CONTENT:

1.0 PURPOSE AND SCOPE:

This instruction outlines the operational procedure to be followed for all royalty measurement of hydrocarbon liquids. The liquids involved are crude oil, natural gasoline (A180/A305), natural gas liquid (NGL), butane, propane and Hexane services

*2.0 REFERENCES & RELATED DOCUMENTS:

Saudi Aramco Standards:

SAES-Y-103, Royalty/Custody Metering of Hydrocarbon Liquids.

Saudi Aramco Engineering Procedures (SAEP):

SAEP-21, Project Execution Requirements for Saudi Aramco Royalty/Custody Metering Systems
SAEP-50, Project Execution Requirements for Third Party Royalty/Custody Metering Systems

General Instructions:

GI 405.004, Royalty Gauging of Crude Oil
GI 405.005, Royalty Custody Metering Facility Responsibilities

Other Documents:

Accounting Instructions Manual No. 809, Accounting for Royalties.
MINPET Measurement Guidelines.

International Standards:

API Manual of Petroleum Measurement Standards (MPMS)
Chapter 1, Vocabulary

Chapter 2, Tank Calibration
Chapter 3, Tank Gauging
Chapter 4, Proving Systems
Chapter 5, Metering
Chapter 7, Temperature Determination
Chapter 8, Sampling
Chapter 9, Density Determinations
Chapter 10, Sediment & Water
Chapter 12, Calculations of Petroleum Quantities

3.0 DEFINITIONS AND ACRONYMS:

Custody Transfer Measurement:	A specialized form of measurement which is the basis for selling or transferring oil, gas and products from Saudi Aramco to another company or between Departments within the company.
Royalty Transfer Measurement:	A specialized form of custody transfer measurement which is the basis for paying royalty to the Saudi Arabian Government. The method of calculations for royalty payments and other details are given in Accounting Instructions Manual No. 809.
Meter proving:	The procedure required determining the ratio between the true volume of liquid measured by a meter to the volume indicated by the meter. This ratio is defined as the meter factor.
Base Meter Factor:	An initial meter factor obtained at flow rate conditions determined at each location, for a new meter or a serviced meter.
Meter calibration:	The procedure required to establish a relationship between a range of flow rates and corresponding meter factors obtained by series of meter provings.
MINPET:	Ministry of Petroleum & Mineral Resources
BANOCO	Bahrain National Oil Company
P&CSD:	Process & Control Systems Department
PID:	Process Instrumentation Division
CMU:	Custody Measurement Unit
NIST:	National Institute of Standards & Technology
SASO:	Saudi Arabian Standards Organization
ISO:	International Standards Organization
SASREF:	Saudi Aramco Shell Refinery
SAMREF:	Saudi Aramco Mobil Refinery

4.0 RESPONSIBILITIES:

4.1 Operating Department:

4.1.1 Each operating department involved in the royalty transfer of hydrocarbon liquids shall be responsible for the implementation of this GI. The department head shall designate personnel to monitor and assist in its implementation.

4.1.2 The Operating Department shall ensure that the Instructions Manuals pertaining to the royalty measurement activities are prepared and reviewed as necessary or a minimum every 2 years to ensure proper operation of the royalty transfer measurement facilities. These Instructions and any revisions shall be reviewed by the Custody Measurement Unit of PID/P&CSD for concurrence prior to their approval and implementation.

*4.1.3 The operating department shall ensure that:

- The equipment required for royalty transfer are operated in accordance with the approved operating instructions of that station.
- MINPET seals are applied as necessary to the meters, bypass valves around meters, inlet/outlet valves on tanks, temperature/pressure transmitters and other equipment that affect measurement. Specific sealing requirements for each location will be determined by the Operating Instruction for that location. The removal/installation of a seal shall be done by the MINPET representative and recorded by the Supervising Operator in the shift logbook.
- Records are maintained to provide a traceable history of the operation and maintenance of the royalty measurement equipment
- Net volume calculations are per appendices given in Saudi Aramco Engineering Standard SAES-Y-103, Royalty/Custody Metering of Hydrocarbon Liquids.

4.1.4 The Operating Department shall ensure that personnel responsible for royalty measurement, maintain accurate records. Such records may include but not limited to: location, dates and time of transfer, ship/customer name, type of liquid, opening and closing readings, temperature, pressure and other information necessary for proper accountability of the transfer.

4.2 Maintenance Department:

4.2.1 The Maintenance Department, as part of Preventive Maintenance (PM) program, shall ensure that all the instruments used in the transfer are properly maintained and calibrated against reference standards.

4.2.2 The reference standards shall be traceable to recognized accredited standards agencies (e.g. NIST, SASO or ISO). The standard shall be checked and certified by the Saudi Aramco laboratory or an Independent Calibration Agency.

4.2.3 The calibration and checking of the reference standards shall be done annually or earlier if required.

4.3 Financial Accounting Department:

4.3.1 For the automated metering stations with flow computer, the Financial Accounting Department (FAD) is responsible for obtaining the delivery tickets, proving reports or other shipping documents from the Operating Department, duly signed by the responsible operating personnel, witnessed and signed by the MINPET representative.

4.3.2 For the non-automated stations, FAD is responsible for processing and verifying the meter proving reports and the delivery tickets or other shipping documents from the Operating Department, after being signed by the responsible operating personnel, witnessed and signed by the MINPET representative.

4.4 Process & Control Systems Department:

4.4.1 Process & Control Systems Department, represented by the Custody Measurement Unit (CMU), shall conduct periodic joint surveys of the transfer points with the representatives of the Operation, Maintenance and/or Engineering Department to ensure compliance with the Saudi Aramco measurement standards and MINPET Guidelines. Approved operating instructions and recommendations on what parts of the royalty measurement facilities need to be upgraded or modified. Representatives from Maintenance & Operation Engineering may participate.

