuring tank.

Dump—That volume of oil (corrected or uncorrected for temperature) which is delivered to the pipeline in one complete cycle of the measuring tank, or the running of that volume of oil.

Run—A series of dumps or periods of meter measurement, either interrupted or uninterrupted, which are covered by a single run ticket.

III—BASIC SYSTEM REQUIREMENTS

A. General

There are a great number of basic alternative arrangements which could be used to accomplish automatic custody transfer with satisfactory results. It is the purpose of this section to describe the basic requirements that should be met by all systems and to describe some of the various arrangements of equipment for volume measurement which are considered to fulfill these requirements. Optional features which may be desirable under certain conditions are described where appropriate. For convenience, the basic systems are categorized according to the method used for measurement of volume. Briefly, these methods are: 1, parallel-tank measuring; 2, tandem storage with single measuring tank; and, 3, positive-displacement metering.

B. Requirements for All Types

The following list contains the general requirements of any system for automatic custody transfer. Some features are indicated as optional, or to be used by mutual agreement where conditions warrant; and others are applicable where required by regulations.

1. The lease oil handling arrangement must provide ample time for settling to insure that the oil, when measured, is sufficiently stable and free from volatile fractions to permit accurate measurement and, later, conventional

* For the purpose of this bulletin, automatic determination of quality includes any necessary assurance that the oil is merchantable prior to movement of oil from the lease, and automatic sampling for subsequent measurement of quality.

handling and storage without abnormal or excessive losses. The time required for settling is subject to mutual agreement. Depending upon local conditions and the equipment arrangement selected, normal filling or residence time in the system may be ample.

2. Provision must be made for accurate determination and recording of uncorrected volume and average temperature, or of temperature-corrected volume. The overall accuracy of the system must equal or surpass present manual methods.

3. Provision must be made for representative sampling of the oil transferred for determination of API gravity and the BS&W (sediment and water) content.

4. Means must be provided, if required by mutual agreement, to give adequate assurance that the oil is merchantable before it is run.

5. If required by mutual agreement, control shall be provided over the time of oil entry into the system of the purchaser or his agent.

6. Where regulations require, control shall be provided to stop the flow of oil into the system of the purchaser or his agent at the time, or prior to the time, the allowable is run. To eliminate need for partial dumps from systems using tank measurement, this would normally provide for stopping after the last complete dump which could be made without exceeding the allowable. The correction from the preceding period for the difference between the net oil run and the allowable would be applied to the current allowable control setting.

7. The control and recording system must include "fail-safe features" that will provide adequate assurance against mismeasurement in the event of power failure or the failure of the system's component parts.

8. All necessary controls and equipment must be enclosed and sealed, or otherwise be so arranged as to provide assurance against, or evidence of, accidental or purposeful mismeasurement resulting from tampering.

9. All components of the system which require periodic calibration and inspection for proof of continued accuracy must be accessible and arranged for calibration and inspection at a frequency and following a procedure mutually agreeable to the parties concerned.

10. All usual codes, regulations, and standards covering measurement of crude oil shall be used where applicable. This specifically includes *API Standard 2500, API Standard 2501,* and *ASME-API Code 1101.*

C. Equipment Arrangements

The following general equipment arrangements are suggested as satisfactory for measurement of volume.

1. Volume Measurement in Tanks

Either of two tank arrangements are satisfactory for automatic custody transfer, namely: 1, parallel measuring tanks; or, 2, a single measuring tank in tandem with surge or storage tankage.

The capacity of the measuring tank between the upper and lower control levels can be determined by strapping or by means of liquid calibration. Means should be provided for the accurate checking of control levels to determine whether the level controllers are functioning properly.

The following basic methods are suggested for automatic measurement of volume by tank:

a. *Fixed Volume—Weir-Controlled* (See Appendix 1, Fig. 1 and Fig. 5): With this arrangement, the opening and closing levels are established by draining down to the lip of a weir box. The opening gage is established by first filling to a point slightly above the upper-weir level. After a mutually agreed interval, during which the oil should be properly weathered and the surface of the oil settled and calm, and/or at whatever time the run-scheduling timer will allow oil to be run to the pipeline, the oil will be drained down to the upper-weir level. Simultaneously, the temperature of the oil in the tank will be measured and recorded.

The tank then will open and remain open to the pipeline long enough to assure complete draindown to the lip of the lower weir. At this point the pipeline valve will close and, simultaneously, the temperature of the oil remaining in the tank will be recorded, if required by mutual agreement. The control of levels by use of this weir arrangement is considered to be inherently very sound.

b. *Fixed Volume by Reduced Cross-Section Area:* While as yet untested in automatic-custody-transfer operations, the use of tanks having reduced cross-sectional areas at the desired upper and lower liquid levels has sufficient merit to warrant inclusion in this bulletin. Standard prover tanks for calibrating PD (positive-displacement) meters have used this principle in accurate volume meas-

urement for many years. In recent years, this idea has also been used in metering vessels, particularly for testing oil wells; and indications are that it can be used for the accurate measurement of crude oil.

There are actually two methods for using this type of tank which should prove satisfactory in automatic custody transfer. The first and simplest method is to use the level switches located in the reduced cross-sectional areas to control the full and empty levels by causing the inlet and outlet valves to close. It is essential that this type of measuring tank be equipped with very fast-acting valves to reduce the amount of delay between the time the level switches are actuated and the time the liquid flow has stopped. Means may also be used to reduce the inflow and outflow rates to regulate the overshooting of the control level. The second method operates in a manner exactly like that of tanks using weirs to control levels and is suggested as probably the most accurate method for controlling volumes by level control. This system should combine the high accuracy of both the weir and the reduced cross section.

c. *Varying Volume—Float and Tape:* Float-and-tape (automatic gage) measurement is approved by the American Petroleum Institute as a substitute for manual gaging. This type of measurement appears readily adaptable to automatic custody transfer by an automatic recording of the liquid levels after automatic filling or emptying. Temperature measurement would be necessary at the time of top-level measurement and, in some instances, at the time of bottom measurement. To date, the recording mechanism for the float-and-tape measurement systems has not been tested in automatic custody transfer. This system would have the advantage of facilitating manual or partial runs if required in an emergency.

2. Volume Measurement by Positive-Displacement Meter

a. *Introduction:* The purpose of this section is to outline an acceptable and practical method for obtaining reliable and accurate measurements of lease runs for automatic custody transfer by means of the PD meter. The meter is to be a part of a system of devices arranged in such a manner that custody transfer of lease runs can be automatically made while unattended. This section and Part C of Appendix 1 outline procedures and practices for meter selection, installation, operation, maintenance, and calibration, which are considered essential to accomplish the measuring accuracy and reliability required.

To avoid duplication and prevent confusion, it is considered advisable to make use of *ASME-API Code 1101* where portions of that code are applicable to the type of measurement under consideration.

b. *Types of Meters and Definition of Terms:* PD meters are meters which measure a fluid by separating the fluid into segments and count these segments. These meters displace or carry through their measuring elements, a fixed quantity plus the slippage for each stroke, revolution, or cycle of the moving elements. The terms pertaining to PD metering which are in common usage within the petroleum industry have been set out in the introduction of *ASME-API Code 1101*, and will have the same identical meaning and significance when used in this bulletin. The meter used should be of a type specifically recommended for crude-oil service.

c. *Arrangement of Meter Facilities:* In general, volume-measurement equipment for automatic custody transfer by PD meter consists of tankage for adequate storage with a meter placed in the line discharging from this tankage to the pipeline. If a pump is used for injection into the pipeline or for recirculation of bad oil and/or tank bottoms, it is suggested that the pump be placed upstream of the meter, with a back-pressure valve located downstream of the meter in order to decrease the possibility of metering free gas.

Under certain conditions it is possible that a pump may not be required. It is essential in this case that the system be so designed as to provide an adequate head at the meter, and to provide a sufficiently constant flow through the meter to insure that the rate of flow is in the accurate range of the meter.

The sampler used in obtaining a representative sample of the metered oil should be placed as near the meter as practicable. A monitor may be connected in the line between the sampler and production tank and used to prevent objectionable quantities of BS&W from being delivered to the pipeline, if re-

quired by mutual agreement. A check valve should be used to prevent reversal of flow through the meter. A typical arrangement of equipment and auxiliary controls considered satisfactory for automatic-custody-transfer measurements by PD meters are discussed in Part C of Appendix 1, and are shown in detail in Fig. 7.

IV—EQUIPMENT AND INSTALLATION STANDARDS

A. General Standards, Codes, and Regulations

All existing American Petroleum Institute codes and other codes and government regulations shall be used where applicable in design, construction, calibration, and operation of systems for automatic custody transfer.

B. Control Equipment

Control equipment may be electric, pneumatic, or hydraulic. Components should be high-quality materials which are resistant to moisture, corrosion, and dust.

C. Valves

Valves should be of a type that assure tight shutoff; it is preferred that the valve actuators be of a type, or so arranged, that they will permit interruption of the power supply without causing mismeasurement.

D. Weirs

Weirs for level determination may be either internal or external to the tank. In either case, the lip of the weir should be horizontal and sufficiently long to allow reasonably quick draindown to the fixed level. For external weirs, the top of the opening from the tank should be just above the weir edge for maximum utilization of the tank-opening area and for assurance that syphoning or vapor lock will not occur. The weirs should be firmly fixed to the shell of the tank and adequately braced, so that the vertical distance between the upper and lower weirs remains constant.

E. Counting Devices

Particular attention must be given to the methods used for recording the number of dumps from measuring tanks, so that false counts will not result from interruptions in power. It is recommended that at least two independent methods for counting dumps be utilized. A pressure-recording instrument for recording the "head" in the tank at all times is of a particular value, since it will not only provide a check on the number of dumps made, but will also provide a record of the time the tank takes to fill and empty when it tops out and goes on the line. It also provides evidence that the tank fills and empties completely during each cycle.

F. Meter Installation, Operation, and Proving

Each location and application of meters will require a certain amount of individual consideration and, in general, *ASME-API Code 1101* is used as a guide for the installation, operation, and proving of meters.

Methods for proving meters, such as by master meters or portable prover tanks, as outlined in *ASME-API Code 1101*, may be used by mutual agreement. The automatic-custody-transfer installation shall provide a test spool or outlet for these methods, should the parties concerned elect to use them.

Alternatively, the surge tank may be used as the prover tank, if the following described conditions can be met. A suitable portion of the surge tank should be equipped with sight glasses, graduated scales, and thermometers. The surge-tank portion to be so used should be calibrated by water displacement or other methods yielding equivalent accuracy. The minimum surge-tank capacity so used is established by two factors. First, the diameter should be sufficient to provide the required volume within limits fixed by the second factor; namely, that the value of the maximum gage-glass reading error, when expressed as a percentage of error by volume ratio in terms of depth of surge tank so used, shall not exceed 0.05 per cent by volume, thus establishing the minimum depth of surge tank required. (In general, it is suggested that the minimum surge-tank capacity so used should be not less than ten times the maximum rated volume delivered per minute by the largest meter to be proved. It is also suggested that if the surge tank is to be cali-

brated by field-strapping methods, the portion of the surge tank used should be free insofar as possible from appreciable changes in volume per increment, caused by items such as manhole boxes, significant intermediate deadwood displacement, etc.)

The suggested frequency of calibration should be such that a deviation of meter factor of 0.05 per cent will be detected.

The calibration record for each meter should be kept on file as long as is the run ticket on which it applies. A copy of each official calibration record should be supplied by the meter owner to each party concerned.

To insure satisfactory accuracy in the metered measurement of liquid hydrocarbons, it is essential that associated meter-operating procedures and interparty understandings and relationships in connection with metered transactions be understood and accepted by all concerned.

The degree of accuracy desired in each installation is the governing factor in determining the extent of operation control. As used in connection with lease automatic-custody-transfer service, the greatest degree of meter accuracy should be sought. For successful meter operation, the proving system shall provide good flexibility, and in all cases the proving of meters shall, as nearly as possible, simulate actual operating conditions.

The accurate operation of meters necessitates very careful handling of the various phases of metering which are affected by temperature. Obviously, precision temperature measurement is a prerequisite of precision metering, whether the temperature is determined by an independent thermometer or indirectly by means of an automatic temperature compensator. Providing a reliable automatic temperature-compensating device can be procured for the meter used, this method of obtaining volumes at the base temperature of 60 F is more desirable than using some temperature-indicating or recording device, and then mathematically reducing indicated volumes to 60 F.

In either case, the coefficient of expansion used must be consistent with agreements maintained between the parties concerned.

V—FAIL-SAFE FEATURES

Fail-safe features and interlocks should be included in the design of an automatic-custody-transfer installation to provide reasonable assurance against mismeasurement.

Insofar as any possible mismeasurement is concerned, the producer must install fail-safe features as requested by the purchaser or his agent. The producer can also install, upon mutual agreement with the purchaser or his agent, other fail-safe devices which he considers necessary to prevent mismeasurement.

A. Suggested Fail-Safe Features

1. Sequence of operation of measuring cycle should be retained in event of power interruption.

2. The valves and control system should be interlocked with the inlet valve and float controls so that it is impossible to open the inlet valve on a tank at any time when this would interfere with accurate measurements.

B. Optional Fail-Safe Features

The producer may install other fail-safe features which he deems necessary to the automatic operation of the lease, provided they do not interfere with accurate measurement, such as:

1. An overflow line above the normal upper-fill height in the measuring tank to provide for overflow of oil into an overflow tank in the event of failure of the upper-level control device.

2. An overflow tank arranged so that oil cannot flow from this tank through an open line into a measuring tank.

3. An upper float in the overflow tank or the measuring tank to initiate lease shutdown controls and actuate an alarm in the event oil reaches the level of the float switch.

4. Manually operated valves may be installed in the discharge line on the downstream side of the discharge valve on the metering tank or tanks. Such valves should be sealed in the open position and used only in case of emergency.

VI—EQUIPMENT ENCLOSURES AND SECURITY

Control equipment should be housed and locked or sealed, if necessary. Automatic valves shall be of such design and so connected that operation can only be accomplished through locked or sealed control equipment.

The producer must install such enclosures and tamperproof devices as required by the purchaser or his agent. In addition to these devices, he may install other tamperproof devices, provided that they do not interfere with accurate measurement.

VII—QUALITY MONITORING

A. Protection against Excessive Water Admission

Deliveries from an automatic-custody-transfer installation are made on an unattended basis, and the samples taken for determination of gravity and BS&W content are not analyzed until the run has been made. For this reason, where there is any reasonable probability that excessive water might be run, e.g., as a result of failure or faulty operation of the dehydration facilities, it is considered advisable to install special equipment to guard against admission of such excessive water into the pipeline.

The type and amount of equipment or procedures selected to provide adequate protection are subject to mutual agreement between the parties concerned, and are generally dependent upon the likelihood of occurrence of objectionable quantities of water, and the limit of BS&W content specified by contract.

B. Protection against Running Bad Oil

The following are suggested methods, procedures, and equipment which can be used singly or in combination to afford protection against running bad oil:

1. A water-cut instrument (dielectric monitor) based on measurement of dielectric constant of the measured stream can be installed in the line to the measuring tank or meter and/or to the pipeline, and used either to divert oil containing excessive water back to the dehydration system for further treating, and/or to stop the flow of oil to the measuring tank or meter or to the pipeline.

2. On tank-measuring systems a dielectric monitor can be installed to monitor a stream taken from a point 4 in. below the pipeline outlet prior to the running of the tank; and the monitor can be set to prevent running if the water content is above a preset limit.

3. On tank-measuring systems where oil is extracted from the measuring tank and circulated past an automatic sampler, a dielectric monitor can be installed to monitor the oil so extracted and can be set to prevent running and, if desired, to recirculate the oil in the tank if the water content is above the preset limit.

4. To prevent buildup of tank bottoms to an objectionable level, it is suggested that bottoms be circulated back to the dehydration facilities as required by the rate of buildup. This can be done manually on a routine basis, or automatically by recirculation of total bottoms or a portion thereof after each dump or run, or on signal from a bottoms dielectric monitor or another suitable bottoms-sensing device.

