Engineering Standard

SAES-Y-103 29 September 2013

Royalty/Custody Metering of Hydrocarbon Liquids

Document Responsibility: Custody Measurement Standards Committee

Saudi Aramco DeskTop Standards

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1 Scope

This Standard describes the minimum mandatory requirements governing the design, construction and installation of metering stations and equipment for royalty and custody transfer measurement of liquid hydrocarbons (e.g., crude oil, petroleum products, butane, non-refrigerated propane, natural gas liquids).

This standard does not apply to measurement applications involving refrigerated propane (Specification A-140), liquefied petroleum gas (Specification A-150) and asphalt. SAPMT shall consult P&CSD/PASD/Custody Measurement Unit for requirements for royalty or custody measurement projects involving these hydrocarbons.

2 Conflicts and Deviations

Any conflicts between this standard and other applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Process and Control Systems Department of Saudi Aramco, Dhahran.

Direct all requests to deviate from this standard in writing to the Company or Buyer Representative, who shall follow internal company procedure SAEP-302 and forward such requests to the Manager, Process and Control Systems Department of Saudi Aramco, Dhahran.

Direct all requests for interpretation of this standard in writing to the Company or Buyer Representative who shall forward them to the Chairman, Custody Measurement Standards Committee for resolution. The Chairman, Custody Measurement Standards Committee shall be solely responsible for determining whether a proposed installation meets the requirements of this standard.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below, unless otherwise noted.

3.1 Saudi Aramco Documents

Saudi Aramco Engineering Procedures

SAEP-21	*Project Execution Requirements for Saudi Aramco Royalty/Custody Metering Systems*
SAEP-36	*Proving Systems Calibration Requirements*

SAEP-50	*Project Execution Requirements for Third Party Royalty/Custody Metering Systems*
SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Engineering Standards

SAES-A-112	*Meteorological and Seismic Design Data*
SAES-A-400	*Industrial Drainage Systems*
SAES-B-054	*Access, Egress, and Materials Handling for Plant Facilities*
SAES-B-068	*Electrical Area Classification*
SAES-H-001	*Coating Selection and Application Requirements for Industrial Plants and Equipment*
SAES-J-002	*Technically Acceptable Instrument Manufacturers*
SAES-J-003	*Instrumentation Basic Design Criteria*
SAES-J-004	*Instrumentation Symbols and Identification*
SAES-J-005	*Instrumentation Drawings and Forms*
SAES-J-200	*Pressure*
SAES-J-400	*Temperature*
SAES-J-600	*Pressure Relief Devices*
SAES-J-700	*Control Valves*
SAES-J-902	*Electrical Systems for Instrumentation*
SAES-L-102	*Regulated Vendors List for Valves*
SAES-L-105	*Piping Material Specifications*
SAES-L-108	*Selection of Valves*
SAES-L-140	*Thermal Expansion Relief in Piping*
SAES-N-001	*Basic Criteria, Industrial Insulation*
SAES-P-101	*Regulated Vendor List for Electrical Equipment*
SAES-P-104	*Wiring Methods and Materials*
SAES-P-111	*Grounding*
SAES-P-116	*Switchgear and Control Equipment*
SAES-Y-100	*Regulated Vendors List for Custody Measurement Equipment*

SAES-Y-501	*Dynamic Sampling of Hydrocarbon Liquids for Royalty/Custody Transfers*