4.4.2 A survey report with recommendations to eliminate deficiencies and improve measurement practices shall be submitted to the Operating Department. If the report indicates action items, the responsible Department should provide an action plan for implementing the issued recommendations within the date specified in the report and CMU shall follow up the plan of action items.

5.0 PHILOSOPHY OF OPERATION:

No loading or delivery shall be permitted to continue with any failed device related to measurement that might result in potential loss and/or uncertainty of the delivered volume, or cause it to be questioned. Where such circumstances exist, preventive measures, such as an orderly shutdown of the affected measurement equipment at the shortest possible time and timely repair/replacement of the defective equipment must be taken up. Refer to individual section for the necessary action required achieving this philosophy.

6.0 METHODS OF TRANSFER MEASUREMENT:

Royalty transfer measurement is based on the following two methods.

A. Static Measurement

B. Dynamic Measurement

6.1 Static Measurement

Manual tank gauging is currently the only approved static measurement method for royalty transfer. This method can be used for billing in case of failure of the metering system and after obtaining the necessary approval from MINPET. Other tank gauging methods can be used upon MINPET approval.

For gauging of on-shore crude oil tanks, refer to GI 405.004, Royalty Gauging of Crude Oil. For Propane and butane exported from Plant 59, Ras Tanura Terminal South, ship-gauging figures are used for billing purposes.

A Saudi Aramco Inspector must witness and verify all the records obtained by the Third Party Inspector and MINPET representative.

"Royalty/Custody Tank Gauging of Hydrocarbon Liquids" standard is currently under development.

6.2 Dynamic Measurement (Metering)

6.2.1 Provers:

6.2.1.1 The prover shall be calibrated every 5 years or less using Waterdraw method or every 3 years using Master Meter method. The re-calibration of the prover is required after any maintenance work that may affect the volume of the calibrated section of the prover.

6.2.1.2 The Operating department is responsible of initiating a request to CMU informing of its plans to calibrate the prover(s) and the method to be used to conduct the calibration. The notification shall be two months prior to the calibration due date to liaison with MINPET. Delay of prover calibration might subject Saudi Aramco to measurement uncertainty.

6.2.1.3 The proponent maintenance department shall make all the necessary preparation for conducting this calibration and providing the required equipment to be used in this activity and coordinate with P&CSD/PID/CMU to provide the calibrated water meter for the master meter method and calibrated measurement tanks for the water draw method of prover calibration. The proponent maintenance department shall insure that the system is mechanically and electrically ready to officially calibrate the prover.

6.2.1.4 The Third Party Calibration Agency shall perform the calibration in the presence of representatives from MINPET, CMU and the proponent. The requirement for an Independent agency for local royalty sales may be waived if agreed to by the local customer and approved by MINPET.

6.2.1.5 Independent Inspection Agency shall issue the official prover volume certificate. CMU verifies the new prover volume calculations and submits it to MINPET for approval. If the proving operation is needed before obtaining the official approval from MINPET, the old prover volume shall be used provided that no physical modifications have been made to the calibrated segment of the prover that can affect the prover volume.

6.2.2 Meter Proving:

A meter factor shall be determined by proving the meter under conditions of flow rates, hydrocarbon liquid type and grade, temperature and pressure similar to those that exist during the intended period of operations.

6.2.2.1 Frequency of Proving:

The proving frequency given below is for normal operation. In case of non-availability of prover (e.g. due to calibration or major maintenance), the last valid meter factor shall be used. However, high priority shall be given to put the prover back to service.

6.2.2.1.1 Pipeline Operation: Meters shall be proved at least once a month, preferably, on the 15th of the month or whenever is requested by MINPET. The meter factor obtained, if within the acceptable tolerance as specified in paragraph 6.2.2.2 below, shall be effective from 00.01 hr of the next day of the proving until the next proving. In case of the new meter factor obtained by proving with an automatic system and then declared "Official" shall be effective at the time declared official, and causes a batch recalculation for the current batch.

6.2.2.1.2 Terminal Operation: Meters shall be proved for every ship-loading batch and for each grade of crude oil. The proving shall be done when the flow rate and temperature are stable, normally at about 1/3 of the batch size. The meter factor obtained for the batch shall be used for that ship-loading batch provided that the factor is within the acceptable tolerance as specified in paragraph 6.2.2.2 below.

6.2.2.2 Tolerances:

During proving the temperature difference between the prover and the meter shall be within 2 0F for the crude oil, naphtha and 0.5 0F for Propane and Butane

A meter factor is acceptable if:

1. The deviation between the current meter factor vs. initial meter factor is less than ±0.25% for the following hydrocarbon liquids:

   · Propane
   · Butane
   · NGL
   · Hexane
   · Arab Super Light Crude Oil (ASL)
   · Arab Extra light Crude Oil (AXL), and
   · Arab Light Crude Oil (AL)

The deviation between the current meter factor vs. initial meter factor is less than ±0.35% for AH.

Action to be taken: If the deviation is more than those specified above and a recheck of the proving system does not indicate any malfunction, for example, leaking 4-way valve, block & bleed valve, not venting the prover etc., the meter shall be removed from service immediately.

2. a). Pipeline Operation: The deviation between the current meter factor vs. the average of the last two meter factors, is less than ±0.1%

   b). Terminal Operation: The deviation between the current meter factor vs. the average of the last 10 meter factors, is less than ±0.1%.

Action to be taken: If the deviation is more than those specified above, proving shall be repeated after a thorough check of the system for any malfunction, such as, leaking 4-way valve, block & bleed valve, not venting the prover etc.

Appendix-1, The Troubleshooting Guide on Meter Proving Operation, can be used as guidelines for investigating the probable causes of the meter proving failure.

The last acceptable meter factor obtained shall be used for the delivery.

Note:

If the proving operation failed from first time, additional provings shall be conducted to confirm that the meter needs to be taken out of service.

6.2.2.3 Calibration of Meter:

6.2.2.3.1 A meter shall be calibrated throughout its full linear flow range only whenever a new or a serviced meter is installed. The calibration shall be performed in the presence of a MINPET representative. Proving data shall be signed by the operating personnel and MINPET representative and submitted to CMU for obtaining approval from MINPET. The meter shall not be used until an approval is granted by MINPET in writing.