C. Calibration and Recalibration

A dielectric monitor shall consist of a device or instrument designed to measure the dielectric constant of the fluid between the electrodes of a probe mounted in the flowing stream. It shall be calibrated in units of per cent BS&W, and shall have a full-scale range not to exceed 5 per cent of BS&W. Although the overall field-calibration checks shall be made against readings of the centrifuge, the instrument should be equipped to allow simple field checking of its internal calibration or operation by switching to one or more self-contained, standardizing, zero-temperature-coefficient capacitors for calibration reference. The instrument shall be of a type which measures true dielectric constant, independent of fluid electrical losses, in order that the effect of salinity of the water content shall not affect the instrument reading. Since the dielectric-constant reading is affected by the temperature* of the measured stream as well as by the per cent of BS&W, suitable temperature compensation should be used where stream temperatures are expected to vary appreciably. The instrument shall not

* Data, to date, indicate that without compensation, a fluid temperature change of 30 F can be expected to result in a change of calibration equivalent to approximately 0.35 per cent of BS&W.

be affected adversely by reasonable or expected variations in supply voltage or frequency or ambient temperature.

To date, data have shown that readings taken on oil which is not moving through the probe tend to drift upward to a false high reading after the probe is energized. Caution should be taken, therefore, to ensure either that the oil is moving through the probe, or that the readings are taken immediately after the probe has been energized. Movement of oil through the probe at some velocity may also serve to keep the probe clean.

The initial instrument calibration shall be made in conformance with the manufacturer's recommendations, and should be based on measurement of the base dielectric constant of a clean, fresh sample of the specific crude to be measured.

Adjustment of the zero-setting for initial field calibration after installation and for all subsequent field recalibration shall be made on the basis of measurement of the BS&W content of the crude by centrifuge, according to *ASTM Method D 96-46*. Readjustment of the span setting, if required, shall be made by checking against the instrument's reference capacitors.

Recalibration as described hereinbefore may be made at mutually agreed intervals or may be requested at any time by either party, if the instrument readings should deviate more than a mutually agreed amount from the BS&W content measured by the field-centrifuge method.

Probe materials should be selected to resist corrosion by the measured fluid. The coaxial cable used to connect the probe and instrument should conform to the recommendations of the manufacturer and should be selected for minimum ambient-temperature error.

VIII—RUN SCHEDULING

A. Scheduling for Pipeline Load

Pipelines must prorate their capacity equitably among all connected leases. Therefore, in many areas where line-load factors are high, special care must be exercised in scheduling automatic deliveries. There are so many factors present in this problem that no attempt will be made to discuss them here. Any producer contemplating the installation of an automatic-custody-transfer battery should confer with representatives of the receiving carrier. They should work out a system of scheduling which would be mutually agreeable and advantageous to each. Some considerations are:

1. Determine the periods when line capacity would be available.

2. Correlate producer's ability to have oil ready with line-space availability.

3. Determine how many barrels per hour can be received by the pipeline.

4. Determine how much time will be required for each tank dump; determine total time-cycle sequence from tank empty, to full, to empty.

5. Correlate items 3 and 4.

It is likely that automatic scheduling should generally improve pipeline-load factors.

B. Stopping at Allowables

Receiving carriers are held responsible by regulatory bodies for keeping runs from leases within the allowable, where allowables are applicable; and, therefore, such carriers must have assurance that the runs from automatic-custody-transfer batteries do not exceed the lease allowable. Any accurate and reliable system may be used, however, should it meet the following specifications:

1. It must be fail-safe, tamperproof, and sealable in such a way that neither the pipeline's nor the producer's representatives could change the setting without the consent and knowledge of the others.

2. It must be able to be preset for the number of tank dumps, or barrels, in the case of PD meters, that will approach but not exceed the lease allowable in barrels as measured by the system (temperature-compensated or not temperature-compensated).

3. When the preset number of barrels or tank dumps is reached, the system must prevent any further movement of oil from the lease.

4. It must be adjustable in order to take care of allowables changes. Such changes should be made only when representatives of both parties are present.

5. Counters should be visible so that oil deliveries can be checked at any time.

IX—SAMPLING

Samples for determination of API gravity and BS&W content shall be obtained by use of automatic sampling equipment and by procedures as described and set out in *API Standard 2500*. Samples may be commingled during the period of a complete run, provided that the resulting sample is truly representative of the total volume run.

For systems measuring volume either by tank or by PD meter, samples may be taken from the tank just prior to opening the pipeline outlet, provided that the variation in volume measured in consecutive dumps does not exceed approximately 5 per cent. Such samples may be commingled for those consecutive dumps constituting a complete run.

Alternatively, for systems measuring volume either by tank or by PD meter, samples may be taken from the tank-discharge stream to the pipelines, provided that the variation between the rate of sampling and the rate of tank discharge does not exceed approximately 5 per cent.

The number and location of tank-sampling points will depend upon the tank size and, in regard to location and dimension, shall conform with the requirements of *API Standard 2500* for installation of sample cocks. Where more than one sample tube is located in the tank, the samples from all tubes (except the clearance sample or monitor tube 4 in. below the pipeline outlet) may be commingled, provided that the sampling equipment is arranged to withdraw equal sample volumes from each tube. By mutual agreement, purging of the sample tubes and sampler will not be required prior to each dump or run, provided that the volume contained by these lines does not exceed 5 per cent of the accumulated sample volume for the complete run.

X—TEMPERATURE MEASUREMENT

Temperature measurement for correction of volume measured by tank or un-temperature-compensated PD meter to standard temperature shall be made in accordance with *API Standard 2500*, "Part IV—Automatic Temperature Devices." Temperature compensation for temperature-corrected PD meters shall conform with *ASME-API Code 1101*.

For measurement by tank, the temperatures measured at the same time that the upper level is measured may be averaged for consecutive dumps in a computation of the corrected volume for the complete run, provided that the variation in uncorrected volume between any dumps in a run does not exceed 5 per cent. By mutual agreement, temperatures of the oil remaining at bottom gage may be required for bottom-gage temperature correction.

For temperature correction of uncompensated PD-meter volumes, the temperature may be taken in the tank just prior to opening to the pipeline through the meter and may be averaged for computation of net volume for the complete run, provided that the volumes run through the meter after each such temperature measurement do not differ by more than 5 per cent.

Alternatively, the temperature in the line at the meter may be recorded and averaged as hereinbefore, provided that the conditions are the same as those described, and provided that the rate of delivery does not vary by more than 5 per cent.

Alternatively, for measurement of variable rates of flow with PD meter and/or variable duration or volume of flow for each flow period, the temperature chart may be driven by the meter, and the average temperature integrated with respect to flow.

Temperature charts, in certain cases, may serve as a secondary check on the count of the number of dumps made in the run.

XI—PRESENTATION OF MEASURED INFORMATION

The method and procedure for recording the measurements obtained by the automatic-custody-transfer system and those measurements taken manually at the end of each run, the procedure for computing net volume, and the manner and form for presenting the resulting information on a suitable run ticket and for storing any records or charts made by the automatic system shall be determined by mutual agreement and shall comply with any applicable regulations. In general, it is suggested that the procedures used be as simple as possible, and that they be compatible with conventional run tickets and usual accounting procedures. There are several methods of recording dumps, temperatures, etc., now being used in connection with automatic-custody-transfer installation, and others are being developed. Eventually, general practice will probably resolve many of the differences; however, until some trend is more clearly established, it is believed desirable to continue the use of the conventional run ticket.

APPENDIX 1

TYPICAL DESIGNS

This section contains diagrams and descriptions of typical arrangements of equipment for accomplishing automatic custody transfer based on the suggestions outlined in the preceding sections of this bulletin. Three typical arrangements are included, one for each of the basic methods described: A. Parallel-Tank Measuring System, B. Tandem-Tank Measuring System, and C. Positive-Displacement Meter System.

These descriptions are intended only to illustrate the basic methods by providing an example of each. They are not meant to be restrictive or to indicate in any way that the methods shown are preferred to others which have been, or will be, developed to accomplish the same basic ends.

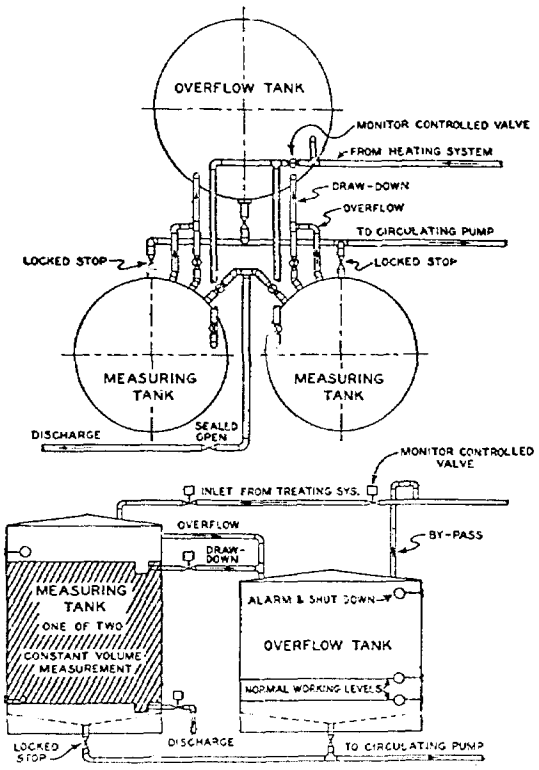
The first two of these systems have been built and are operating satisfactorily. The third, covering the use of the PD (positive-displacement) meter, although it is not in operation in exactly this form, is an adaptation of crude-oil metering systems which are operating satisfactorily in similar service.

A. Parallel-Tank Measuring System

A suggested combination of major items of equipment to provide two parallel, alternatively filled and emptied tanks with weir-controlled, constant-volume measurement is shown in Fig. 1. Use of electrically operated valves and controls does not preclude use of pneumatically or hydraulically operated valves and controls, if mutually acceptable.

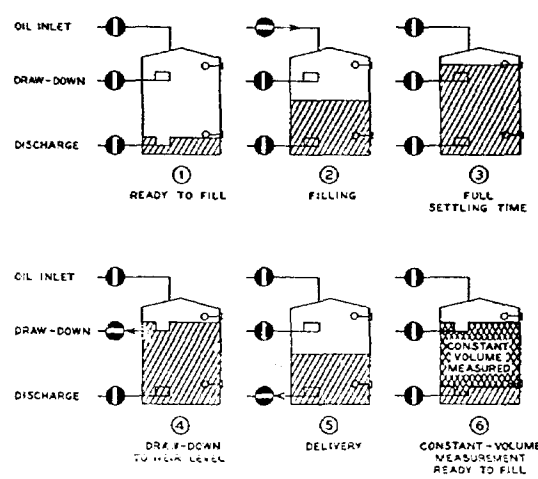
The typical sequence of operation, as shown in Fig. 2, is: 1, tank ready to receive oil; 2, filling; 3, full with incoming oil diverted into empty parallel tank, settling of oil; 4, drawdown of oil over upper weir to establish exact known top gage, activation of temperature recorder; 5, opening of discharge valve, starting of delivery, activation of sampler; 6, oil withdrawn over lower weir to establish exact known lower gage, closing of discharge valve, delivery and sampling completed, tank ready to again receive oil.

Suggested wiring and control equipment is shown in Fig. 3. Basic control for sequence



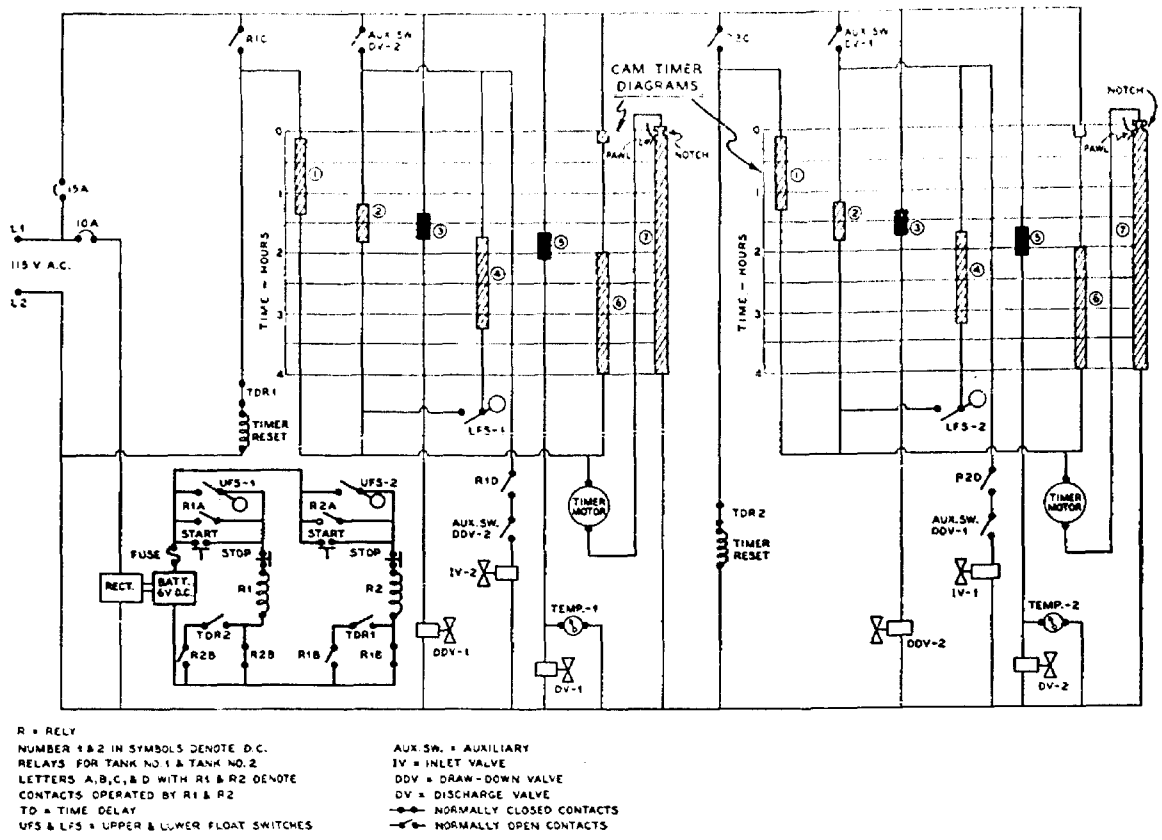
Schematic Diagram of Parallel-Tank Measuring System with Weir-Controlled Constant Tank Volume.

FIG. 1



Parallel-Tank Measuring System with Weir-Controlled Constant-Volume Measurement; Sequence of Operation in One Tank.

FIG. 2



R = RELY
NUMBER 1 & 2 IN SYMBOLS DENOTE D.C. RELAYS FOR TANK NO. 1 & TANK NO. 2
LETTERS A, B, C, & D WITH R1 & R2 DENOTE CONTACTS OPERATED BY R1 & R2
TD = TIME DELAY
UFS & LFS = UPPER & LOWER FLOAT SWITCHES
AUX. SW. = AUXILIARY
IV = INLET VALVE
DDV = DRAW-DOWN VALVE
DV = DISCHARGE VALVE
NORMALLY CLOSED CONTACTS
NORMALLY OPEN CONTACTS

Wiring Diagram of Parallel-Tank Measuring System.