Saudi Aramco Materials System Specifications

01-SAMSS-010	*Fabricated Steel Piping*
04-SAMSS-001	*Gate Valves*
04-SAMSS-041	*Expanding Plug Valve*
04-SAMSS-051	*Ball Valves, API 6D*
17-SAMSS-515	*Auxiliary Electrical Systems for Skid Mounted Equipment*
34-SAMSS-117	*Turbine Flow Meters in Liquid Service*
34-SAMSS-118	*Positive Displacement Meters*
34-SAMSS-119	*Bi-Directional Meter Prover*
34-SAMSS-120	*Uni-Directional Meter Prover*
34-SAMSS-121	*Small Volume Prover*
34-SAMSS-122	*Atmospheric Portable Tank Prover*
34-SAMSS-167	*Truck Loading Metering System*
34-SAMSS-168	*Truck Unloading Metering System*
34-SAMSS-517	*Density Meters*
34-SAMSS-525	*Automatic Sampling Systems for Crude Oil and Refined Products*
34-SAMSS-711	*Control Valves – General Services*
34-SAMSS-718	*Electric Motor Operated Valve Actuators*
34-SAMSS-820	*Instrument Control Cabinets - Indoor*
34-SAMSS-821	*Instrument Control Cabinets - Outdoor*
34-SAMSS-830	*Programmable Logic Controller*
34-SAMSS-831	*Instrumentation for Packaged Units*
34-SAMSS-841	*Flow Computer for Custody Transfer Measurement of Hydrocarbon Liquids*
34-SAMSS-847	*Preset Controller for Truck Loading and Unloading Systems*
34-SAMSS-851	*Metering Supervisory Computer for Custody Transfer Measurement of Hydrocarbon Liquids*

34-SAMSS-913	*Instrumentation and Thermocouple Cable*

Saudi Aramco Standard Drawings

AB-036019	*Thermowell Assembly and Detail*
AA-036513	*Custody Transfer Metering and Proving Station (Liquid),* Typical Schematic

Saudi Aramco Library Drawings

DC-950040	*Pressure Indicators and Switches, Locally Mounted Instrument Piping Details*
DC-950042	*Pressure Instruments, Blind and Indicating Type*
DC-950043	*Electrical Connections for Field Mounted Instruments*

Saudi Aramco Product Specifications

A-140	*Refrigerated Propane LPG*
A-150	*Liquefied Petroleum Gas*
A-180	*LPG Condensate*
A-300	*Naphtha's and Gasoline*

3.2 Industry Codes and Standards

API Manual of Petroleum Measurements Standards (MPMS)

Chapter 4	*Proving Systems*
Chapter 5	*Metering*
Chapter 7	*Temperature Determination*
Chapter 8	*Sampling*
Chapter 11	*Physical Properties Data*
Chapter 12	*Calculation of Petroleum Quantities*
Chapter 14	*Natural Gas Fluids Measurement*

Other Documents

NFPA 70	*National Electrical Code (NEC)*
ASME B31.3	*Process Piping*
ASME B31.4	*Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids*

API 1004	*Bottom Loading and Vapor Recovery for MC-306, Tank Motor Vehicles*
API RP 2003	*Protection Against Ignitions Arising Out of Static, Lightning and Stray Currents*
ASME SEC VIII	*Boiler and Pressure Vessel Code*
ASTM D1250-52	*Petroleum Measurement Tables*
ASTM D1250-04	*Standard Guide for Use of Petroleum Measurement Tables*
ASTM D3700	*Obtaining LPG Samples Using a Floating Piston Cylinder*
ASTM E1	*Specification for ASTM Liquid-In-Glass Thermometers*
IEC 60751	*Industrial Platinum Thermometer Sensors*
IEC 61000-4-3	*Electromagnetic Compatibility (EMC) - Testing and Measurement Techniques - Radiated, Radio Frequency Electromagnetic Field Immunity Test*
IEC 61000-6-2	*Electromagnetic Compatibility (EMC) - General Standards - Immunity for Industrial Environments*
2004/108/EC	*Directive 2004/108/EC of the European Parliament and of the Council of 15 December2004 on the approximation of the Laws of the Member States Relating to Electromagnetic Compatibility and Repealing Directive 89/336/EC*

4 Definitions

Air Fueling Operation (AFO): A Distribution Operations plant that stores aircraft fuel and distributes it to aircraft. For the purpose of this standard, the associated pipeline receiving metering system(s), truck unloading meters, refueler loading meters, refueler meters, defueler meters, and dispensing meters are considered a part of the air fueling unit.

Bulk Plant: A Distribution Operations plant that stores refined product and distributes it to domestic customers, contract haulers, and/or other plants. For the purpose of this standard, the pipeline receiving and shipping metering system(s), marine unloading metering system(s), truck and rail car loading and unloading meters are considered a part of the bulk plant.