6.2.2.3.2 The minimum no. of points required for calibrations are:

Meter size (nominal)	No of points
4 inch & below	5
6 inch to 12 inch	8
16 inch and larger	12

Note:
Meters shall be operated only in the flow range approved by MINPET.

6.2.2.4 Integrity of Barrel Counts:

When the individual pulse comparison error occurs and an alarm informs the operator, the affected meter run must be taken out of service if a spare meter is available. Where no spare meter is available and loading cannot be interrupted or reduced, the metering results from either the individual flow computer or the master computer shall be used for billing. Refer for more details to flow computer failures in Section 9.

7.0 TEMPERATURE MEASUREMENT:

7.1 General

7.1.1 Certified mercury-in-glass test thermometers (MIGT) are inserted in thermowells located near the temperature transmitter.

7.1.2 MIGT are required to have a readability of at least 1 ˚F and accuracy of 0.5 ˚F or better and certified by the Saudi Aramco Laboratory.

7.1.3 The temperature transmitters outputs shall be checked monthly against flow computer reading and a MIGT. If the difference is more than 0.25%, and/or 0.5 ˚F, then the temperature transmitter shall be calibrated. The calibration shall be witnessed and signed by a MINPET representative

7.2 Meter Temperature:

7.2.1 The temperature of the hydrocarbon liquids in the meter run shall be taken either from the temperature transmitter installed on the upstream header of the metering skid or from the transmitter installed on the individual meter run for computation.

If an outlet header temperature transmitter is installed, it should be used for checking purposes only.

7.2.2 The flow computer shall scan the meter temperature every 30 seconds or less and use that value in calculating an incremental fluid volume or flow weighted temperature. These values are stored in the computer according to the software. A single value (flow weighted) is printed out on the shipping ticket.

In case of failure of the transmitters, temperature readings from the MIGT in the test thermowells shall be used.

7.3 Prover Temperature:

7.3.1 The prover temperature of the hydrocarbon liquids shall be measured on the outlet of the meter prover.

7.3.2 Item 7.2.2 also applies to meter provers.

7.3.3 The prover temperature shall be taken manually or by the flow computer at least once for each run (round trip) of the prover.

7.3.4 The prover temperatures taken for each run are recorded manually or by the computer on the meter proving report.

7.4 Calibration of Temperature Measuring Instruments:

7.4.1 All glass thermometers shall be certified to ASTM standards before initial use and annually thereafter. Portable electronic thermometers shall be certified to ASTM standards before initial use and quarterly thereafter. They shall be checked against a glass thermometer at each use. Calibration shall be witnessed by a MINPET representative.

7.4.2 A resistance decade box is used for calibrating the temperature transmitters.

7.4.3 The resistance box is connected to the temperature transmitter input terminal and a calibrated meter shall be connected to the transmitter output terminal. Resistance is applied at the resistance box and the transmitter output and computer reading is checked to give the required output signal (4-20 mA or 0-10 volts for zero and span) in 25% range increments up and down scale of the instrument. Adjustments are made to the transmitter if output signal is not within tolerance. Conventional-type and the Smart-type of the temperature transmitters shall be calibrated to 0.2% and 0.1% of transmitter span, respectively.

All other elements in the temperature transmitters instrument loop i.e. process recorders, indicators (dedicated and via MMI screen) and the input to a Terminal Remote Unit (RTU) shall be checked at the same time as the calibration of the temperature transmitter and any necessary adjustments shall be made.

7.4.4 After calibration the temperature transmitter, the accuracy of the temperature element (TE) shall be checked by comparing to the temperature transmitter reading at the flow computer with the reading indicated by the certified glass thermometer.

7.4.5 The calibration results shall be recorded on an appropriate calibration report and signed by company and MINPET representatives.

7.4.6 The calibration should be conducted over the entire set range of the temperature measuring devise.

7.4.7 Gauge and temperature recorders shall be adjusted during calibration to agree with the calibration device.

7.5 Tank Temperature:

Cup case or portable electronic thermometers shall be used for crude oil service. Refer to GI 405.004 for details.

8.0 PRESSURE MEASUREMENT

8.1 Meter pressure

8.1.1 The pressure of the hydrocarbon liquids at the meter shall be taken on each meter run on the downstream section beyond the required straight length of pipe.

8.1.2 A local pressure gauge shall be installed in close proximity of the pressure transmitter.

8.1.3 The flow computer shall scan the meter pressure every 30 seconds or less and use that value in computing an incremental fluid volume or volume weighted pressure.

These values are stored in the computer according to the software and a single value (flow weighted) is printed out on the shipping ticket. If volumes are calculated for each scan there is no visual record of the pressures taken during each scan and the average pressure does not appear on the meter ticket.

In case of transmitter failure, the pressure gauge shall be used.

8.2 Prover Pressure

8.2.1 The prover pressure (crude oil, propane or butane) shall be measured on the inlet or outlet of the meter prover.

8.2.2 Items 8.1.2 and 8.1.3 also apply to meter provers.

8.2.3 The prover pressure shall be taken manually or by the flow computer at least once for each run (round trip) of the prover.

8.2.4 The prover pressures taken for each run shall be recorded manually or by the flow computer on the meter proving report.

8.3 Calibration of Pressure Measuring Devices

8.3.1 The pressure gauge and pressure recorder shall be calibrated on a monthly basis using a certified dead weight tester or other approved device in the presence of the MINPET representative. If a dead weight tester is used, follow the procedure listed in items 8.3.2 and 8.3.3 below.