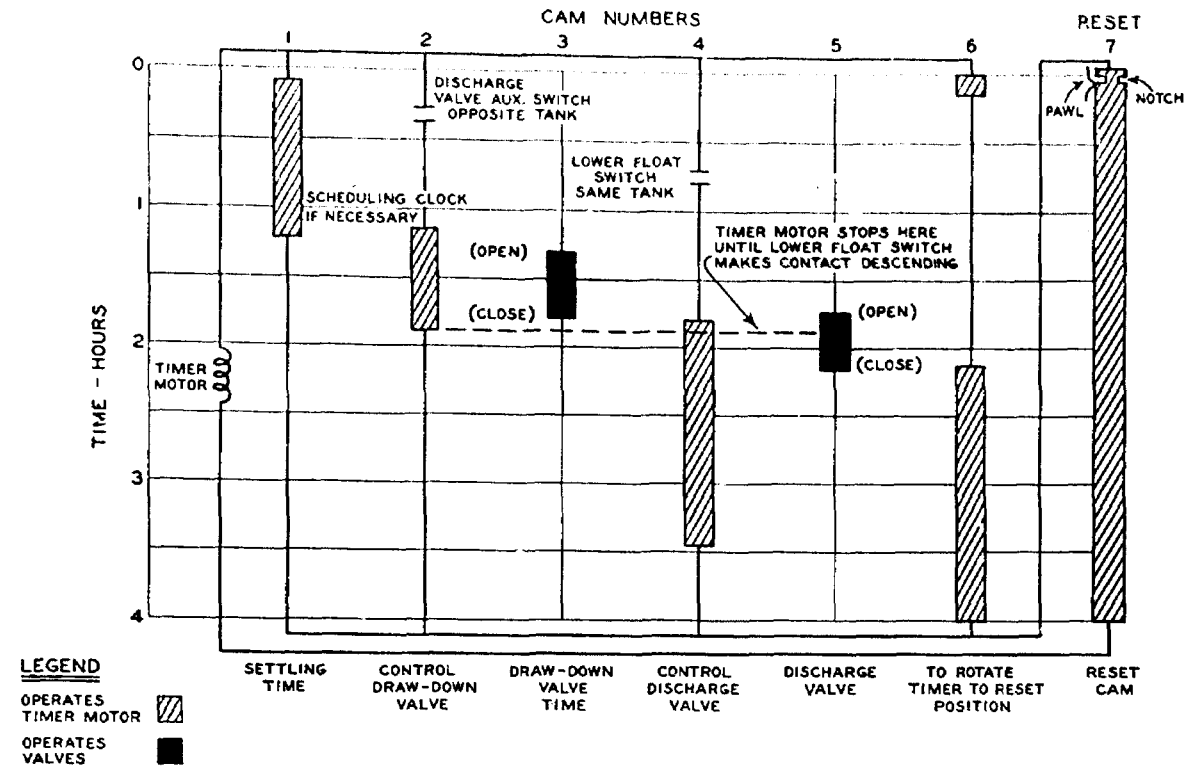
FIG. 3

of operation is obtained through use of a multicam timer (Fig. 4). The function of each cam and the time in which that cam is effectively controlling the operation are also shown.

When the oil in a tank filling reaches the upper float, the inlet valve is closed on that tank, and the inlet valve on the opposite tank is opened. Also, the multicam-timer motor is started. No. 1 cam controls the length of settling time; No. 2 cam provides drawdown valve control; and No. 3 cam regulates the time between opening and closing of the drawdown valve. At the time that the drawdown valve closes the discharge valve is opened and rotation of the temperature-recorder chart is started. Cam No. 4 takes over the control of the discharge valve, and cam No. 5 regulates the operation of the discharge valve. The timer motor is stopped shortly after the discharge valve is opened to allow for a non-determinable time, such as might occur in a gravity delivery. The motor is again started through the action of the float switch set immediately above the lower weir. At a predetermined interval after the lower float switch makes contact, the discharge valve closes. The measuring cycle being completed and the tank again ready to receive oil, cam No. 6 rotates to reset position. If necessary, a scheduling clock can be incorporated into the system before drawdown valve control in order to permit scheduling of deliveries.

The minimum fail-safe features included in this design are as follows:

1. Valves are of "normally closed" design.
2. Sequence of operation of measuring cycle is retained in the event of power failure.
3. Interlocking of the valves and control system with the inlet valve and float switches



Measuring Cycle Control—Cam-Timer Diagram of Parallel-Tank Measuring System.

FIG. 4

is such that it is impossible to open the inlet valve on a tank when it is full, when it is being drawn down, or when the discharge valve is open. Fig. 3 shows the location of the interlocks which were used in this system.

Certain optional fail-safe features also included in this design, as shown in Fig. 1, are:

1. An overflow line above the upper float in the measuring tank to provide for overflow of oil into an overflow tank in event of failure of the upper float switch.

2. An overflow tank of less height than the measuring tanks so that oil cannot flow from this tank through an open line into a measuring tank.

3. An upper float in the overflow tank to initiate lease shutdown controls and sound an alarm in the event oil reaches the level of the float switch.

4. Manually operated valves may be installed in the discharge line on the downstream side of the discharge valve on the measuring tanks. Such valves should be sealed in the open position and used only in case of emergency.

With this system, at mutually agreed intervals the pipeline gager and a representative of the producer are to meet at the automatic-custody-transfer battery. The recorded number of runs for each tank is to be taken off recording devices operated independently of the operational controls. The number of runs from each tank times the constant-volume measurement per tank is the total gross oil run per tank during the agreed period. The temperature-recorder chart is to be removed and the temperature of each run listed on the chart and averaged. This chart can also be used as a check of the number of runs. The sample container is to be disconnected and replaced with an empty container. BS&W and gravity of oil in the sample collected over the period are to be determined by usual methods.

A run ticket is then prepared for each measuring tank, showing gross oil run, average temperature and BS&W content, and average indicated gravity.

B. Tandem-Tank Measuring System

A suggested combination of major items of equipment to provide a surge tank (or tanks) and a single metering tank with weir-controlled, constant-volume measurement is shown in Fig. 5. Use of electrically operated valves and controls does not preclude use of pneumatically or hydraulically operated valves and controls, if mutually acceptable.

The typical sequence of operation, as shown in Fig. 6, is: 1, tank ready to receive oil; 2, filling; 3, full with incoming oil produced into surge tank, settling of oil; 4, drawdown of oil over upper weir to establish exact known top gage, activation of temperature recorder and tank sampler (if used); 5, opening of discharge valve, starting of delivery, activation of line sampler (if used); 6, oil withdrawn over lower weir to establish exact known lower gage, closing of discharge valve, delivery and sampling completed, tank ready to again receive oil.

The minimum fail-safe features included with this design are:

1. Valves are of "normally closed" design.

2. Sequence of operation of measuring cycle is retained in the event of power failure.

3. Mechanical and electrical interlocking of the valves and control system with the inlet discharge and drain valves, float switches, and relays is such that it is impossible to open the inlet valve on a tank when it is full, when it is being drawn down, or when the discharge valve is open; it is also impossible to drain oil from the bottom of tank while tank is discharging to the pipeline. Three-way plug valves and mechanical linkages provide positive, easily sealed and checked interlocks, as shown in Fig. 5.

The optional fail-safe features which have been included in the design shown in Fig. 5 are:

1. An emergency float switch located above the normal top level to stop the transfer pump should there be a failure of the normal-level float switch.

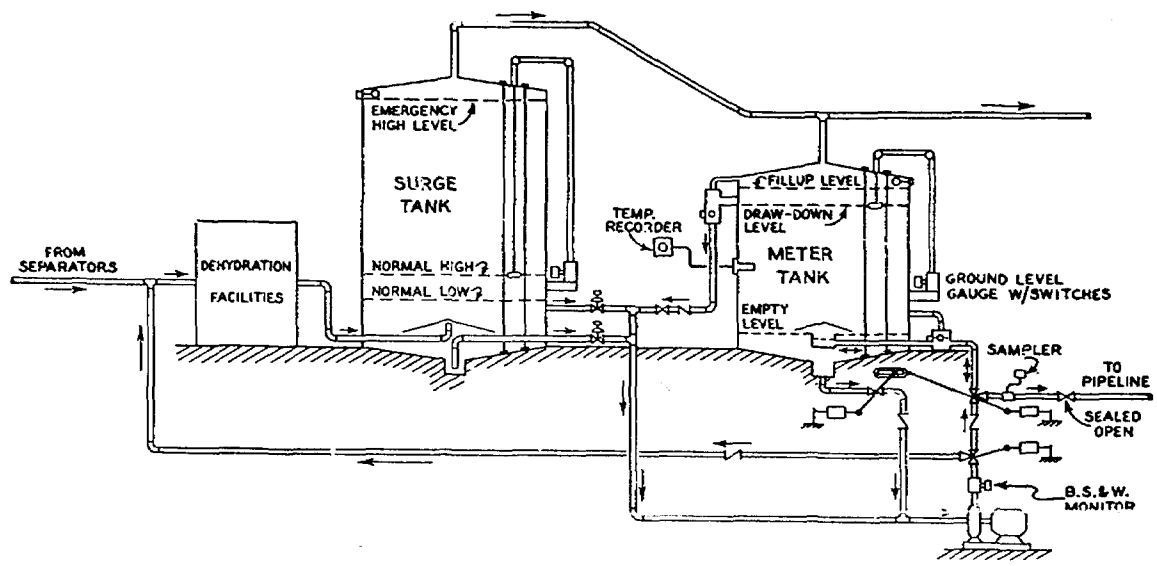
2. A surge tank to produce into while the meter tank is full or on the line in order to permit uninterrupted production.

3. An upper float in the surge tank to initiate lease shutdown controls and sound an alarm in the event oil reaches the level of the float switch.

4. A manually operated valve installed in the discharge line on the downstream side of the discharge valve on the measuring tanks. This valve should be sealed in the open position and used only in case of emergency.

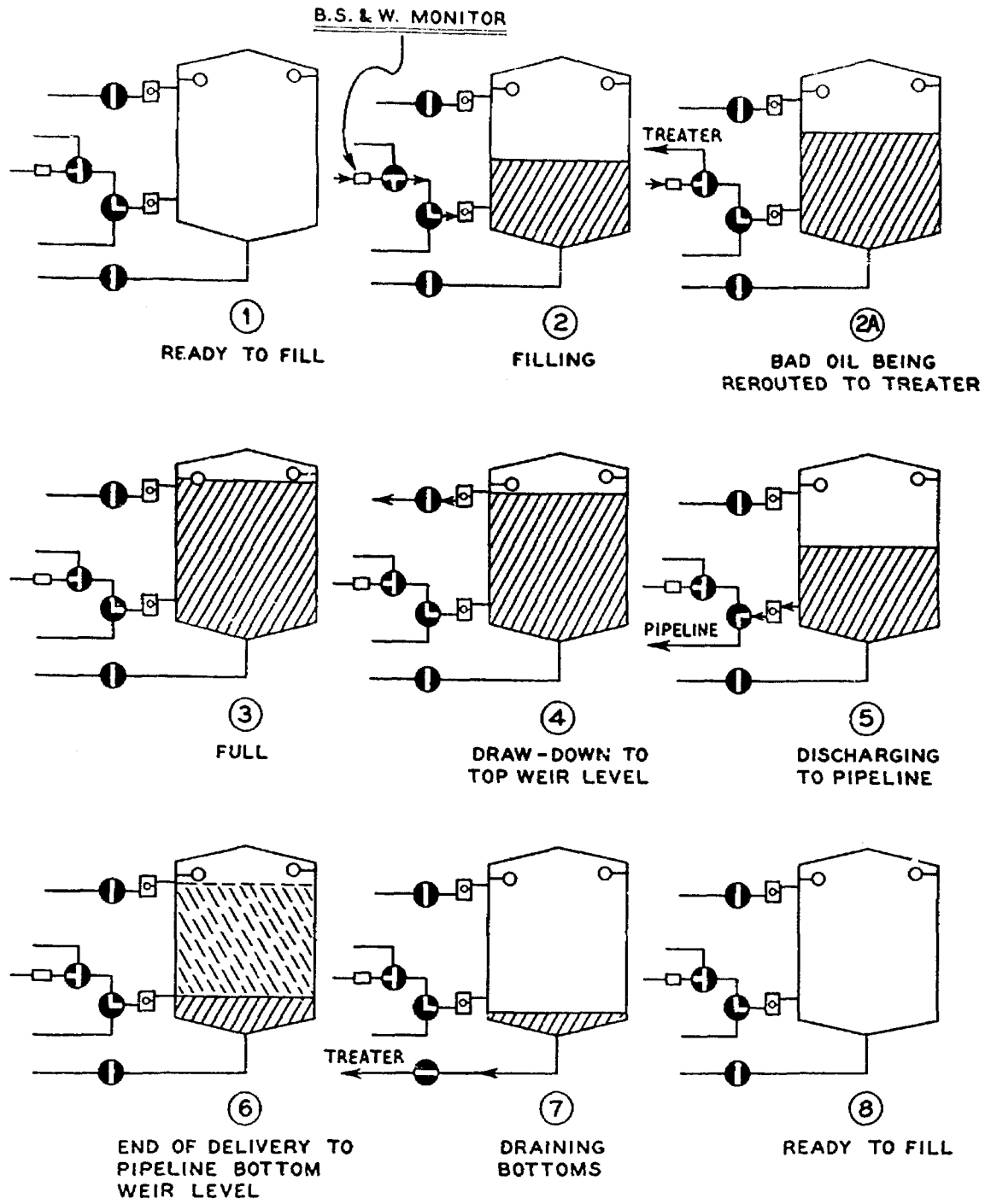
5. A BS&W monitoring system to prevent the entry of non-merchantable oil into the meter tank.

6. Periodic pumping-out of tank bottoms to prevent buildup.



Tandem-Tank Measuring System with Weir-Controlled Constant Tank Volume.

FIG. 5



NOTE:

DRAIN VALVE & TANK FILL-DISCHARGE 3-WAY VALVE MECHANICALLY LINKED TO PREVENT ACCIDENTALLY OPENING DRAIN VALVE WHILE OIL IS BEING DELIVERED TO THE PIPELINE.

Tandem Measuring and Surge Tanks with Weir-Controlled Constant-Volume Measurement; Sequence of Operation.

FIG. 6

7. Predetermined counters to limit the number of tanks run during any time interval.

With this system, at mutually agreed intervals the pipeline gager and a representative of the producer are to meet at the automatic-custody-transfer battery. The recorded number of runs for each tank is to be taken off recording devices operated independently of the operational controls. The number of runs from each tank times the constant-volume measurement per tank is the total gross oil run per tank during the agreed period. The temperature-recorder chart is to be removed and the temperature of each run listed on the chart and averaged. This chart can also be used as a check of the number of runs. The sample container is to be disconnected and replaced with an empty container. BS&W and gravity of oil in the sample collected over the period is to be determined by usual methods.

A run ticket is then prepared for each measuring tank, showing gross oil run, average temperature and BS&W content, and average indicated gravity.

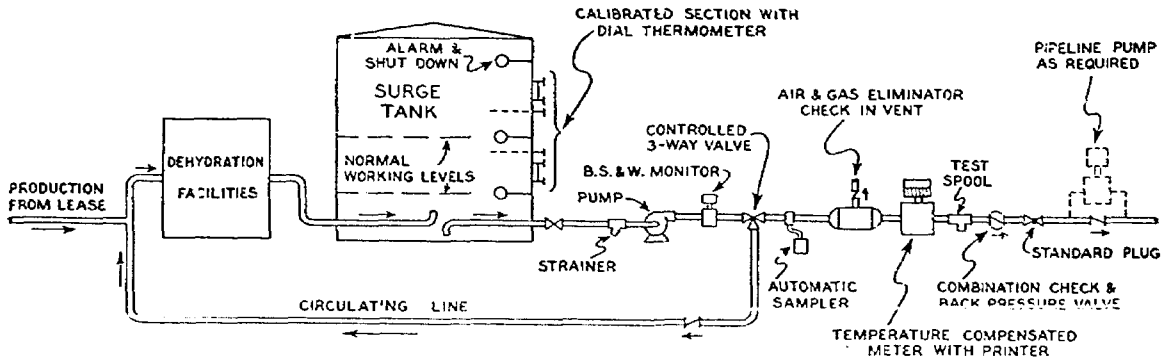
C. Positive-Displacement Meter System

A suggested combination of major items of equipment to provide automatic measurement by the positive-displacement meter method is shown in Fig. 7. The sequence of operation will vary slightly, depending on the type of pipeline facility connected and the operating schedule of the pipeline. The typical operating sequence for two types of automatic measurement to the pipeline is outlined as follows:

a. *Normal Delivery to a Gravity-Flow Pipeline—Nonscheduled Operation:* When the liquid level in the surge tank reaches normal high-working level: 1, the circulating pump starts and circulates the liquid from the surge tank back to the dehydration facilities for three minutes after the monitor indicates that the BS&W content is within permissible limits; 2, the three-way valve opens to the pipeline, admitting flow through the meter; 3, when the three-way valve reaches its open-to-pipeline position, the automatic sampler is energized and begins sampling, as mutually agreed; 4, under normal conditions, delivery to the pipeline continues until the liquid level reaches the normal low-level position; 5, the three-way valve closes the pipeline outlet and opens to the return line; 6, the automatic sampler is de-energized; and, 7, the circulating pump continues to circulate for five minutes, then is shut down.

After delivery to the pipeline has begun, should non-merchantable oil flow for two minutes continuously past the BS&W monitor, the delivery shall be automatically interrupted and, 1, the three-way valve shall switch the flow from the pipeline to the dehydration facilities; 2, the automatic sampler shall be de-energized; 3, circulation from the surge tank to the dehydration facilities shall continue until merchantable oil has flowed over the BS&W monitor for three minutes; then, 4, the flow shall be switched back to the pipeline and the delivery continued, as under normal conditions.

b. *Normal Delivery to a Pressurized Pipeline—Nonscheduled Operation:* When the liquid level in the surge tank reaches normal



Positive-Displacement Meter System.