Commentary Note: A sub-paragraph that contains comments that are explanatory or advisory in nature. These comments are not mandatory, except to the extent that they explain mandatory requirements contained in this standard.

Custody Transfer Measurement: A specialized form of measurement that provides quantity and quality information used for the physical and fiscal documentation of a change in ownership and/or responsibility of hydrocarbon commodities. This includes measurement of hydrocarbon liquid or gas movements (deliveries or receipts) between Saudi Aramco and its customers, suppliers, joint ventures and transport contractors including VELA ships.

Delivery: A custody transfer from a bulk plant, fractionating center, gas plant, refinery or terminal to a customer, marine vessel, pipeline or contract hauler.

Dual Devices: Two identical devices that perform the same function independent of each other.

Flow Computer: A dedicated off-the-shelf electronic device specifically designed for calculating and totaling metered volumes, and/or calculating meter factors during meter proving for one or more meters.

Fractionating Center: Juaymah NGL Fractionation Plant or Yanbu NGL Fractionation Plant. For the purpose of this standard, the associated marine loading and unloading metering systems are considered a part of the fractionating center.

Field Proven: A system shall be considered to be field proven when it has been installed, commissioned, and operational in a customer facility for a period of six months or longer (excluding beta test periods). It shall be possible for Saudi Aramco to verify the field proven status of any equipment.

Gas Plant: Berri Gas Plant, Haradh Gas Plant, Hawiyah Gas Plant, Khursaniyah Gas Plant, Shedgum Gas Plant, Uthmaniyah Gas Plant.

Graphical User Interface (GUI): An operator interface to the metering system that is a part of the Metering Supervisory Computer (MSC).

Meter Run: A single pipeline meter and its associated inlet block valve, check valve, strainer, flow conditioning sections, control valve, outlet block valve, prover inlet valve and instrumentation.

Meter Skid: The field portion of a metering system consisting of the meters, strainers, density meter, flow-conditioning sections, block valves, control valves, piping, instruments, electrical equipment, and associated structural steel.

Meter Station: A facility that is primarily dedicated to the measurement of the quantity and quality of a liquid or gas hydrocarbon.

Metering Supervisory Computer (MSC): Computer that performs supervisory functions (data archiving, report generation, system integrity checks, alarm logging and operator interface) for a metering system.

Metering System: A complete assembly of equipment that is designed to measure the quantity and quality of a liquid or gas hydrocarbon. The metering system includes, but is not limited to, the meter skid (meters, strainers, density meter, flow conditioning sections, valves), prover skid, samplers, and control system (flow computers, programmable logic controllers, metering supervisory computers, etc.).

Prover Skid: The field portion of a metering system consisting of the meter prover, outlet block valve, control valve, piping, instruments, electrical equipment and associated structural steel.

Receipt: A custody transfer to a bulk plant, fractionating center, gas plant, refinery or terminal from a supplier, marine vessel, pipeline or contract hauler.

Redundant Devices: Two identical devices that operate in an interchangeable primary/secondary arrangement in which the functions of the primary device are duplicated in the secondary and are automatically transferred to the secondary if the primary fails without the intervention of a third device.

Refinery: Jeddah Refinery, Rabigh Refinery, Ras Tanura Refinery, Riyadh Refinery, Yanbu Refinery. For the purpose of this standard, the associated pipeline receiving and shipping metering system(s), and marine loading and unloading metering system(s) are considered a part of the refinery.

Royalty measurement: A specialized form of Measurement that provides quantity and quality information used for the physical and fiscal documentation on which Royalty is paid or credited to the Saudi Arabian Government.

Terminal: Juaymah Terminal, Juaymah Gas Plant Sea Island, Ras Tanura Terminal, Yanbu Crude Oil, Distribution or refinery Terminals. For the purpose of this standard, the associated pipeline receiving and shipping metering system(s) and marine unloading and loading metering system(s) are considered a part of the terminal.

Terminal Management System: A supervisory computer system that manages the operation of a bulk plant or air fueling unit.