8.3.2 The dead weight tester shall be connected to the pressure transmitter input port on the meter run or prover and a calibrated meter shall be connected to the transmitter output terminals. The transmitter output signal (4-20 mA or 0-10 volts for zero and span) shall be compared in 25% range increments up and down scale with the pressure indicator value and the recorder and the flow computer readings in the instrument control room. Adjustments shall be made to the transmitter if the output signal is not within tolerance. Conventional-type and the Smart-type of the Pressure transmitters shall be calibrated to 0.2% and 0.1% of transmitter span, respectively.

All other elements in the pressure transmitters instrument loop i.e. process recorders, indicators (dedicated and via MMI screen) and the input to a Terminal Remote Unit (RTU) shall be checked at the same time as the calibration of the pressure transmitter and any necessary adjustments shall be made.

8.3.3 The calibration results shall be recorded on an appropriate calibration report and signed by company and MINPET representatives

8.3.4 The calibration should be conducted over the entire set range of the pressure measuring devise.

8.3.5 Transmitter, gauge, and pressure recorders shall be adjusted during calibration to agree with the dead weight tester.

9.0 COMPUTERS:

For royalty metering facilities which use an on-line computerized control system, the following shall apply:

9.1 A flow computer shall be designated as the primary device for net volume calculations and official billing for each meter run.

9.2 In case of failure of the primary flow computer, data from the redundant flow computer shall be utilized for net volume and official billing.

9.3 Access to critical computer based data that may alter the metering results shall be safeguarded using a password and/or key lock combination and MINPET seals.

9.4 All changes to system software shall be documented in a facility logbook and be approved by the Superintendents of Operations and Engineering. All changes that will affect the metering results must receive CMU approval prior to being implemented.

9.5 All flow computers, flow transmitters, pressure and temperature transmitters, sampling system and MOV's shall have dedicated power input. The disconnections or shutdown of other equipment shall not have any effect on the mentioned components

10.0 VALVES:

10.1 Double block and bleed valves or twin seal valves shall be used where valve leakage can effect the integrity of metering and proving results. Bypass valve shall be locked and sealed by MINPET.

10.2 All block and bleed valves shall be checked regularly, at least every three months for leakage and the Operating Supervisor shall maintain a log.

11.0 SAMPLING:

Samples of crude oil are collected to obtain sediment & water, API gravity and salt content. For Liquefied propane and butane service, samples are collected to obtain specific gravity and composition.

11.1 Crude Oil Sampling:

11.1.1 Manual Tank Sampling:

Refer to GI 405.004, Royalty Gauging of Crude Oil.

11.1.2 Automatic sampling:

11.1.2.1 Sampler Calibration;

Samplers shall be calibrated prior to their initial use by the water injection method as specified in API MPMS Chapter 8.2. The sampler shall not be put in service until it passes this test and approved by MINPET.

Sample mixing test shall also be performed to determine the optimum mixing time over a range of collected sample volumes.

11.1.2.2 Sample Collection:

- Prior to collection of samples, the container shall be completely drained and cleaned. All valves (drain and transfer valves) should be closed and the container sealed by MINPET.
- The sampler shall be regulated to take the quantity of sample desired for the entire loading period, or a batch, in case of pipeline operations. A minimum of 10,000 bites shall be collected per batch.
- The sampling rate shall not be changed during a delivery.
- Samples shall be mixed in the container by circulating pump for the duration determined under item 11.1.2.1 above.
- The following samples shall be collected for:

Pipeline Operation:

Samples shall be collected from the automatic sampler directly in centrifuge tube for S&W analysis, unless MINPET approves collection in quart bottles. Two samples of 50 ml. each are withdrawn in two centrifuge tubes for S&W content and one quart in glass bottle for API gravity and salt content. The sample bottle should be 80% filled to allow for liquid/gas expansion.

Additional samples are collected as required for retention purposes and if requested by the buyer.

Sample System Failure: In the event of failure of the automatic sampling system, manual samples shall be withdrawn from the manual sampling probe installed on the pipelines following the procedure documented in API MPMS Chapter 8.1, Manual Sampling of Petroleum and Petroleum Products.

Terminal Operation:

* Samples are withdrawn as stated under Pipeline Operation above. In addition to the these samples, three one-quart bottles (total nine bottles) shall be drawn from the line at

one-third, one-half and two-third of the load and labeled as alternate sample. These alternate samples can be discarded after the results of the main sample are recorded and accepted.

11.1.2.3 Retain Samples:

The retained samples shall be sealed by MINPET representative. The following retain sample and retention periods are presently allowed by MINPET:

Location	Retain Sample	Period	Sample to Buyer
All export terminal	Yes	6 months	Yes
Crude to BANOCO	Yes	1 month	No
Crude to Export Ref (SASREF, SAMREF)	Yes	1 month	Yes
Local royalty Sales (Ghazlan, Qurayyah, RT, Khurais and Yanbu refineries)	No		No

11.1.2.4 Samples shall be identified by vessel name, tank no., date, crude type and location. Official and retained samples shall be sealed by MINPET.

11.1.2.5 Samples should be stored in a temperature-controlled environment.

11.1.2.6 The retained sample can not be opened unless required by the Operating Department or Accounting Department. These departments shall inform CMU and request the approval of the Oil Supply Planning & Scheduling Dept. (OSPAS) for opening and analyzing the retained sample. The sample shall be analyzed in the presence of representatives from the Operating Department, the customer or his Independent inspector and MINPET.

11.1.3 Sampler Performance Monitoring:

A Sampler Performance record shall be maintained for each batch, which logs the flow rate, total bites collected, volume collected and a performance factor based on the actual volume divided by the theoretical volume. This factor shall be within 0.8 to 1.2. If the factor is out of this range the sampler is considered failed for that batch.

11.2 Sampling Liquefied Propane and Butane:

Refer to API MPMS Chapter 8.4, Standard Practice for Manual Sampling and Handling of Fuel for Volatility Measurement.

11.2.1 General comments and instruction for sampling liquid propane and butane:

1. Liquefied propane and butane samples shall be taken only by a certified sample gatherer.

2. Certificate holders shall be recertified every two years.
3. Samples are taken from only approved and identified sampling stations.
4. Sampling stations are equipped with approved valves and sample line fittings.
5. The type of cylinder has been designated for the product being sampled.
6. The sample shall be tagged with all the information required and shall be signed by the Company and MINPET representatives.