FIG. 7

high-working level: 1, the circulating pump starts and circulates the liquid from the surge tank back to the dehydration facilities for three minutes after the monitor indicates that the BS&W content is within permissible limits; 2, the three-way valve opens to the pipeline, admitting flow to the meters; 3, when the three-way valve reaches its open-to-pipeline position, the pipeline pump starts and the automatic sampler is energized; 4, under normal conditions, delivery to the pipeline continues until the liquid reaches the normal low-level position; 5, the three-way valve closes the pipeline outlet and opens to the return line; 6, the pipeline pump is shut down and the sampler de-energized; and, 7, the circulating pump continues to circulate for five minutes, after which it is shut down.

After the delivery to the pipeline has begun, should non-merchantable oil flow for two minutes continuously past the BS&W monitor, the delivery shall be automatically interrupted and, 1, the three-way valve shall switch the flow from the pipeline to the wash tank; 2, the pipeline pump is shut down and the sampler is de-energized; 3, the circulation from the surge tank to the wash tank shall continue until merchantable oil has flowed over the BS&W monitor for three minutes; then, 4, the flow shall be switched back to the pipeline and the delivery continued, as under normal conditions.

c. *Normal Delivery to a Pipeline—Scheduled Operation:* Some pipeline systems are operated on a schedule whereby it is desirable to admit delivery only during a certain interval of time. For this condition the operation sequence shall be the same as for nonscheduled delivery, except that a time-interval controller shall be added to the circuit which overrides the normal high-working-level control.

APPENDIX 2

MEMBERS OF COMMITTEE ON LEASE AUTOMATIC CUSTODY TRANSFER

Officers

H. L. Shatto (*Chairman*)	Shell Oil Co.	New York, N. Y.
R. C. Buchan (*Vice Chairman*)	Humble Oil and Refining Co.	Houston, Texas

Members

C. E. Curry	Sohio Pipeline Co.	St. Louis, Mo.
R. A. Hamill	Service Pipe Line Co.	Tulsa, Okla.
D. C. McKinley	Interstate Pipe Line Co.	Shreveport, La.
D. C. Meyers	Shell Oil Co.	Hobbs, N. Mex.
S. H. Pope	Gulf Oil Corp.	Wichita, Kans.
G. A. Smith (alternate to D. C. Meyers)	Shell Oil Co.	Tulsa, Okla.
J. W. Tinnin	Texas Pipe Line Co.	Wichita Falls, Texas
J. Zaba	Stanolind Oil and Gas Co.	Tulsa, Okla.
C. H. Kangas (member until September 1955)	Formerly with Phillips Petroleum Co.	Bartlesville, Okla.

3M—August 1956

CASE NO. 2243 - ORDER NO. R-1959

Form C-106 ACT Permit No. 1

NOTICE OF INTENTION

TO UTILIZE AUTOMATIC CUSTODY TRANSFER EQUIPMENT

Operator Cities Service Petroleum Company Field North Justis

Address Box 97, Hobbs, New Mexico County Lea

Lease(s) to be served by this ACT Unit 1 -- Hodges "B"

Pool(s) to be served by this ACT Unit 5

Location of ACT System: Unit I Sec 1 Twp 25-S Rge 37-E

Order No. authorizing commingling between leases if more than one lease is to be served by this system Date

Order No. authorizing commingling between pools if more than one pool is to be served by this system: PC-43 Date 11-9-61

Authorized transporter of oil from this system Texas-New Mexico Pipeline Co.

Transporter's address Box 1510, Midland, Texas

Maximum expected daily through-put for this system: 1400 (350 initial) Bbls/day

If system fails to transfer oil due to malfunction or otherwise, waste by overflow will be averted by: (Check One)

A. [X] Automatic shut-down facilities as required by Section (3) h-1 of Rule 309-A.

B. [ ] Alternative (3) h-2, providing adequate available capacity to receive production during maximum unattended time of lease operation.

If A above is checked, will flowing wells be shut-in at the header manifold or at the well-head? Well head Maximum well-head shut-in pressure 750#

If B above is checked, how much storage capacity is available above the normal high working level of the surge tank? 800 Bbls.

What is the normal maximum unattended time of lease operation? 16 Hours

What device will be used for measuring oil in this ACT Unit? (Check One)

[X] Positive displacement meter [ ] Weir-type measuring vessel

[ ] Positive volume metering chamber [ ] Other; Describe

Remarks: Multiple allowable

I hereby certify that the information given above is true and complete to the best of my knowledge and that the subject ACT system will be installed and operated in accordance with Rule 309-A.

Approved, Oil Conservation Commission By E. J. Motter

By Joe D. Ramey Title Asst. Division Engineer

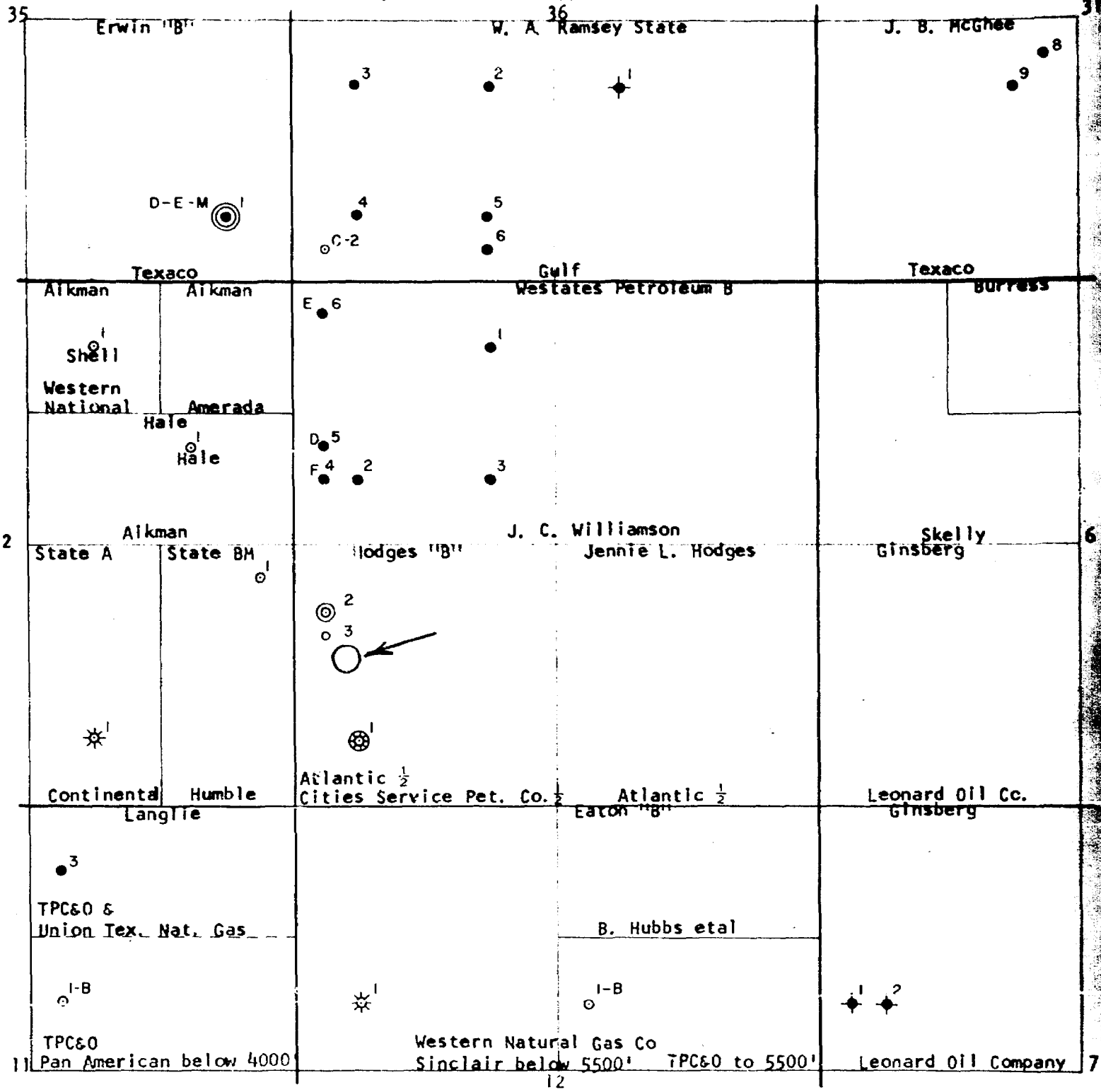
Title Date Date 11-14-61

Approval of Form C-106 does not eliminate the necessity of an approved C-110 prior to running any oil or gas from this system.

Kerr-McGee 915
SECTION PLAT
Scale: 1 inch = 660 feet

CITIES SERVICE PETROLEUM COMPANY

SECTION 1 TOWNSHIP 25-S RANGE 37-E COUNTY Lea STATE New Mexico



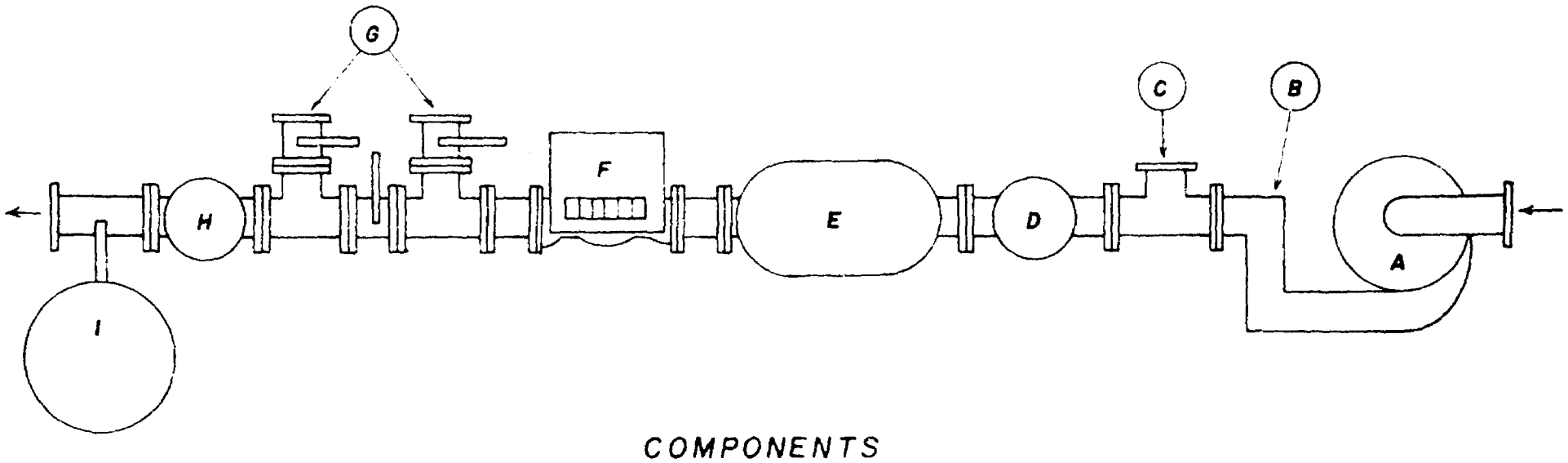
D - Drinkard
E - Ellenburger
F - Fusselman
M - McKee

Plat Showing the Proposed Completion, Hodges B #2 and offset operators

HODGES B LEASE

Cities Service Petroleum Company — Operator

PROPOSED A C T INSTALLATION



COMPONENTS

A PUMP

B BS&W MONITOR

C 3 WAY 2 POSITION VALVE

D FILTER

E DEAERATOR

F P.D. METER

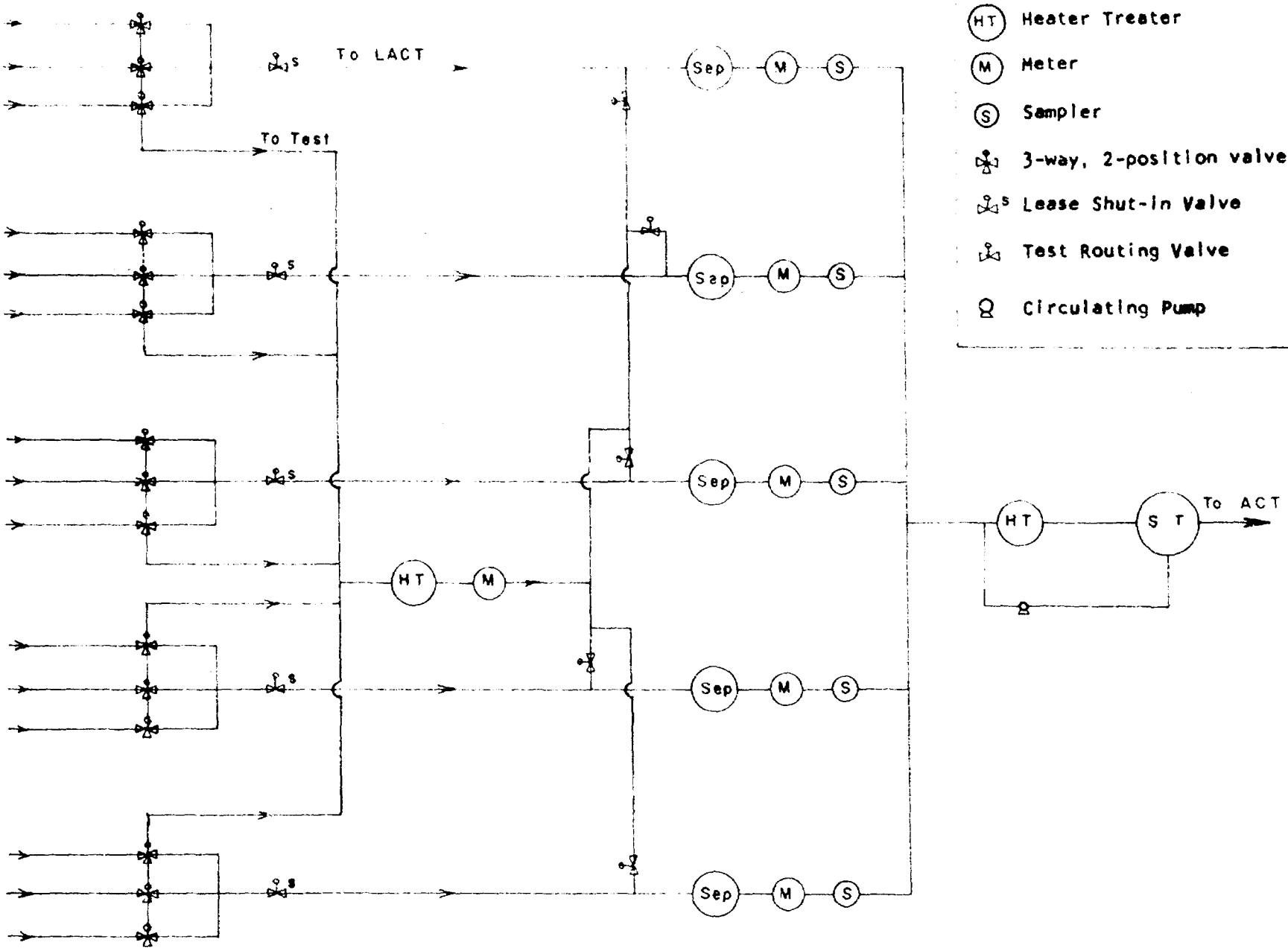
G PROVER CONNECTION

H BACK PRESSURE VALVE

I SAMPLER

CITIES SERVICE PETROLEUM COMPANY
HODGES B LEASE

Schematic Diagram Proposed Commingling



TEXAS-NEW MEXICO PIPE LINE COMPANY

F. B. WHITAKER, JR.
DIVISION MANAGER

November 8, 1961

P. O. BOX 1990
MIDLAND, TEXAS

New Mexico Oil Conservation Commission
P. O. Box 871
Santa Fe, New Mexico

Gentlemen:

Cities Service Petroleum Company advises that they intend to make application to the New Mexico Oil Conservation Commission for permission to permanently install and operate a lease automatic custody transfer system on their Hodges "B" Lease located in the SW/4 of Section 1, T-25-S, R-37-E, Lea County, New Mexico.