5 General Requirements

SAPMT is responsible for ensuring the design and construction contractors provide a fully operational metering system that meets both the provisions of this standard and the approved project functional specifications. Project execution shall conform to the requirements of SAEP-21 or SAEP-50, as applicable.

The following general requirements apply to all categories of royalty and custody transfer measurement.

Commentary Note:

Specific requirements for each measurement application and measurement equipment are provided in Sections 6 and 7, respectively.

5.1 Units of Measurement

Depending upon the facility and the application, either the U.S. Customary (USC) or International System (SI) system of units shall be used:

Item	International System (SI)	U.S. Customary (USC)
Mass	Kilograms, Metric Tons	Long Tons
Volume	Cubic Meters, Liters	Barrels, U.S. Gallons
Temperature	Degrees Celsius (°C)	Degrees Fahrenheit (°F)
Pressure	Kilopascals Gauge [kPa (ga)]	Pounds per Square Inch Gauge (psig)
Density	Kilograms per Liter, Kilograms per Cubic Meter	Degrees API, Relative Density (Specific Gravity)

5.1.1 Pipelines

All liquid hydrocarbons shall be measured using equipment registering in U.S. Customary (USC) units.

All volumes shall be expressed in barrels.

5.1.2 Refineries, Terminals and Fractionating Centers

All liquid hydrocarbons shall be measured using equipment registering in U.S. Customary (USC) units.

All volumes except that of bunker fuel shall be expressed in barrels. Bunker fuel volumes shall be expressed in barrels or gallons. Volumes shall also be expressed in cubic meters when transfers are to be made to Distribution Operations.

5.1.3 Distribution Bulk Plants and Air Fueling Units

Crude oil volumes shall be measured using equipment registering in the U.S. Customary (USC) units and shall be expressed in barrels.

All refined products (e.g., gasoline, diesel, kerosene, Jet A1, JP4, JP5, JP8, and fuel oil) shall be measured using equipment registering in International System (SI) units.

Refined product volumes shall be expressed in liters, dekaliters or cubic meters. Jet A1 and JP4 sales quantities may also be expressed in kilograms.

5.2 Reference Conditions

All observed liquid volumes shall be corrected to the reference temperature and pressure appropriate for the system of units.

Item	International System (SI)	U.S. Customary (USC)
Reference Temperature	15°C	60°F
Reference Pressure	101.325 kPa (abs) (0 kPa (ga)) or Equilibrium Vapor Pressure at Operating Temperature, whichever is Greater	14.696 psia (0 psig) or Equilibrium Vapor Pressure at Operating Temperature, Whichever is Greater

5.3 Volume Correction Factors

Volumes shall be corrected to reference conditions using factors determined from the following standards published by the American Society of Testing and Materials (ASTM) and/or the American Petroleum Institute (API):

Correction	Commodity	International System (SI)	U.S. Customary (USC)
Observed Density to Density at Reference Temperature	Crude Oil		ASTM D1250-52 Table 5
	JP4	ASTM D1250-04[1]	ASTM D1250-04[1]
	Gasoline, Jet A1, JP5, JP8, Kerosene, Diesel, Fuel Oil	ASTM D1250-04[2]	ASTM D1250-04[2]
	Naphtha		ASTM D1250-04[2]
	Lube Oils, Lube Oil Blending Stocks		ASTM D1250-04[3]
	Natural Gasoline		ASTM D1250-52 Table 23
	Butane, Propane, NGL		ASTM D1250-52 Table 23
Volume at Observed Temperature to Volume at Reference Temperature	Crude Oil		ASTM D1250-52 Table 6*
	JP4	ASTM D1250-04[1]	ASTM D1250-04[1]
	Gasoline, Jet A1, JP5, JP8, Kerosene, Diesel, Fuel Oil	ASTM D1250-04[2]	ASTM D1250-04[2]
	Naphtha		ASTM D1250-04[2]