11.2.2 Sample Cylinder

1. Any appropriate size and type of LPG cylinder may be used for sampling LPG products. Every cylinder should be provided with outage at one end to release 20% liquid after filling them with LPG. These cylinders and sampling valves fitted to the cylinders should have at least 1800 psig pressure rating. All the cylinders In service should be hydrostatic tested for the minimum pressure rating of 1800 psig at least once every two years.

2. The copper strip corrosion should meet the requirement as specified in ASTM method D-1838, 'Copper Strip Corrosion by Liquefied Petroleum (LP) Gases'. The whole assembly shall be capable of withstanding a hydrostatic test pressure of 1000 psig. No leak shall be discernible when tested at 500 psig with gas.

3. Each cylinder shall be individually numbered and a record of the tests of each cylinder shall be maintained by the laboratory.

4. Liquefied propane and butane sample cylinders shall be inspected and in good condition before they are sent out for filling. Check hydrostatic test dates and pressure stamped on the cylinder.

11.2.3 Sampling Procedure:

Circulate the liquefied propane or butane for at least 4 hours prior to sampling. Vent all sample lines, valves and flexible hoses to atmosphere after the sampling is done. Bleed off 20% liquid after filling the cylinders to provide space for expansion. Precautions shall be taken as given in the LPG Sampling Instruction Manual.

11.2.4 Sampling Precautions

1. Liquefied, high pressure, propane and butane can be very dangerous if contact is made with the skin or eyes. Therefore, facemask or goggles appropriate clothing and gloves shall be worn while sampling these liquids.

2. These products are also very volatile and easily ignite if in contact with a spark or flame. Sampling personnel are therefore forbidden to carry matches or cigarette lighters.

3. Make sure that the sample cylinders have been bled off to provide ample space for expansion of the fluid.

4. Make sure that the cylinder valves are properly closed and plugged so there are no leaks.

11.3 For sampling other royalty hydrocarbon liquids, i.e. natural gasoline (A180/A305), natural gas liquid (NGL), and Hexane, the plant procedure will be implemented.

12.0 CALCULATIONS:

All the following calculations shall comply with the relevant appendices of the SAES-Y-103, Royalty/Custody Metering of Hydrocarbon Liquids. Any deviations from the standard format and calculations requires approval from CMU and MINPET:

1. Meter Proving Report

   The minimum requirements and format for the meter proving report shall comply with Meter Proving Report as shown in Appendix 1-1. An explanation of each of the specific items required in the meter proving report is presented in Appendix 1-2.

   Each step in the meter factor calculation is discussed per the specified API-MPMS Chapter 12.2.

2. Meter Factor Control Procedure

   Meter factor control procedure defines how the historical data are corrected to base conditions. The tolerances are defined and an explanation of procedures and events are given if the deviations are outside of the limits. The specific meter factor control procedures shall, as a minimum, conform to Appendix 1-3.

3. Measurement Ticket

   The minimum requirements and formats for the measurement tickets shall comply with Measurement Ticket as shown in Appendix 1-4. An explanation of each of the specific items specified in the measurement ticket is also presented in Appendix 1-5.

   A measurement ticket shall be generated for each meter used for each cargo or delivery.

   A single summary batch report showing the total volumes handled by the metering skid as well as each meter used in the transfer application.

RECOMMENDED BY:

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Manager, Process & Control Systems Department

CONCUR :

Vice President, Ras Tanura Refining

Vice President, Southern Area Producing

Executive Director, Yanbu refining

Vice President, Producing Plants & Pipelines

Executive Director, Sales & Marketing

APPROVED:

Vice President, Engineering Services

Appendix 1

TROUBLESHOOTING GUIDE
ON
METER PROVING OPERATIONS

by
Elmer Ner Garcia
and
Khalid A. Al-Fadhl
of
Saudi Arabian Oil Company
(Saudi Aramco)
Dhahran, Saudi Arabia

This paper offers a convenient, user-friendly troubleshooting guide (Appendix I) in determining poor operational practices, faulty equipment, human errors and other causes of unsuccessful proving or full calibration of flow meters. It effectively prevents premature condemnation of a completely operational flow meter that usually entails taking it out of service needlessly, then servicing it fully which is totally unnecessary, time-consuming and costly.

The guide lists different peculiarities or irregularities that may occur during a proof, the most probable causes, suggested checks, and recommended actions to remedy the situation.

Common Practices. Under the care of a team of experienced metering engineers, operators, and maintenance technicians, both the metering and proving systems (Figs. 1-3) can be run smoothly over a considerable period of time. These individuals will, over the years, develop a "sixth sense", so to speak, in maintaining the proving system in top working condition.

Because of operational changes, however, new people with limited or no experience in this field may be introduced into the system. In such instances, insignificant and routine problems have a way of developing into complex ones.

As in any undertaking, a few "rules-of-thumb" should be observed before running of a proving operation. Among the major items to be considered are the following:

- **Calibration of instruments.** Be certain that all the instruments (e.g., pressure/temperature transmitters, thermometers, readouts, controllers, etc.) for both the metering and proving equipment are calibrated. The metering station's operating instruction manual should specify the required calibration frequencies.

- **Operability of equipment.** It is surprising that in many occasions, a proving activity that has been carefully planned and arranged has to be postponed due to a malfunctioning component like the four-way diverter valve or a prover take-off valve. During the regular calibration of the instruments, it pays to check also the functional aspects of all equipment involved.

- **Line-up preparation.** This activity includes, but not necessarily limited to, closing and opening of the appropriate valves needed to prepare a given meter for proving, venting of trapped gases or vapors in the meter run and prover, and making sure that the pressure, temperature, and flow-rate fluctuations in the line are within the prescribed limits.

This is also the ideal time to check for any leakage in the system such as lines, fittings, and valves.