Texas-New Mexico Pipe Line Company gathers production from this lease and concurs in the operator's application for permanent approval to install and operate this LACT unit.

Yours very truly,

TEXAS-NEW MEXICO PIPE LINE COMPANY

By F B Whitaker, Jr.
F. B. Whitaker, Jr.
Division Manager

FBWjr-btk

cc: Cities Service Petroleum Company
P. O. Box 97
Hobbs, New Mexico

STANDARD OIL COMPANY OF TEXAS

Drawer "S"
Monahans, Texas
March 1, 1962

New Mexico Oil Conservation Commission
P. O. Box 2045
Hobbs, New Mexico

Gentlemen:

Standard Oil Company of Texas, A Division of California Oil Company, requests permission to install an automatic custody transfer unit on for sale of crude oil from the State 6-34 Lease, Vacuum (Abo) Field, located in Section 34, Township 17 South, Range 35 East, Lea County, New Mexico. In support of this request we are submitting a Form C-106, area plat, pipeline acceptance letter and schematic of the proposed system. This system has been designed to conform with specifications outlined in NMOCC Case 2243, Rule 309-A, and with your approval we should like to begin installation as soon as possible.

The attached diagram of the battery shows a tank No. 3. This tank is presently installed; however, its volume is not included in the design or in any calculations concerning the operation of the automatic custody transfer unit. The tank may be removed at some future date.

Texas-New Mexico Pipe Line Company is now gathering the oil from this lease and will continue to serve as gatherer.

Thank you for your consideration in this matter.

Very truly yours,

S. J. Mathews, Jr.
S. J. Mathews, Jr.
District Superintendent

WHA:jd

Attachments

STANDARD OIL COMPANY OF TEXAS

Drawer "S"
Monahans, Texas
March 1, 1962

New Mexico Oil Conservation Commission
P. O. Box 2045
Hobbs, New Mexico

Gentlemen:

Standard Oil Company of Texas, A Division of California Oil Company, requests permission to install an automatic custody transfer unit for sale of crude oil from the State 6-3% Lease, Vacuum (Abo) Field, located in Section 3%, Township 17 South, Range 35 East, Lea County, New Mexico. In support of this request we are submitting a Form C-106, area plat, pipeline acceptance letter and schematic of the proposed system. This system has been designed to conform with specifications outlined in NMOCC Case 2243, Rule 309-A, and with your approval we should like to begin installation as soon as possible.

The attached diagram of the battery shows a tank No. 3. This tank is presently installed; however, its volume is not included in the design or in any calculations concerning the operation of the automatic custody transfer unit. The tank may be removed at some future date.

Texas-New Mexico Pipe Line Company is now gathering the oil from this lease and will continue to serve as gatherer.

Thank you for your consideration in this matter.

Very truly yours,

S. J. Mathews, Jr.
District Superintendent

WHA:jd

Attachments

TEXAS-NEW MEXICO PIPE LINE COMPANY

F. B. WHITAKER, JR.
DIVISION MANAGER

P. O. BOX 1510
MIDLAND, TEXAS

February 23, 1962

New Mexico Oil Conservation Commission
P. O. Box 871
Santa Fe, New Mexico

Gentlemen:

Standard Oil Company of Texas advises that they intend to make application to the New Mexico Oil Conservation Commission for permission to permanently install and operate an automatic custody transfer unit on their State 6-34 Lease located in the Vacuum Abo Field, Lea County, New Mexico.

Texas-New Mexico Pipe Line Company gathers production from this lease and concurs in the operator's application for permanent approval to install and operate this ACT unit.

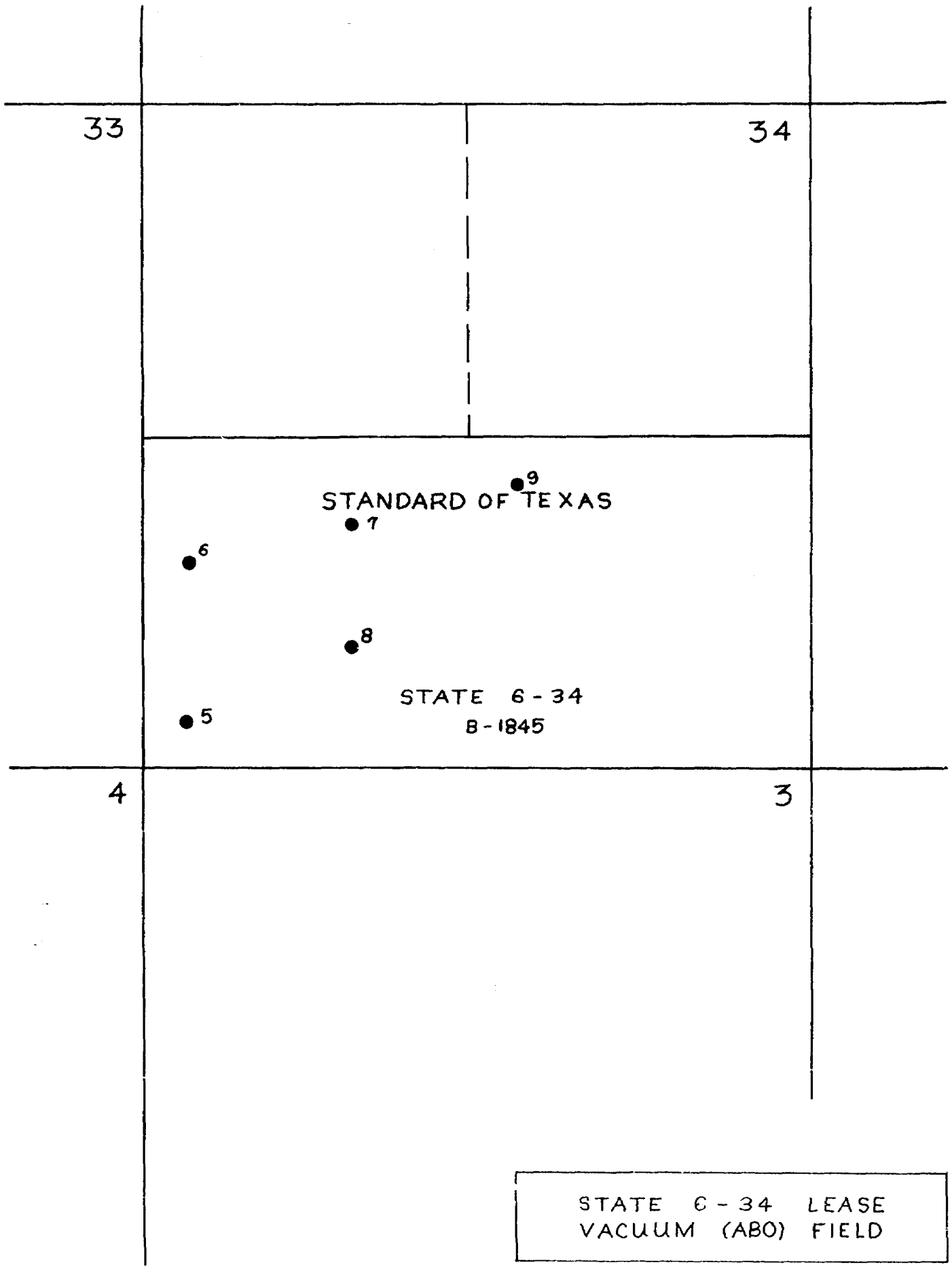
Yours very truly,

TEXAS-NEW MEXICO PIPE LINE COMPANY

By _____
F. B. Whitaker, Jr.
Division Manager

FBWjr-btk

cc: Standard Oil Company of Texas
Monahans, Texas



STATE C-34 LEASE
VACUUM (ABO) FIELD

ORDER NO. R-1059

ACT Permit No. I-38

NOTICE OF INTENTION

TO UTILIZE AUTOMATIC CUSTODY TRANSFER EQUIPMENT

Operator Standard Oil Company of Texas, A Division of California Oil Company Field Vacuum (Abo)

Address Drawer "S", Monahans, Texas County Lea

Lease(s) to be served by this ACT Unit [redacted] State 6-34

Pool(s) to be served by this ACT Unit Vacuum (Abo)

Location of ACT System: Unit K Sec 34 Twp 17S Rge 35E

Order No. authorizing commingling between leases if more than one lease is to be served by this system _____ Date _____

Order No. authorizing commingling between pools if more than one pool is to be served by this system _____ Date _____

Authorized transporter of oil from this system Texas-New Mexico Pipe LineCompany

Transporter's address P. O. Box 1027, Lovington, New Mexico

Maximum expected daily through-put for this system: 600 Bbls/day

If system fails to transfer oil due to malfunction or otherwise, waste by overflow will be averted by: (Check One)

A. [ ] Automatic shut-down facilities as required by Section (3) h-1 of Rule 309-A.

B. [X] Alternative (3) h-2, providing adequate available capacity to receive production during maximum unattended time of lease operation.

If A above is checked, will flowing wells be shut-in at the header manifold or at the well-head? _____ Maximum well-head shut-in pressure _____

If B above is checked, how much storage capacity is available above the normal high working level of the surge tank? 400 Bbls.

What is the normal maximum unattended time of lease operation? 16 Hours

What device will be used for measuring oil in this ACT Unit? (Check One)

[X] Positive displacement meter [ ] Weir-type measuring vessel

[ ] Positive volume metering chamber [ ] Other; Describe _____

Remarks: _____

I hereby certify that the information given above is true and complete to the best of my knowledge and that the subject ACT system will be installed and operated in accordance with Rule 309-A.

Approved, Oil Conservation Commission

By _____

Title _____ Date _____

By J. L. Borland

Title District Engineer

Date March 1, 1962

Approval of Form C-106 does not eliminate the necessity of an approved C-110 prior to running any oil or gas from this system.

TIDEWATER OIL COMPANY

Box 547
Hobbs, New Mexico
March 7, 1962

New Mexico Oil Conservation Commission
District I
P. O. Box 2045
Hobbs, New Mexico

Attention: Mr. Joe D. Ramey, Supervisor & Proration Manager

Re: Proposed Automatic Custody Transfer System, State "AN" Lease.
Unit B, Section 7, Township 18S, Range 35E, Lea County, New Mexico.

Dear Mr. Ramey:

Tidewater Oil Company proposes to install a Automatic Custody Transfer System on the State "AN" Lease. This system will be located in Unit B, 750' SNL and 1650' WEL of Section 7, Township 18S, Range 35E, Lea County, New Mexico.

The ACT System is designed to transfer 40° API sweet crude produced from the Vacuum-Abo Reef on the State "AN" Lease to Texas-New Mexico Pipe Line Company.

Exhibit A shows the location of the ACT Unit with respect to the other lease facilities. Exhibit B shows the proposed ACT Unit and the component parts. At the present time, Well #1 is producing pipeline oil and does not require treating facilities. Tenative plans are to install a B.S.&W. monitoring system in conjunction with treating facilities when required at a later date.

Attached please find a letter from Texas-New Mexico Pipe Line Company concuring with Tidewater's application for permanent approval to install and operate the ACT system. Also attached is the Oil Conservation Commission Form C-106 "Notice of Intention to Utilize Automatic Custody Transfer Equipment."

We respectfully request that administrative approval be granted to the proposed ACT System to be installed on the State "AN" Lease.

Respectfully,

TIDEWATER OIL COMPANY

C. L. Wade

C. L. Wade,
Area Superintendent

ARS:bw

Tidewater Oil Company

State NM "L" No. 2

Proposed Automatic Custody Transfer

Unit B Section 7 Township 18S Range 35E

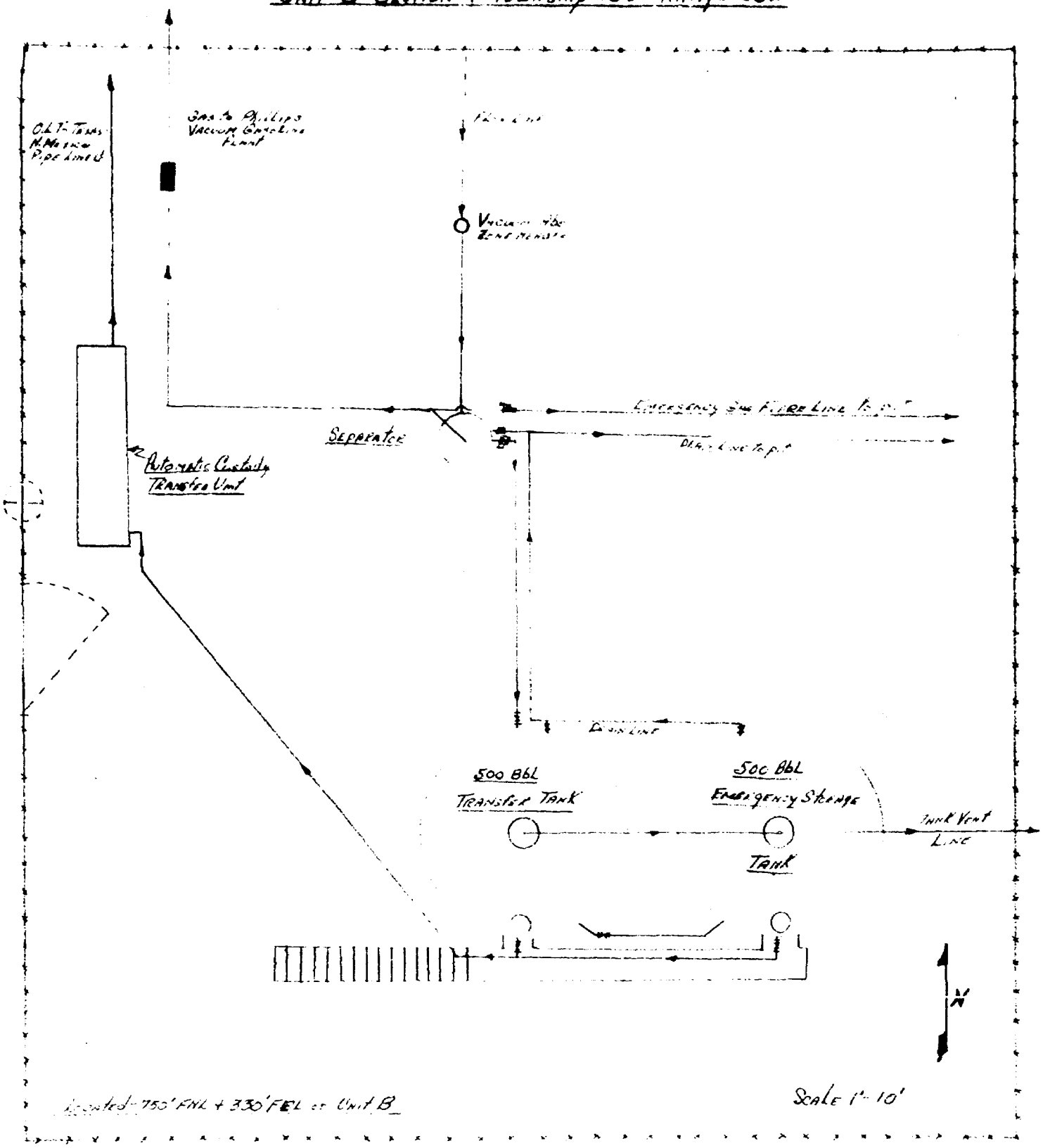
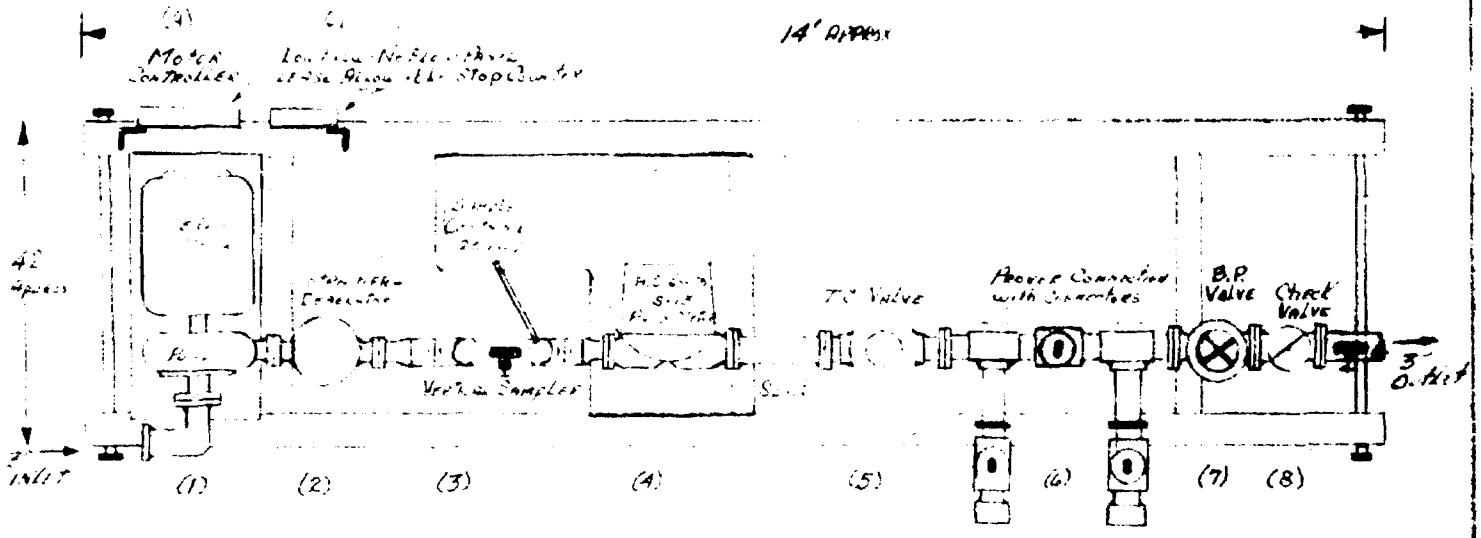


EXHIBIT A

Tidewater Oil Company

State "AN" Lease

Sec. 7 T-18S R-35E



Proposed Automatic Custody Transfer Unit

(1) Pump - 100 Bbls per Hour at 120 ft Head. Gould Model - 2C. Elec. Motor - 5 H.P. T.E.F.C. 1750 RPM 220-440 Volt 3 Phase.