Correction	Commodity	International System (SI)	U.S. Customary (USC)
	Lube Oils, Lube Oil Blending Stocks		ASTM D1250-04[3]
	Natural Gasoline		ASTM D1250-52 Table 24
	Butane, Propane, NGL		ASTM D1250-52 Table 24
Volume at Observed Pressure to Volume at Reference Pressure	Crude Oil		ASTM D1250-04[1]
	JP4	ASTM D1250-04[1]	ASTM D1250-04[1]
	Gasoline, Jet A1, JP5, JP8, Kerosene, Diesel, Fuel Oil	ASTM D1250-04[2]	ASTM D1250-04[2]
	Naphtha		ASTM D1250-04[2]
	Lube Oils and Lube Oil Blending Stocks		ASTM D1250-04[3]
	Natural Gasoline		ASTM D1250-04[1]
	Butane, Propane, NGL		API MPMS 11.2.2 and Addendum

* ASTM D1250-52 Table 24" may be used after converting API Gravity

[1]Generalized Crude Oils Commodity Group

[2]Generalized Refined Products Commodity Group

[3]Generalized Lubricating Oils Commodity Group

Commentary Note:

The product commonly referred to as "Naphtha" at Yanbu Gas Plant is considered to be "Natural Gasoline" for measurement purposes. This Naphtha is different from the Naphtha indicated in the above table

A look-up table shall be used whenever ASTM D1250-52 is specified. A computer algorithm and its implementation procedures shall be used whenever ASTM D1250-04 is specified. A mathematical model shall be used when API Manual of Petroleum Measurement Standards, Chapter 11.2.2 is specified.

5.4 Environmental Conditions

Equipment shall be suitable for installation in the applicable environment specified in SAES-A-112 and shall meet the environmental conditions specified in SAES-J-003.

5.5 General Design

5.5.1 Custody metering systems shall be furnished by approved vendors in accordance with SAES-Y-100.

5.5.2 The metering system components, instruments, valves and electrical equipment shall be furnished from approved vendors as specified in SAES-Y-100, SAES-J-002, SAES-L-102 and SAES-P-101, respectively.

5.5.3 Meters, meter provers and control equipment shall be purchased as integrated systems. The metering system shall be designed from off-the-shelf components which are field proven in the intended application.

5.5.4 At a minimum, the following data shall be provided and used to design the measurement system:

- Type of meter operation (pipeline; marine loading or unloading; truck loading or unloading; aircraft refueling, defueling or dispensing)
- Fluid properties (e.g., specific gravity, viscosity, vapor pressure from the Saudi Aramco product specification or other source)
- Operating temperature and pressure
- System maximum and minimum flow rate
- Maximum and minimum batch size (for crude oil systems)
- Available utilities (e.g., electrical power, instrument air)
- Pipe I.D. and line pressure at sample point (for crude oil systems)
- Meter proving method

5.5.5 Provisions for meter proving shall be considered as part of the design of each meter station. Metering system design shall permit proving of meters and associated equipment in-situ with permanent or portable provers. Pumps and prover inlet and outlet piping shall be sized to permit proving of each meter at its maximum linear or continuous flow rate (capacity).

5.5.6 Temperature transmitter and test thermowell) and pressure transmitter shall be provided for each meter and for each prover. Unless specified otherwise for a particular application.

5.5.7 Installation of primary temperature measurement devices and test thermowells shall conform to Detail 1 or 3, as applicable, of Standard Drawing AB-036019.

5.5.8 Pressure transmitters shall be installed in accordance with Library Drawings DC-950042 and DC-950043. Pressure gauges shall be installed in accordance with Detail 1 or 2, as applicable, of Library Drawing DC-950040.

5.5.9 A manual sampling probe shall be provided for a group of parallel meters. See Section 7.3.5 for design requirements.

5.5.10 Walkways, stairways, platforms, and material handling equipment shall be provided in accordance with SAES-B-054.

5.6 Layout

5.6.1 The meter skid shall discharge to only one downstream delivery point.

5.6.2 The layout of equipment shall provide for unencumbered access for operations and maintenance, and shall permit easy removal of equipment.

5.6.3 Distances between meters and meter provers shall be kept as short as possible. Where a fixed meter proving station is provided to service multiple meters (e.g., truck loading) or meter skids, it shall be centrally located to minimize the distance between the meters and the prover.