- **Volume and flow-rate availability.** In some instances, everything has been arranged, until one realizes that either there is not enough proving volume from the source or that storage space on the receiving side is inadequate.

Where volume is not a problem, there were times when the desired high flow rates cannot be met, either by the pumping capacity on hand, or the handling limitation on the receiving side. This point seems academic but such instances occur at times.

Troubleshooting Techniques. Over a period of time, certain practices and techniques are developed by the operators and maintenance technicians. One of the most common and cost-effective techniques is the process of elimination which applies to many types of activities.
To illustrate this point, let us say that the meter factors obtained from one of the meters in a multi-stream skid showed a sudden and consistent decrease in value, in comparison with previous ones. A quick check of the readouts and field devices such as four-way diverter valve, lines, fittings, and flanges showed no leakage or malfunction.

For all practical purposes, one may readily suspect that the prover sphere may have deflated to some extent, thus leakage between the sphere and the prover lining could occur. To an inexperienced operator, this is sufficient reason to automatically issue a work order to remove the sphere from the prover, then reinflate or replace it as necessary.

A more prudent move under this situation is to prove another meter in the same skid then observe if the previous results occur.

If the second meter proves properly and did not exhibit a comparable set of questionable data as before, then the source of trouble is obviously not the prover sphere but something else.

One possible cause in this case is that the main outlet block valve for the meter in question was passing but was improperly inspected or simply overlooked prior to the proving operation.

Much time and effort would have been wasted if, after removal of the sphere, which is not an easy task, it was found out that the sphere still retains its original inflation and is in excellent condition. The importance of coming up with an accurate diagnosis of the problem on hand cannot be over-emphasized.

Another interim but handy approach during functional testing of equipment is the transposition or switching around of equipment such as counters, indicators, or recorders, whenever they malfunction, with an identical one from the same panel.

While using the guide, the user is encouraged at any stage to apply the process of elimination and transposition and any variations thereof whenever possible. Moreover, always carry out a minimum of 2 or 3 confirming proving runs whenever an unsuccessful proof is encountered. In most cases, the offending glitch in the system inexplicably clears up by itself mysteriously, resulting in a completely normal and successful proof. These proven techniques will save time, labor, and expenses whenever applied. Such advice was not included in the guide for brevity.

Using the Troubleshooting Guide. The guide is easy to use and self-explanatory in format.

From a list of peculiarities or irregularities observed from the proving reports that are identical or similar to those listed in Column A of the guide, one needs only to look for the possible causes, suggested checks, and the recommended remedial steps to be taken as specified in Columns B, C, and D, respectively.

It should be noted that in certain cases, identical causes, checks and remedial actions appear also under different types of peculiarities. This is completely normal and is dictated solely by the situation on hand.

Although the guide does not claim to be an "all-encompassing" document to cure all the ills of meter proving, it nevertheless covers a wide range of problems normally encountered on a day-to-day basis.

Other isolated cases that may not be covered by the guide fall under unusual circumstances and practices that tend to be exceptions rather than the norms.

References

For additional and more detailed information on metering and proving topics, consult the standards, technical bulletins, and catalogs from the following organizations:

· American Petroleum Institute/ Manual of Petroleum and Measurement Standards (API/MPMS)

· Daniel Flow Products, Inc.
· Smith Meters/Geosource
· Brooks Instrument Division/Emerson Electric Co.
· SGS Redwood International

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The authors

E.N. Garcia is with the Consulting Services Department of the Saudi Arabian Oil Company (Saudi Aramco), Dhahran, Saudi Arabia as an engineering specialist on standards, design, and technical support for all royalty and custody measurement facilities handling hydrocarbon liquids and gases. He holds a B.S. degree in Electrical Engineering from the Mapua Institute of Technology, Manila, Philippines, and a Certificate in Business Management for Technical Personnel from the University of California at Los Angeles (UCLA). He is a registered professional Control Cystems Engineer in the State of California, USA, a past president of ISA, Saudi Arabia Section, and currently a member of the Institute of Petroleum, U.K.

Khalid A. Al-Fadhl is with the Consulting Services Department of Saudi Aramco in Dhahran, Saudi Arabia as a metering engineer for custody measurement of oil, gas and oil products. He holds a B.S. degree in Chemical Engineering from the King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia. With 14 years of wide-ranging experience behind him, he is currently Saudi Aramco's sole representative to Saudi Arabian Standards Organization's (SASO) Technical Committee on Measurement and Calibration.

APPENDIX I - TROUBLESHOOTING GUIDE ON METER PROVING OPERATIONS

A. Peculiarities (1)	B. Possible cause(s)	C. Suggested check(s)	D. Remedial action(s)
1. Repeatability exceeds the designated limit. See note (2).	1a. Entrapped air or gas.	1a. Open vent valves at highest points of meter and prover skid piping and continue venting until indication of gas disappears.	1a. Make several proving runs completely to eliminate entrapped air or gas.
	1b. Unstable proving temperature	1b. Check meter and prover temperature difference.	1b. Difference between meter and prover temperatures must not exceed 1 degree F. (See note (3).
	1c. Unstable proving pressure.	1c. Check system pressure fluctuation.	1c. Limit pressure fluctuation to within 5 psig. See note (4).
	1d. Unstable proving flow rate.	1d. Check significant flow rate fluctuation.	1d. Limit flow rate variation to within +/- 5%.
	1e. Sporadic or irregular slippage due to inadequate sphere inflation.	1e. Take sphere out then measure the diameter or circumference along the longitudinal (through the filling and venting holes) and latitudinal (through the seam) planes.	1e. The smaller of the two diameters should be inflated to about 3 to 4% larger than the prover inside diameter. See note (5).