(2) Combination Strainer - Deaerator - 2" A.O. Smith TEB-10

(3) Vertical Sample Loop + Probe - 3" Y-Z Sampler R-1E w/ 20 gal Sample Container.

(4) Production Meter 2" A.O. Smith S-13 w/ ATC. Large Numeral Counter, + Safety Switch.

(5) T-C Motor Valve - 3" w/ solenoid. G.O.T.

(6) Meter Prover Connections - 3". 3 Plug Valves c/w Lock Type handles. and Evertite Adapters c/w Dust Caps.

(7) Back-Pressure Valve - 3" B.S.+B. Model-18.

(8) Check Valve - 3"

(9) Motor Controller

(10) Control Panel Low-Flow-No Flow Circuit. Lease Allowable-Stop Counter.

Exhibit-B

TEXAS-NEW MEXICO PIPE LINE COMPANY

F. B. WHITAKER, JR.
DIVISION MANAGER

March 2, 1962

P. O. BOX 1510
MIDLAND, TEXAS

New Mexico Oil Conservation Commission
P. O. Box 871
Santa Fe, New Mexico

Gentlemen:

Tidewater Oil Company advises that they intend to make application to the New Mexico Oil Conservation Commission for permission to permanently install and operate an automatic custody transfer unit on their State "AN" Lease located in Section 7, T-18-S, R-35-E, Lea County, New Mexico.

Texas-New Mexico Pipe Line Company gathers production from this lease and concurs in the operator's application for permanent approval to install and operate this ACT unit.

Yours very truly,

TEXAS-NEW MEXICO PIPE LINE COMPANY

By F B Whitaker Jr
F. B. Whitaker, Jr.
Division Manager

FBWjr-btk

cc: Tidewater Oil Company
P. O. Box 547
Hobbs, New Mexico

CASE NO. 2243 - ORDER NO. R-1959

Form C-106 ACT Permit No. [illegible]

3 - OCC
1 - Houston
1 - Midland
1 - File

NOTICE OF INTENTION
TO UTILIZF AUTOMATIC CUSTODY TRANSFER EQUIPMENT

Operator Tidewater Oil Company Field Undesignated (Vacuum Abo)

Address Box 547, Hobbs, N. Mex. County Lea

Lease(s) to be served by this ACT Unit State "AN"

Pool(s) to be served by this ACT Unit Undesignated (Vacuum Abo)

Location of ACT System: Unit B Sec 7 Twp 18S Rge 35E

Order No. authorizing commingling between leases if more than one lease is to be served by this system _____ Date _____

Order No. authorizing commingling between pools if more than one pool is to be served by this system _____ Date _____

Authorized transporter of oil from this system Texas-New Mexico Pipeline Company

Transporter's address Box 1510, Midland, Tex.

Maximum expected daily through-put for this system: 600 Bbls/day

If system fails to transfer oil due to malfunction or otherwise, waste by overflow will be averted by: (Check One)

A. [ ] Automatic shut-down facilities as required by Section (3) h-1 of Rule 309-A.

B. [x] Alternative (3) h-2, providing adequate available capacity to receive production during maximum unattended time of lease operation.

If A above is checked, will flowing wells be shut-in at the header manifold or at the well-head? _____ Maximum well-head shut-in pressure _____

If B above is checked, how much storage capacity is available above the normal high working level of the surge tank? 900 Bbls.

What is the normal maximum unattended time of lease operation? 23 Hours

What device will be used for measuring oil in this ACT Unit? (Check One)

[x] Positive displacement meter [ ] Weir-type measuring vessel

[ ] Positive volume metering chamber [ ] Other; Describe _____

2" A.O. Smith S-13 w/ ATC, Large Numeral Counter, and Safety Switch

Remarks: _____

I hereby certify that the information given above is true and complete to the best of my knowledge and that the subject ACT system will be installed and operated in accordance with Rule 309-A.

Approved, Oil Conservation Commission By C. X. Wade

By [signature] Title Area Supt.

Title _____ Date _____ Date February 27, 1962

Approval of Form C-106 does not eliminate the necessity of an approved C-110 prior to running any oil or gas from this system.

FORM. A-104

HUMBLE OIL & REFINING COMPANY
HUMBLE DIVISION

[illegible] OFFICE OCC

1962 APR 2 AM 8 [illegible]

Hobbs, New Mexico
March 16, 1962

Re: Proposed ACT Unit
New Mexico State "BM" Lease
North Justis Pools
Lea County, New Mexico
File: 22-2

Mr. Joe Ramey
New Mexico Oil Conservation Commission
P. O. Box 2045
Hobbs, New Mexico

Humble Oil and Refining Company respectfully requests administrative approval to utilize automatic custody transfer equipment on its New Mexico State "BM" Lease comprising the E/½ of the SE/4 of Section 2, T-25-S, R-37-E. This lease is located in the North Justis Pools, Lea County, New Mexico.

Commission Form C-106 and related plats and schematic drawings are enclosed.

Your approval of this proposed ACT will be appreciated.

Yours truly,

HUMBLE OIL AND REFINING COMPANY

R. R. Alworth

R. R. Alworth

ARB/mcb

CASE NO. 2243 - ORDER NO. R-1959

Form C-106 ACT Permit No. I-40

NOTICE OF INTENTION

TO UTILIZE AUTOMATIC CUSTODY TRANSFER EQUIPMENT

Operator Humble Oil and Refining Company Field North Justis

Address Box 2347, Hobbs, New Mexico County Lea

Lease(s) to be served by this ACT Unit New Mexico State "BM"

Pool(s) to be served by this ACT Unit Ellenburger, Waddell, McKee, Fusselman, Drinkard & Blinebr

Location of ACT System: Unit I Sec 2 Twp 25S Rge 37E

Order No. authorizing commingling between leases if more than one lease is to be served by this system _____ Date _____

Order No. authorizing commingling between pools if more than one pool is to be served by this system Application applied for PC-69 Date March 1, 1962

Authorized transporter of oil from this system Texas-New Mexico Pipeline Company

Transporter's address Box 1510, Midland, Texas

Maximum expected daily through-put for this system: 1,008 Bbls/day

If system fails to transfer oil due to malfunction or otherwise, waste by overflow will be averted by: (Check One)

A. [ ] Automatic shut-down facilities as required by Section (3) h-1 of Rule 309-A.

B. [X] Alternative (3) h-2, providing adequate available capacity to receive production during maximum unattended time of lease operation.

If A above is checked, will flowing wells be shut-in at the header manifold or at the well-head? _____ Maximum well-head shut-in pressure _____

If B above is checked, how much storage capacity is available above the normal high working level of the surge tank? 1,000 Bbls.

What is the normal maximum unattended time of lease operation? 16 Hours

What device will be used for measuring oil in this ACT Unit? (Check One)

[X] Positive displacement meter [ ] Weir-type measuring vessel

[ ] Positive volume metering chamber [ ] Other; Describe _____

Remarks: System must be equipped with a lockable set stop counter

I hereby certify that the information given above is true and complete to the best of my knowledge and that the subject ACT system will be installed and operated in accordance with Rule 309-A.

Approved, Oil Conservation Commission By _____

By _____ Title Agent

Title _____ Date _____ Date March 16, 1962

ARB/mcb

Approval of Form C-106 does not eliminate the necessity of an approved C-110 prior to running any oil or gas from this system.

TEXAS-NEW MEXICO PIPE LINE COMPANY

F. B. WHITAKER, JR.
DIVISION MANAGER

March 14, 1962

P. O. BOX 1510
MIDLAND, TEXAS

New Mexico Oil Conservation Commission
P. O. Box 871
Santa Fe, New Mexico

Gentlemen:

Humble Oil & Refining Company advises that they intend to make application to the New Mexico Oil Conservation Commission for permission to permanently install and operate an automatic custody transfer system on their New Mexico State "BM" Lease located in Section 2, T-25-S, R-37-E, Lea County, New Mexico, in the North Justis Pools.

Texas-New Mexico Pipe Line Company gathers production from this lease and concurs in the operator's application for permanent approval to install and operate this ACT unit.

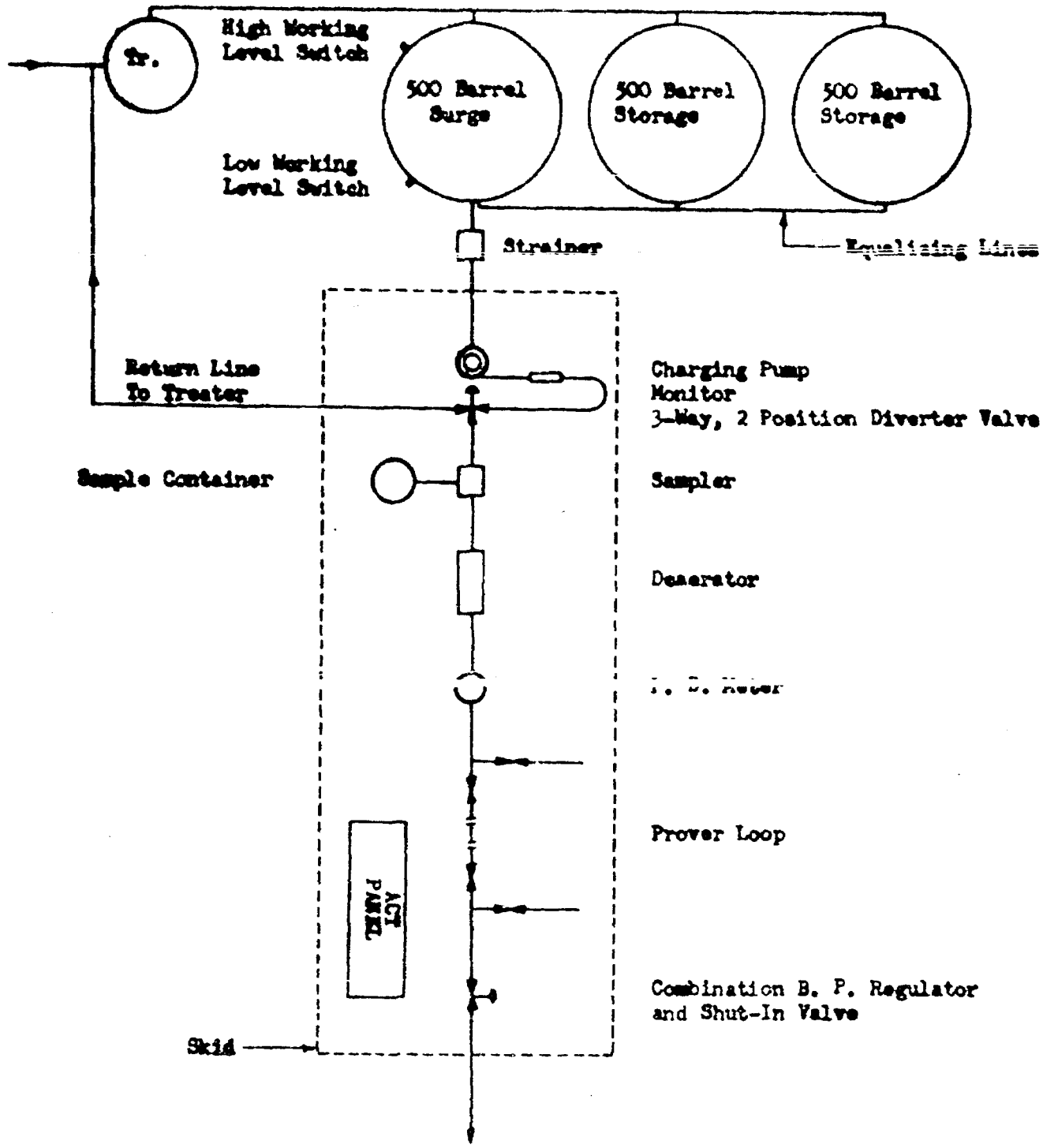
Yours very truly,

TEXAS-NEW MEXICO PIPE LINE COMPANY

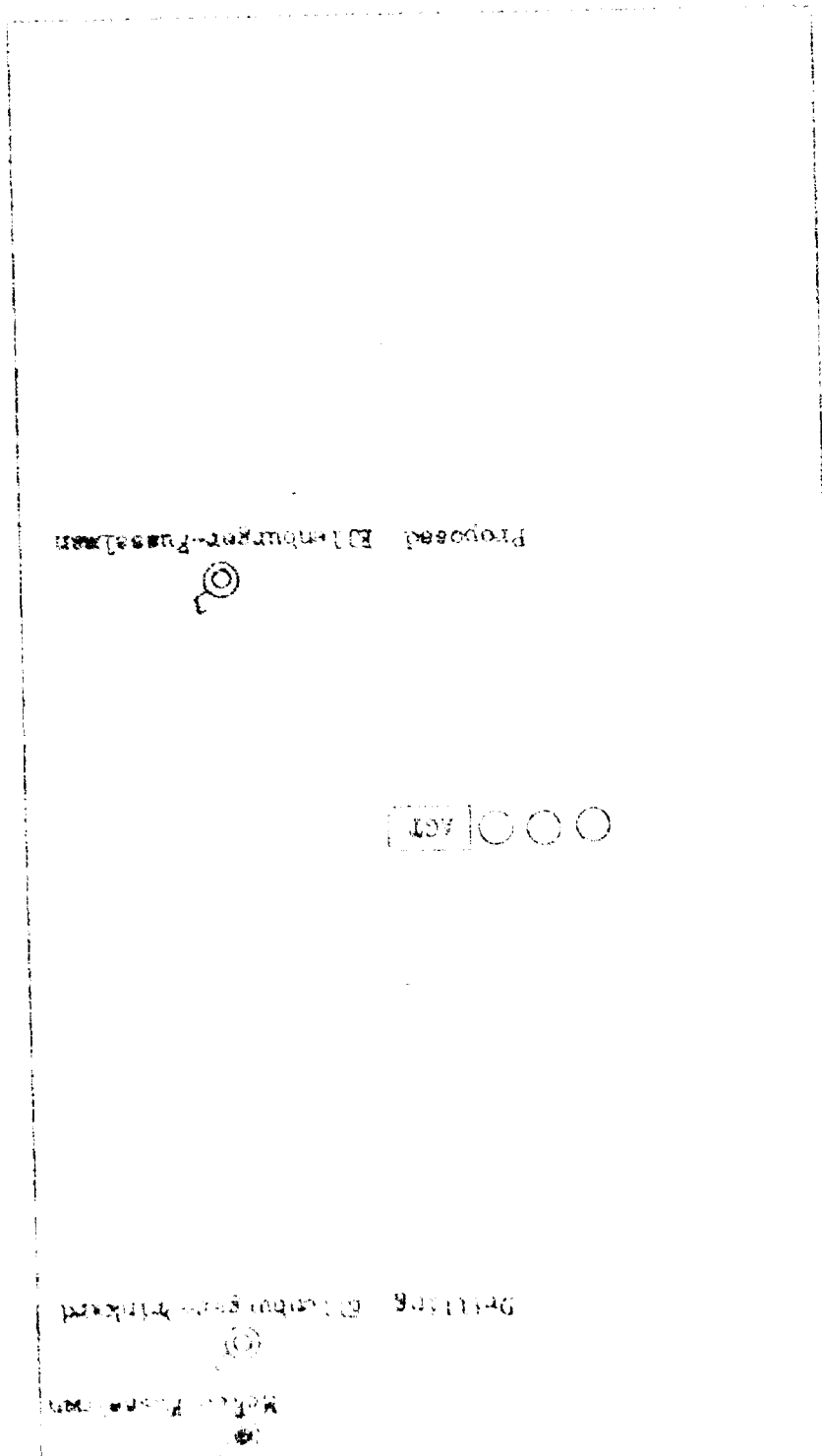
By_____
F. B. Whitaker, Jr.
Division Manager