5.6.4 Space shall be provided adjacent to each fixed prover for positioning of prover calibration equipment.

5.6.5 Where a portable prover is to be used, space shall be provided adjacent to the meter skid for the prover and associated equipment (e.g., generators, tank trucks, etc.).

5.6.6 For a positive displacement meter, temperature and pressure measurement devices shall be located within a one meter long piping segment adjacent to, and preferably downstream of, the meter. For a turbine meter, these devices shall be located within a 0.5-m long pipe segment beginning at a distance of 5 pipe diameters downstream from the meter.

5.6.7 The temperature and pressure measurement devices shall be located in the specified piping segment in the following order: 1) Primary temperature measurement device (temperature transmitter, RTD or thermometer); 2) Test thermowell at a distance of no more than 0.3 m from the primary temperature measurement device; 3) Pressure transmitter and/or pressure gauge.

5.6.8 No connections, instruments or other devices shall be located within the upstream (10 pipe diameters) except the flow conditioning section of a turbine meter and downstream (5 pipe diameters).

5.6.9 Density meters, automatic samplers and manual sample probes shall be located in accordance with instructions provided in Sections 7.3.3,

7.3.4 and 7.3.5, respectively.

5.7 Piping

5.7.1 All skid-mounted piping and pressure containing components shall be designed and constructed in accordance with ASME B31.3, ASME B31.4, SAES-L-105 and 01-SAMSS-010, as applicable. The ANSI rating of the metering system shall be consistent with inlet piping rating.

5.7.2 A double block-and-bleed valve shall be provided whenever leakage through a valve could result in fluid bypass around a meter or prover, or fluid could be introduced into a prover at a point after the meter.

5.7.3 A bypass around the meter skid is not permitted. A bypass around the meter skid shall be provided only after proper justification has been presented and approval has been obtained from the Chairman, Custody Measurement Standards Committee. If the bypass line is approved, it shall include a double block-and-bleed valve.

5.7.4 If the metering skid will be used for both deliveries and receipts, cross-over piping with double block-and-bleed valves and check valves shall be installed between the upstream and downstream piping to ensure the flow through the meters and prover is always in the same direction.

5.7.5 The cavity bleed on each double block-and-bleed valve in butane or propane service shall be equipped with a pressure gauge and vent to a flare or other safe location. The cavity bleed on each double block-and-bleed valve in any other service shall discharge to an open funnel.

5.7.6 Provision shall be made to isolate and drain each individual meter, without affecting the operation of adjacent meters.

5.7.7 Valve selection shall conform to the requirements of SAES-L-108. A gate valve or ball valve may be specified for any block valve except where a double block-and-bleed valve is required as stated in paragraph 5.7.2.

5.7.8 High point vents shall be provided in all systems to facilitate the venting of trapped air or vapor.

5.7.9 Thermal relief valves shall be provided in accordance with SAES-L-140, and shall discharge into a closed drainage system or routed to storage or holding vessel as per SAES-A-400.

5.7.10 The number of vents, drains and thermal relief valves on the piping between a meter(s) and a prover (connections) and between a meter(s) and the point of custody transfer shall be kept to a minimum. Each vent, drain or thermal relief shall be provided with a means to permit examination for, or prevention of, leakage. Each vent shall discharge to an open funnel or be plugged. Each drain connection shall be furnished with a spectacle blind on the discharge side of the drain valve.

5.7.11 Threaded connections on meter bodies, prover interchanges and 4-way valves, and double block-and-bleed valves shall not be seal welded.

5.7.12 Piping shall be fabricated and installed, and pipe supports provided to prevent external stresses on and distortion of the meter body.

5.8 Stream Conditioning

5.8.1 A strainer shall be provided directly upstream of each individual meter or group of parallel meters. For strainers in continuous operation on common supply headers, provision shall be made for on-line cleaning, or a back-up strainer shall be provided.

5.8.2 An air eliminator shall be provided upstream of each meter whenever air can be introduced or vapor can be released in the metering system.

5.8.3 The system design shall include provisions to ensure that pressure pulsation and surges are minimized. Installation of a pressure surge tank, expansion chamber and/or surge relief system may be provided to meet this requirement.