A. Peculiarities (1)	B. Possible cause(s)	C. Suggested check(s)	D. Remedial action(s)
	1f. Sporadic or irregular slippage due to defective sphere or displacer.	1fa. On sphere-type provers, inspect sphere for long deep pits, cracks, scorings, or bubbles, especially on the seam and the band of surface that contacts the prover lining during proving. 1fb. For piston-type provers, check piston cups for signs of hardening, wear, and tear. 1fc. For piston-type provers in non-LPG service, position piston so that the bleed valve and pressure gauge located at the prover pre-run length falls between the two piston cups. Note piston pressure, crack open the bleed valve thus reducing pressure, then close again. If pressure builds up , leak is evident.	1fa. Replace displacer, preferably with a new one. 1fb. Replace piston cups as necessary. 1fc. Repair or replace piston cups as necessary.
2. Pulse signals continue to accumulate even if the sphere or piston passed by the second detector switch.	2a. Defective detector switch, mechanical assembly and/or pulse counting equipment circuitry. 2b. On sphere-type provers, sphere underinflated or completely disintegrated.	2a. Check detector switch or mechanical assembly, pulse equipment, circuitry for misoperation (e.g., dirty contacts, sticking, misadjustments, etc.). 2b. See item C1fa.	2a. Repair or replace de-detector switch, mechanical assembly, readout equip-equipment, circuitry as needed. Adjust switch setting per manufacturer's specification. 2b. See item D1fa.

A. Peculiarities (1)	B. Possible cause(s)	C. Suggested check(s)	D. Remedial action(s)
3. Pulse signals did not come in at all.	3a. Defective meter signal generator, preamplifier, loose or open wiring.	3a. Check meter signal generator, preamplifier; look for loose or open wiring.	3a. Repair or replace de-defective device or wiring as necessary.
	3b. See item B2 series.	3ba. See item C2 series	3ba. See item D2 series
		3bb. The detector switch and mechanical assembly should be checked for proper actuation when the sphere or piston passes by.	3bb. If found defective, repair or replace as necessary.
	3c. Deflated sphere.	3c. See item C1e. Check also filling gauge for sign of leakage.	3c. See item D1e. Repair or replace defective filling and/or vent gauge as necessary.
	3d. Sphere is broken. See note (6)	3d. Run proving cycle several times. If all other devices or equipment are operational yet no signals come in, there is high probability that the sphere has deflated or disintegrated.	3da. Replace sphere, preferably with a new one. 3 db. If sphere breakage is chronic, consider changing to a different sphere material.
4. Erratic proving results; pulse signals wander around and do not show a discernible and consistent pattern or behavior.	4a. Random electrical noise affecting meter pulse signals.	4a. Trace cause, check terminal connections, shielding, & power source interference.	4a. Repair, correct faults found.
	4b. Defective pulse generator, pickup coils, preamplifier, signal lines, readout devices, loose wiring connections, etc.	4b. Check integrity of all devices and components involved.	4b. Repair, replace defective parts and equipment involved.
	4c. Marginal or erratic meter pulse signals.	4c. Observe pulse signals through oscilloscope. See whether pulse pattern is continuous.	4c. Repair/replace pulse generator/preamplifier as needed.

A. Peculiarities (1)	B. Possible cause(s)	C. Suggested check(s)	D. Remedial action(s)
5. Unexpected, out-of pattern increase in meter factor.	5a. In a multi-stream skid, leakage of the (usually double block & bleed) prover take-off valve(s) from adjacent meter runs.	5a. Observe for any leakage after opening the valve's bleed valve. Leakage means either the upstream or down-stream (or both) seal(s) is defective.	5aa. Manually operate valve handwheel completely to seat valve. 5ab. Inspect valve, repair or replace seals as necessary.
	5b. Unusually high accumulation of dirt/debris inside strainer basket.	5b. Verify that the differential pressure (D/P) across the strainer is 5 psig or higher	5b. Open strainer then clean basket of dirt/debris. If the problem impacts deliveries and is chronic in nature, the supply lines or storage tanks must be cleaned properly.
	5c. Dirt/debris in straightening vane.	5c. Inspect & clean vane. Check for sign of wear and damage. Check physical condition and adequacy of strainer wire mesh/basket.	5c. Repair/replace vane and or strainer wire mesh/basket as needed.
	5d. For turbine meters, presence of grass, fibers on rotor blades.	5d. Take meter out of service, clean, and inspect. Check condition of strainer wire mesh/basket	5d. Remove clingages. Repair/replace strainer wire mesh/basket as needed.
	5e. Uneven deposits on meter body lining and flow elements (rotor, measuring chamber).	5e. Take meter out of service, clean and inspect.	5e. Remove deposits with mechanical means and/or suitable solvents.
	5f. For turbine meters, missing impeller blades or paramagnetic buttons.	5f. Take meter out of service, clean and inspect.	5f. Repair/replace defective part
	5g. Deposits or clingage on prover lining	5g. Check if the meter factor tolerance remains within the acceptable limits.	5ga. If it does, operate the system as is. 5gb. If not, open prover, clean, inspect and make sure clingage or deposits have been cleaned out completely.

A. Peculiarities (1)	B. Possible cause(s)	C. Suggested check(s)	D. Remedial action(s)
6. Unexpected, out-of-pattern decrease in meter factor. (See note 2)	6a. Air or gas slugs in the line.	6a. Check line for air or gas by opening vent lines.	6a. Eliminate air or gas in the line.
	6b. Leakage of meter run outlet isolation valve of meter being proved.	6b. See item C5a.	6b. See items D5aa and D5ab.
	6c. Leakage in lines, flanges, vent/drain/bleed/relief valves, fittings, etc., between meter being proved and second detector switch.	6c. Conduct visual inspection around the metering and proving skids.	6c. Repair/replace defective parts/equipment, etc.
	6d. Leakage of 4-way diverter or interchange valve.	6da. While valve is in travel, the pressure indications at the valve inlet and seal cavity are the same (or the differential pressure is zero, if a D/P gauge is in use). As soon as the valve plug sits, the cavity pressure should decrease by several pounds and stay at that point until the completion of the proof run. If pressure creeps up towards the inlet pressure, (or the differential pressure goes down to zero), the seal is leaking. See note (6).	6d. Valve must be opened for inspection of seals, valve plug & seat. Scorings due to metal to metal contact between valve plug & seat must be repaired. Plug and seals must be properly aligned and adjusted to prevent over-squeezing of seals.
		6db. With system pressurized remove pressure (or D/P) gauge from seat cavity then crack open its block valve slowly. Liquid from cavity, with air or gas will come out momentarily then	