FBWjr-btk

cc: Humble Oil & Refining Company
Hobbs, New Mexico



PROPOSED LEASE AUTOMATIC CUSTODY TRANSFER UNIT
NEW MEXICO STATE BM LEASE BATTERY NO. 1
NORTH JUSTIS FIELD LEA COUNTY, NEW MEXICO
MARBLE OIL AND REFINING COMPANY
HOBBS DISTRICT MARCH 2, 1962 ARB


Proposed Edinburgh-Fusselman
act

CASE NO. 2343 - ORDER NO. R-1959

Form C-106 ACT Permit No. I-41

NOTICE OF INTENTION

TO UTILIZE AUTOMATIC CUSTODY TRANSFER EQUIPMENT

Operator SOCONY MOBIL OIL COMPANY, INC. Field Vacuum Abo

Address Box 2406, Hobbs, New Mexico County Lea

Lease(s) to be served by this ACT Unit State "M" Lease

Pool(s) to be served by this ACT Unit Vacuum Abo

Location of ACT System: Unit SW/4 Sec 34 Twp 17S Rge 35E

Order No. authorizing commingling between leases if more than one lease is to be served by this system N/A Date

Order No. authorizing commingling between pools if more than one pool is to be served by this system N/A Date

Authorized transporter of oil from this system Texas-New Mexico Pipe Line Co.

Transporter's address Box 1027, Lovington, New Mexico

Maximum expected daily through-put for this system: 325 Bbls/day

If system fails to transfer oil due to malfunction or otherwise, waste by overflow will be averted by: (Check One)

A. [ ] Automatic shut-down facilities as required by Section (3) h-1 of Rule 309-A.

B. [X] Alternative (3) h-2, providing adequate available capacity to receive production during maximum unattended time of lease operation.

If A above is checked, will flowing wells be shut-in at the header manifold or at the well-head? Maximum well-head shut-in pressure

If B above is checked, how much storage capacity is available above the normal high working level of the surge tank? 550 Bbls.

What is the normal maximum unattended time of lease operation? 40 Hours

What device will be used for measuring oil in this ACT Unit? (Check One)

[X] Positive displacement meter [ ] Weir-type measuring vessel

[ ] Positive volume metering chamber [ ] Other; Describe

Remarks:

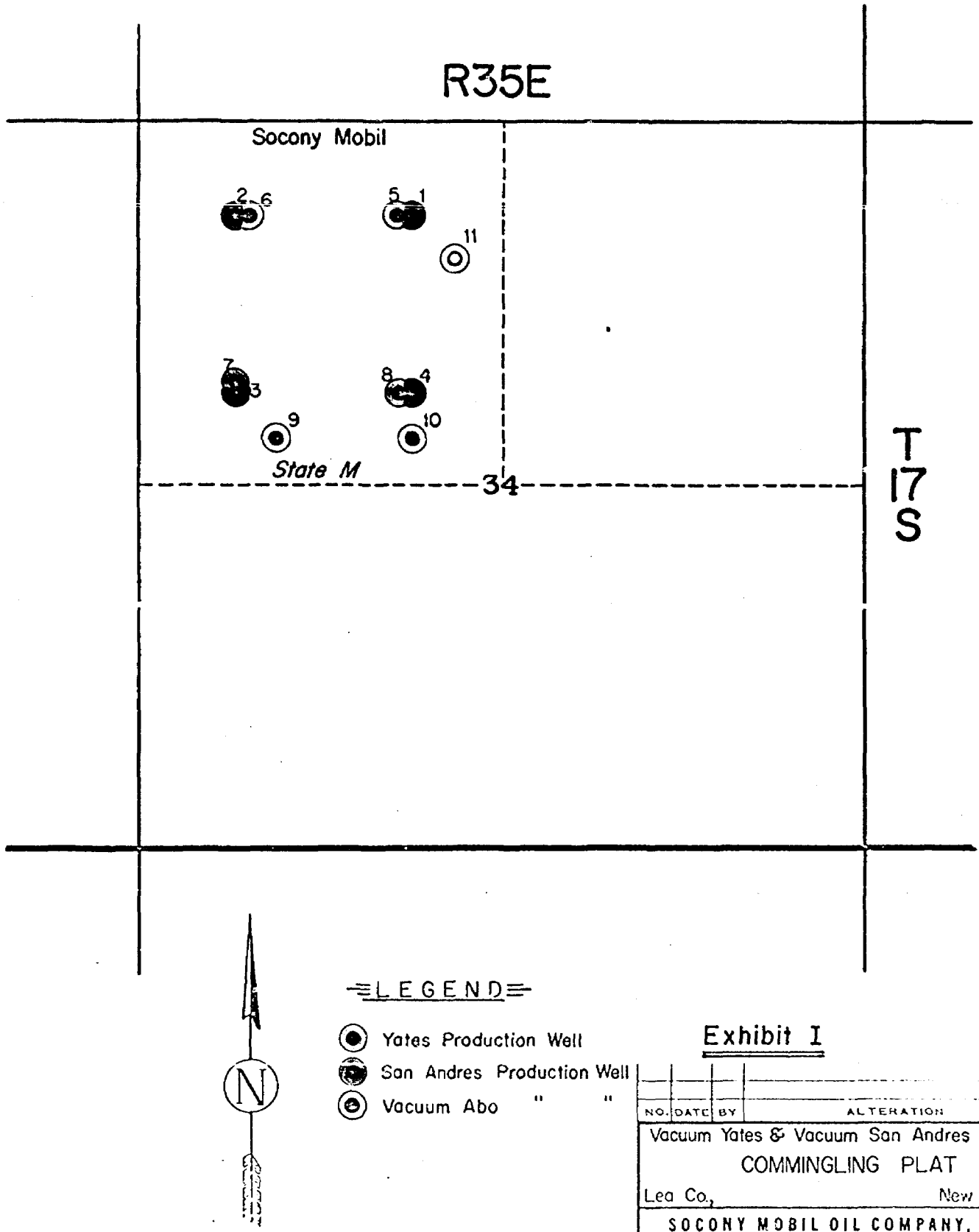
I hereby certify that the information given above is true and complete to the best of my knowledge and that the subject ACT system will be installed and operated in accordance with Rule 309-A.

Approved, Oil Conservation Commission By C. H. Samples

By Joe D. Ramey Title Producing Superintendent

Title Date Date March 19, 1962

Approval of Form C-106 does not authorize the commingling of unapproved C-110 prior to producing any oil or gas from the lease.



LEGEND

- Yates Production Well
- San Andres Production Well
- Vacuum Abo " "

Exhibit I

NO.	DATE	BY	ALTERATION

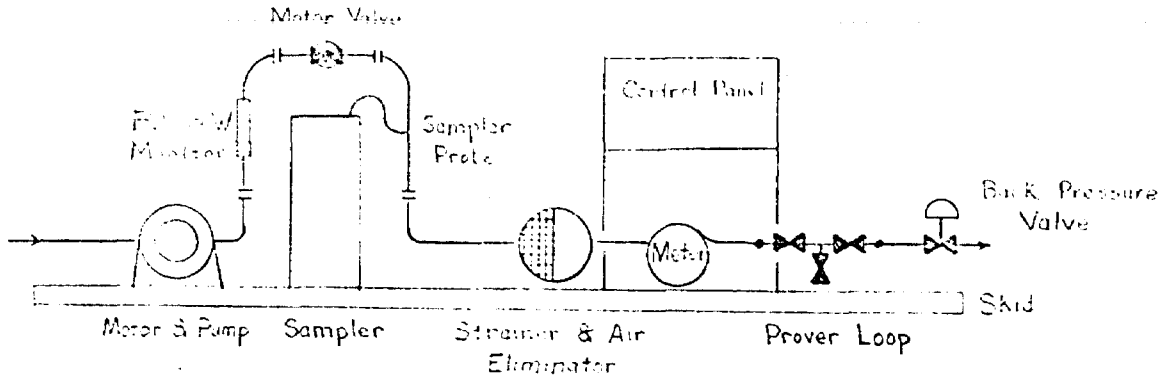
Vacuum Yates & Vacuum San Andres Fields

COMMINGLING PLAT

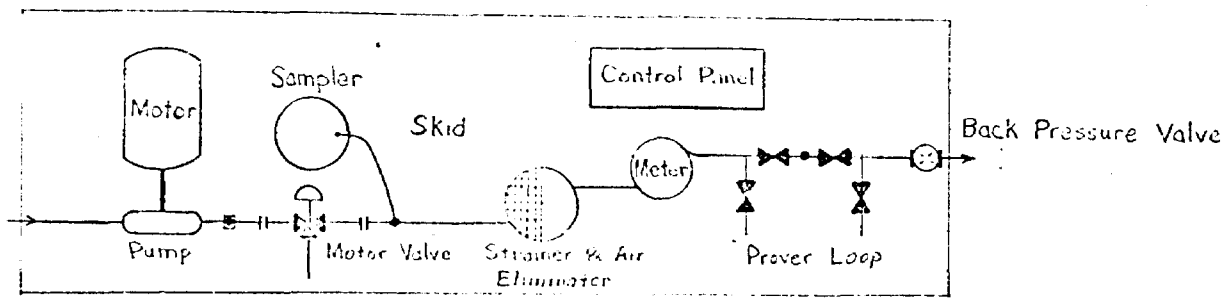
Lea Co., New Mexico

SOCONY MOBIL OIL COMPANY, INC.

DRAWN E.O.B.		DWG. NO.
CHECKED J.R.A.	SCALE 1"=1000'	A-139-D&P
	DATE 12-26-61	



SIDE VIEW



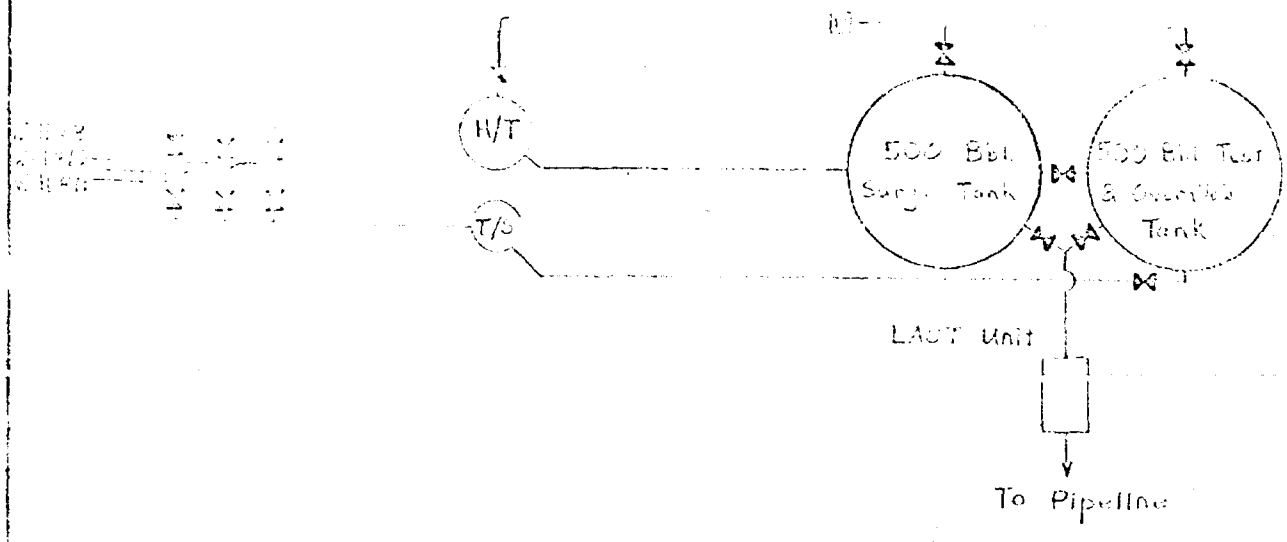
TOP VIEW

NO.	DATE	BY	ALTERATION

SCHEMATIC DIAGRAM
LACT SKID

SOCONY MOBIL OIL COMPANY, INC.

DRAWN		DWG. NO.
CHECKED	SCALE	A



Legend
- Recirculating Pump
- Heater Treater
- Test Separator
- Check Valve

NO.	DATE	BY	ALTERATION

Schematic Diagram
Drake "A" Lease
Vacuum Area Field

SOCONY MOBIL OIL COMPANY, INC.

DRAWN
CHECKED
SCALE
DATE
DWG. NO. A

QUOTATION

Quote No. _____

Sheet No. 1

ODEX ENGINEERING COMPANY

1410 N. GRANT

P. O. Box 1586
ODESSA, TEXAS

Phone FE 7-3566

TO: [illegible] COMPANY

[illegible]

[illegible] 21, NEW MEXICO

Attn. [illegible] D. SUMMERS

Date 2/2/62

Dwg. No. _____

Quote By GENE [illegible]

Re. UNIT FOR HOBBS, NEW MEXICO

Remarks _____

ITEM	QUANTITY	DESCRIPTION	UNIT PRICE	EXTENSION
1	1	2" MODEL K-200U VIKING ROTARY GEAR PUMP WITH 0-100 PSIG INTERNAL RELIEF VALVE, MECHANICAL SEAL, CASE, V-BELT DRIVE, BELT GUARD AND 5 H.P. 1750 RPM, 220/440 VOLT, 3 PHASE, 60 CYCLE EXPLOSION-PROOF FAIRBANKS MORSE ELECTRIC MOTOR. PUMP IS SIZED TO FLOW 35 GPM AGAINST 75 PSIG AT 400 RPM.		
2	1	MODEL 2000 INSTRUMENTS, INC. TEMPERATURE COMPENSATED, FAILSAFE BS&W MONITOR, RANGE 0-3%, 30 SECONDS TIME DELAY, WITH 30", TYPE RG/62U COAXIAL CABLE.		
3	1	2" MODEL CX-205-200 BSP INSTRUMENTS, INC. BS&W PROBE, INTERNALLY COATED WITH EPON RESIN, FLANGED CONNECTIONS COMPLETE WITH EXPLOSION-PROOF CONDULET ASSEMBLY.		
4	1	2" ODEX MODEL R-200-AF 3 WAY 2 POSITION BAD OIL DIVERTER VALVE, S.S. TRIM, COMPLETE WITH EXPLOSION-PROOF SOLENOID OPERATOR. VALVE IS NORMALLY CLOSED TO PIPELINE IN THE EVENT OF POWER OR GAS FAILURE.		
5	1	MODEL RIEX YZ ENGINEERS AUTOMATIC CRUDE OIL PIPELINE SAMPLER COMPLETE WITH 20 GALLON PRESSURE-TIGHT SAMPLE CONTAINER, MIXER, SIGHT GLASS, HAND PURGE PUMP AND SAMPLE PROBE WITH 45° MITER.		
6	1	2" BRODIE MODEL D-23 COMBINATION STRAINER-AIR ELIMINATOR, WITH 20 MESH STAINLESS STEEL STRAINER BASKET.		

(CONTINUED ON PAGE 2)

TOTAL PRICE

Delivery _____

ODEX ENGINEERING COMPANY

Terms _____

By _____

Please examine this quotation carefully, as we agree to furnish only items or services herein described at the prices listed. Prices subject to change without notice.

QUOTATION

Quote No. [illegible]

Sheet No. [illegible]

ODEX ENGINEERING COMPANY

1410 N. GRANT | P. O. Box 1586, ODESSA, TEXAS | Phone FE 7-3566

TO: [illegible] COMPANY

[illegible] P. O. [illegible]

[illegible], TEXAS

Attn. [illegible] J. P. [illegible] JONES

Date 2/2/62

Dwg. No. [illegible]

Quote By [illegible]

Re. [illegible] UNIT FOR MOODS, NEW MEXICO

Remarks

ITEM	QUANTITY	DESCRIPTION	UNIT PRICE	EXTENSION
7	1	2" BRODIE MODEL D-400 BIROTOR POSITIVE DISPLACEMENT TYPE CRUDE OIL METER COMPLETE WITH THE FOLLOWING ACCESSORIES: A. BRODIMATIC HORIZONTAL NON-RESET BARREL COUNTER. B. MODEL 4500-D AUTOMATIC TEMPERATURE COMPENSATOR; RANGE -20° F. TO 150° F. WITH MANUAL GRAVITY SELECTOR. C. METER MONITOR SWITCH, EXPLOSION-PROOF SPDT MOUNTED ON UNIT WHEEL OF COUNTER TO PACE SAMPLER 1:1 RATIO AND LOW FLOW DETECTION CIRCUIT.		
8	1	PROVER LOOP CONSISTING OF THE FOLLOWING COMPONENTS: A. 2 - 2" SHUT-OFF PLUG VALVES FLANGED CONNECTIONS. B. 2 - 2" BY-PASS PLUG VALVES FLANGED CONNECTIONS, WITH LOCKING DEVICES. C. 2 - 2" QUICK-DISCONNECT PART A ADAPTERS WITH DUST CAPS.		
9	1	2" ODEX MODEL R-400-BPF SELF-CONTAINED LIQUID BACK PRESSURE AND CHECK VALVE. VALVE IS DESIGNED TO CLOSE WITH POWER FAILURE OR IN CONJUNCTION WITH SIGNAL TO DIVERT BAD OIL.		
10	1	ODEX NON-GRAPHIC CONTROL PANEL OF FAILSAFE DESIGN COMPLETE WITH THE FOLLOWING COMPONENTS:		

(CONTINUED ON PAGE 3)

TOTAL PRICE

Delivery

ODEX ENGINEERING COMPANY

Terms

By

Please examine this quotation carefully, as we agree to furnish only items or services herein described at the prices listed. Prices subject to change without notice.

QUOTATION

Quote No. [illegible]

Sheet No. 3

ODEX ENGINEERING COMPANY

1410 N. GRANT | P. O. Box 1586, ODESSA, TEXAS | Phone FE 7-3566

TO: [illegible]

[illegible]

[illegible] 21, TEXAS

Attn. [illegible]

Date 2/12/62

Dwg. No. _____

Quote By GENE BELL

Re. [illegible] UNIT, EUNICE, NEW MEXICO

Remarks _____

ITEM	QUANTITY	DESCRIPTION	UNIT PRICE	EXTENSION
		ITEM 10 CONT'D A. SQUARE D - NEMA 3 WEATHERPROOF ENCLOSURE, 14 GAUGE ENAMELED STEEL SINGLE COMPARTMENT. B. LOW FLOW DETECTION CIRCUIT. C. SIZE 1 STARTER WITH THREE OVERLOAD RELAYS. D. 1.0 KVA 440/110 VOLT DRY TYPE TRANSFORMER. E. [illegible] VOLT A.C. F. HAND-OFF AUTOMATIC SWITCH. G. MISCELLANEOUS COMPONENTS INCLUDING 5 DISPLAY LAMPS WITH BULBS, 4 KRPIIAG POTTER-BRUMFIELD RELAYS, WITH MOUNTING SOCKETS, RESISTORS, FUSE, LAMP TEST SWITCH, AND MASTER SWITCH. H. SAFETY DOOR INTERLOCK SWITCH. I. 30 AMP, 600 VOLT FUSIBLE DISCONNECT SWITCH, 3 POLE WITH THREE FUSES.		
11	1	LABOR AND MATERIALS TO FABRICATE SKID.		
12	1	LOT MISCELLANEOUS FITTINGS, LABOR TO ASSEMBLE COMPONENTS, AND FREIGHT TO LOCATION.		
		TOTAL PRICE		$
		OPTIONAL ITEMS		
13	1	ELECTRICAL LABOR AND MATERIALS TO PREWIRE ELECTRICAL COMPONENTS TO CONTROL PANEL MOUNTED ON SKID.		

(CONTINUED ON PAGE 4)

TOTAL PRICE

Delivery _____ ODEX ENGINEERING COMPANY

Terms _____ By _____

Please examine this quotation carefully, as we agree to furnish only items or services herein described at the prices liste ject to change without notice.

QUOTATION

Quote No. [illegible]

Sheet No. 1

ODEX ENGINEERING COMPANY

1416 N. GRANT

P. O. Box 1586
ODESSA, TEXAS

Phone FE 7-3566

TO: [illegible] OIL COMPANY

P. O. BOX 600

DALLAS 21, TEXAS

Attn. MR. J. D. CUMMES

Date 2/2/[illegible]

Dwg. No.

Quote By GENE BELL

Re. LAST UNIT FOR HOBBS, NEW MEXICO

Remarks

ITEM	QUANTITY	DESCRIPTION	UNIT PRICE	EXTENSION
		OPTIONAL ITEM CONT'D		
14	1	NULL METER AND TRANSPARENT COVER FOR MODEL 2000 BS&W MONITOR.	$	
		WE WILL BE ABLE TO START CONSTRUCTION IN THREE WEEKS FROM RECEIPT OF ORDER AND CAN DELIVER THE UNIT IN FOUR WEEKS.		
			TOTAL PRICE	

Delivery 30 DAYS

Terms NET 30

ODEX ENGINEERING COMPANY

By [illegible] JIM CHISM

Please examine this quotation carefully, as we agree to furnish only items or services herein described at the prices listed ject to change without notice.

Sheet No. [illegible]

ODEX ENGINEERING COMPANY

1410 N. GRANT

P. O. Box 1586
ODESSA, TEXAS

Phone FE 7-3508

TO: [illegible]

Quote No. F - 633 - [illegible]

Dwg. No.

Date 3 / 13 / 62

Attn. [illegible]

Quote By J. J. [illegible]

Re. [illegible]

Remarks [illegible] F - 633

ITEM	QUANTITY	DESCRIPTION	UNIT PRICE	EXTENSION
2	1	MODEL 2000 INSTRUMENTS, INC. TYPE RECTURE COMPENSATED, EXPLOSION PROOF BOOM MONITOR, RANGE 0-3%, 30 SECONDS TIME DELAY, W/ 30', TYPE RV/62U COAXIAL CABLE.		
3	1	2" MODEL OX - 205 -300 BSP INSTRUMENTS INC, BOOM PROBE, INTERNALLY COATED WITH [illegible] BOOM, FLANGED CONNECTIONS COMPLETE WITH EXPLOSIONPROOF CONDUIT ASSY.		
5	1	MODEL MLX VZ ENGINEERS AUTOMATIC CRUDE OIL PIPE LINE SAMPLER CONSISTS WITH 20 GALLON PRESSURE TIGHT SAMPLE CONTAINER, MIXER, SIGHT GLASS, HAND PURGE PUMP AND SAMPLE PROBE WITH 45° MITER.		
2A 3-A	1	MODEL TYPE UNITED ENGINEERS TEMPERATURE COMPENSATED, 3", EXPLOSION PROOF BOOM MONITOR WITH PROBE, 0-3% RANGE, 30 SECOND TIME DELAY AND 10' COAXIAL CABLE.		
2A 3-AX	1	MISC. FITTINGS AND LABOR TO CONVERT FROM 2" TO 3" AND FROM 3" BACK TO 2" TO MOUNT MONITOR AND PROBE.		
5-A	1	ODEX "SIMPLEX" AUTOMATIC CRUDE OIL SAMPLER CONSISTS WITH 20 GALLON PRESSURE TIGHT SAMPLE CONTAINER, MIXER, SIGHT GLASS, HAND PURGE PUMP, VACUUM REGULATOR AND SAMPLE PROBE WITH 45° MITER.		
		NET DEDUCTION		
			TOTAL PRICE	

Delivery [illegible]

Terms NET 30

ODEX ENGINEERING COMPANY

By [signature]

PLEASE examine this quotation carefully, as we agree to furnish only items or services herein described at the prices lis subject to change without notice.

TEXAS-NEW MEXICO PIPE LINE COMPANY

F. B. WHITAKER, JR.
DIVISION MANAGER

March 22, 1962

P. O. BOX 1510
MIDLAND, TEXAS

New Mexico Oil Conservation Commission
P. O. Box 871
Santa Fe, New Mexico

Gentlemen:

Mobil Oil Company advises that they intend to make application to the New Mexico Oil Conservation Commission for permission to permanently install and operate an automatic custody transfer system on their State "M" Lease located in the SW/4 of Section 34, T-17-S, R-35-E, Lea County, New Mexico.

Texas-New Mexico Pipe Line Company gathers production from this lease and concurs in the operator's application for permanent approval to install and operate this ACT unit.

Yours very truly,

TEXAS-NEW MEXICO PIPE LINE COMPANY

By L P Schraub
L. P. Schraub
Assistant Division Manager

LPS-btk

cc: Mobil Oil Company
P. O. Box 2406
Hobbs, New Mexico

DRAFT

RSM/esr
April 25, 1961

BEFORE THE OIL CONSERVATION COMMISSION
OF THE STATE OF NEW MEXICO

IN THE MATTER OF THE HEARING
CALLED BY THE OIL CONSERVATION
COMMISSION OF NEW MEXICO FOR
THE PURPOSE OF CONSIDERING:

CASE No. 2243

Order No. R-1959

APPLICATION OF GULF OIL CORPORATION
FOR AN AMENDMENT OF RULE 309 (a).

ORDER OF THE COMMISSION

BY THE COMMISSION:

This cause came on for hearing at 9 o'clock a.m. on April 13, 1961, at Hobbs, New Mexico, before the Oil Conservation Commission of New Mexico, hereinafter referred to as the "Commission."

NOW, on this _____ day of April, 1961, the Commission, a quorum being present, having considered the testimony presented and the exhibits received at said hearing, and being fully advised in the premises,

FINDS:

(1) That due public notice having been given as required by law, the Commission has jurisdiction of this cause and the subject matter thereof.

(2) That Rule 309 (a) should be revised in order to facilitate the administration of requests for approval of automatic custody transfer systems.

(3) That Form C-106, attached to this order as Exhibit A, should be adopted, and that Rule 1103 should be amended to include said form.

IT IS THEREFORE ORDERED:

(1) That Rule 309 (a) is hereby revised to read in its entirety as follows:

RULE 309-A. CENTRAL TANK BATTERIES

Oil shall not be transported from a lease until it has been received and measured in a facility of an approved design located on the lease. Such facilities shall permit the testing of each well at reasonable intervals and may be comprised of manually gauged closed stock tanks for which proper strapping tables have been prepared, with a maximum of sixteen proration units producing into said tanks, or of automatic custody transfer (ACT) equipment. The use of such automatic custody transfer equipment shall be permitted only after compliance with the following:

1. The operator shall file with the Commission Form C-106, Notice of Intention to Utilize Automatic Custody Transfer Equipment, and shall receive approval thereof prior to transferring oil through the ACT system. The carrier shall not accept delivery of oil through the ACT system until Form C-106 has been approved.

2. Form C-106 shall be submitted in quadruplicate to the appropriate District Office of the Commission and shall be accompanied (in quadruplicate) by the following:

(a) Plat of the lease showing thereon all wells which will be produced into the ACT system.

(b) Schematic diagram of the ACT equipment, showing thereon all major components such as surge tanks and their capacity, extra storage tanks and their capacity, transfer pumps, monitors, reroute valves, treaters, samplers, strainers, air and gas eliminators, back pressure valves, metering device (indicating type and capacity, i.e., whether automatic measuring tank, positive volume metering chamber, weir-type measuring vessel, or positive displacement meter). Schematic diagram shall also show means employed to prove accuracy of measuring device.

(c) Letter from transporter agreeing to utilization of ACT system as shown on schematic diagram.

3. Form C-106 will not be approved by the Commission unless the ACT system is to be installed and operated in compliance with the following:

(a) Provision must be made for accurate determination and recording of uncorrected volume and applicable temperature, or of temperature corrected volume. The overall accuracy of the system shall equal or surpass manual methods.

(b) Provision must be made for representative sampling of the oil transferred for determination of API gravity and BS&W content.

(c) Provision must be made if required by either the producer or the transporter of the oil to give adequate assurance that only merchantable oil is run by the ACT system.

(d) Provision must be made for set-stop counters to stop the flow of oil through the ACT system at or prior to the time the allowable has been run. All counters shall provide non-reset totalizers which shall be visible for inspection at all times.

(e) All necessary controls and equipment must be enclosed and sealed, or otherwise be so arranged as to provide assurance against, or evidence of, accidental or purposeful mismeasurement resulting from tampering.

(f) All components of the ACT system shall be properly sized to ensure operation within the range of their established ratings. All components of the system which require periodic calibration and/or inspection for proof of continued accuracy must be readily accessible. The frequency and methods of such calibration and/or inspection shall be as set forth in Rule 309-A, 4-c.

(g) The control and recording system must include adequate fail-safe features which will provide assurance against mismeasurement in the event of power failure, or the failure of the ACT system's component parts.

(h) 1. The ACT system and allied facilities shall include such fail-safe equipment as may be necessary, including high level switches in the surge tank or overflow storage tank which, in the event of power failure or malfunction of the ACT or other equipment, will shut down all artifically lifted wells connected to the ACT system and will shut-in all flowing wells at the well-head or at the header manifold, in which latter case all flowlines shall be pressure tested to at least 1½ times the maximum well-head shut-in pressure prior to initial use of the ACT system and ~~once~~ each two years thereafter.

2. As an alternative to the requirements of paragraph (h) 1 above, the producer shall provide and shall at all times maintain a minimum of available storage capacity above the normal high working level of the surge tank to receive and hold the amount of oil which may be produced during maximum unattended time of lease operation.

4. (a) In all ACT systems employing automatic measuring tanks, weir-type measuring vessels, positive volume metering chambers, or any other volume measuring container, the container and allied components shall be properly calibrated prior to initial use and shall be operated, maintained, and inspected as necessary to ensure against incrustation, changes in slippage factors, valve leakage or other leakage, and improper action of floats, level detectors, etc.

(b) In all ACT systems employing positive displacement meters, the meter(s) and allied components shall be properly calibrated prior to initial use and shall be operated, maintained, and inspected as necessary to ensure against mismeasurement of oil.

Meters may be proved 5/100 of one percent.

(c) The measuring and recording devices of all ACT systems shall be checked for accuracy at least once each month unless exception to such determination has been obtained from the Secretary-Director of the Commission. API Standard 1101, "Measurement of Petroleum Liquid Hydrocarbons by Positive Displacement Meter," shall be used where applicable. ~~Determinations may be made~~ against Master Meters, Portable Prover Tanks, or Prover Tanks permanently installed on the lease. If permanently installed Prover Tanks are used, the distance between the opening and closing levels and the provision for determining the opening and closing readings shall be sufficient to detect variations of ~~.05%~~. Reports of determinations shall be filed on the Commission Form entitled "Meter Test Report," or on another acceptable form and shall be submitted in duplicate to the appropriate District Office of the Commission.

(d) To obtain exception to the requirement of paragraph (c) above that all measuring and recording devices be checked for accuracy once each month, either the producer or transporter may file such a request with the Secretary-Director of the Commission setting forth all facts pertinent to such exception. The application shall include a history of the average factors previously obtained, both tabulated and plotted on a graph of factors versus time, showing that the particular installation has experienced no erratic drift. The applicant shall also furnish evidence that the other interested party has agreed to such exception. The Secretary-Director may then set the frequency for determination of the system's accuracy at the interval which he deems prudent.

5. Failure to operate an automatic custody transfer system in compliance with this rule shall subject the approval thereof to revocation by the Commission.

(2) That Form C-106, attached to this order as Exhibit A, is hereby adopted, and that Rule 1103 is hereby amended to include said form.

(3) That the effective date of this order shall be May 1, 1961.

DONE at Santa Fe, New Mexico, on the day and year hereinabove designated.