A. Peculiarities (1)	B. Possible cause(s)	C. Suggested check(s)	D. Remedial action(s)
		should stop completely. If liquid comes out continuously, valve seals may be defective, or together with valve plug, improperly adjusted or aligned.	
	6e. Four-way diverter or inter-change valve cracked open or stuck in open position du-ring proving.	6e. Check valve plug position limit switches.	6e. Adjust/repair/replace plug position limit switches as necessary.
	6f. Flashing/cavitation in the meter run.	6f. Check pressure at the meter and see if it is below vapor pressure of the liquid.	6f. Increase pressure to above liquid vapor pressure by adjustment of the back-pressure control valve.
	6g. See items B3c and B3d.	6g. See items C3c and C3d.	6g. See items D3c and D3d.
	6h. Recurrent slippage around displacer due to physical defects.	6h. See items C1fa and through C1fc.	6h. See items D1fa through D1fc.
	6i. Deposits or clingages on prover lining broke away.	6i. Check if the meter factor tolerance remains within the acceptable limits.	6ia. If it does, operate the system as is. 6ib. If not, open prover, clean & inspect lining. Remove deposits/clingages completely before putting back in service.
	6j. Patches of prover lining broke away.	6j. Check if the meter factor tolerance remains within acceptable limits.	6ja. If it does, operate the system as is. 6jb. If not, open prover, clean, inspect, repair lining as needed. Prover must be recalibrated first before putting back in service.
9. Linearity exceeds tolerance limits specified by meter manufacturer. See note (9).	9a. See item B4. 9b. Check boundary layer thickness.	9a. See item C4. 9b. Check if operating at low Reynolds number (higher viscosity and/or lower flow rate).	9a. See items D4a and D4b. 9b. Operate within turbulent flow state, i.e., greater than 10,000 Reynolds number.

A. Peculiarities (1)	B. Possible cause(s)	C. Suggested check(s)	D. Remedial action(s)
	9c. Bearing wear.	9c. Take meter out of service, strip and inspect.	9c. Replace bearing as required.
	9d. Deposits on meter body lining, rotor, or impeller blades.	9d. Take meter out of service, clean and inspect.	9d. Clean out all deposits with some mechanical means and/or suitable solvents.
	9e. Flow element imbalance or instability resulting in bearing drag.	9e. Take meter out of service, clean and inspect.	9e. Replace bearing as necessary.
	9f. Erosion/corrosion of flow elements and meter body.	9f. Take meter out of service, clean and inspect.	9f. Repair/replace defective part
8. Slow, persistent and long-term one-way (+/-) drift of meter factor on control chart. See note (8).	8a. See items B8c through B8f.	8a. See items C8c through C8f.	8a. See items D8c through D8f.
	8b. Pressure and temperature instruments out of calibration.	8b. Check calibration of all field and control-room instruments.	8b. Calibrate defective instruments as necessary.
9. Sudden, out-of-pattern, one-way (+/-) change in meter factor on control chart.	9a. Inadvertent, unauthorized change or incorporation of incorrect prover base volume into the flow totalizer or system computer.	9a. Verify if the official pro-ver base volume has been incorporated into the flow totalizer or computer.	9a. If not, enter the correct prover base volume.
	9b. Inadvertent, unauthorized change in the value of the system factor in the system computer.	9b. Verify if the proper system factor has been incorporated into the flow computer or totalizer.	9b. If not, enter the correct system factor.
10. Proving results show zero figures on all parameters (e.g., pressure, temperature, pulses, time, etc.).	10a. Failure of the standalone proving computer or proving module of the system computer.	10a. Check that all parameter signals (e.g., pressure, temperature, pulses, time, etc.) are active at their respective sources.	10a. Check, repair, or replace the faulty software, component, etc., of the proving computer.

NOTES:

(1) It is understood that a given peculiarity may be brought about by a single cause or a combination of causes. For this reason, all applicable causes for a given peculiarity are not necessarily limited to those shown in the list. For the same reason, other peculiarities not specifically mentioned may also be applicable for a set of causes. This basic approach is deemed sufficient without making this guide unnecessarily long.

(2) Typical range of repeatability varies from +/- 0.02 to 0.05%, depending on Company preference or mutual agreement between buyer and seller.

(3) This applies only to meter proving systems in which the temperature of the meter and prover is presumed to be the same. Thus the values of CTLP and CTLM were not taken into consideration when calculating for the meter factor (MF). If these two factors are used in MF calculation, a wider tolerance (e.g., 2 degrees F) in temperature difference may be allowed.

(4) Although the effect of pressure difference between the meter and prover is generally insignificant for most proving operations, keep in mind that the pressure correction factors for CPLP and CPLM, depending on system pressure and type of hydrocarbon liquids involved, may change by about 0.10% at a pressure difference as low as 5 psi. (Refer also to API-MPMS Chapter 11.2 and 12.2.).

(5) Based on peculiarity of service and previous record, the percentage of inflation may be increased or, owing to fast wearing of the sphere, decreased as needed.

(5) Unless specified otherwise, the term "displacer" applies also to both inflatable or non-inflatable spheres or piston seals or cups.

(7) For interchange valve used in uni-directional provers, the seal pressure should increase higher than the line pressure as the seal presses against the valve seat.

(8) For most turbine and positive displacement meters, a linearity of figure between +/- 0.15 to +/- 0.25% is typical.

(9) For a detailed explanation of the principles and practices involved in the development and maintenance of meter factor control charts, refer to API-MPMS Chapter 13.