5.9 Instrumentation/Electrical

5.9.1 Field instruments and electrical equipment shall be designed for the electrical area classification as determined by SAES-B-068.

5.9.2 Design and installation of instruments and electrical equipment shall conform to the requirements of NFPA 70, SAES-J-902, SAES-P-104, and SAES-P-111. Instruments and electrical equipment furnished as part of vendor supplied metering systems shall also conform to 34-SAMSS-831 and 17-SAMSS-515, respectively.

5.9.3 All flow computers, programmable logic controllers, system communications equipment and metering supervisory computers shall be powered by a UPS system which conforms to the requirements of SAES-J-902.

5.9.4 Instrument cabling shall conform to 34-SAMSS-913. Shielded, twisted-pair wire shall be used for all meter pulse signals.

5.9.5 Field junction boxes shall conform to the requirements specified in SAES-J-902 and shall be installed in accessible locations at the edge of the meter or prover skid. Each conduit to or from a location other than on the meter or prover skid (e.g., control room, PIB, etc.) shall be sealed with a weather-tight seal at the entrance to a field junction box.

Commentary Note:

Installation of weather-tight seals as described above is required to prevent or minimize the introduction of moisture from long conduits into field junction boxes.

5.9.6 The original physical structure of each cable shall extend at least 50 cm above the entry point of a junction box or marshaling cabinet. The cable shall be centered at the entry point.

5.9.7 Electrical and electronic equipment supplied as part of the metering systems shall carry the EC conformity mark ("CE") designating compliance with European EMC Directive 2004/108/EC. An authorized agency shall also have tested and certified the equipment is immune to electromagnetic interference, electrostatic discharge, radio frequency interference, surge and fast transients, voltage dips and interruptions at Performance Level A in accordance with IEC 61000-6-2. Tests shall have been performed to confirm the equipment is immune to radiated, radio frequency and electromagnetic emissions in accordance with IEC 61000-4-3 using Test Level 3.

6 Application Requirements

This section outlines specific requirements for particular categories of royalty and custody transfer measurement.

6.1 Pipeline Shipping/Receiving and marine loading/unloading metering systems

6.1.1 General

See Standard Drawing AA-036513 for arrangement and installation details for pipeline and marine metering systems.

Blind flange connections shall be provided on the inlet and outlet header of each meter skid to permit the future addition of at least one meter.

To balance the flow between the various meters and reduce the number of pipe fittings, it is recommended that the inlet and outlet be

positioned on opposite corners of the meter skid.

6.1.2 Meters

Turbine meters shall be used for all pipeline and marine applications unless the viscosity or proving frequency dictates otherwise. See Section 7.1 for meter selection and sizing requirements.

Other type of meters or design may be considered by only upon written approval from the Chairman of Custody Measurement Standards Committee.

A minimum of two operational meters shall be provided as part of each pipeline and marine loading metering system batch delivery of equal or more than 10,000 barrels. Single operational meter is acceptable if the batch delivery is less than 10,000 barrels.

A minimum of three operational meters shall be provided as part of each marine unloading metering system receiving batch delivery of equal or more than 10,000 barrels. Two operational meters are acceptable if the batch delivery is less than 10,000 barrels.

In addition to the operational meters, a fully operational installed spare meter shall be furnished as part of each pipeline, or marine loading or unloading metering system.

6.1.3 Meter Proving

See Section 7.2 for prover selection and design requirements.

6.1.4 Auxiliary Equipment

An on-line density meter shall be provided for each marine loading and unloading metering system and refined products pipeline. See Section 7.3.3 for on-line density meter requirements.

An automatic sampling system shall be provided for each crude oil metering system in accordance with SAES-Y-501.

An automatic sampling system shall be provided as part of each metering system in natural gas liquids (NGL) service. See Section 7.3.4 for requirements associated with automatic sampling.

In marine unloading applications, an air eliminator shall be provided upstream of each meter. The air eliminator shall be located on-shore as close to the marine vessel as possible.

A check valve shall be installed upstream of each meter or group of parallel meters.

If product or crude oil can be received during a power outage at the location (e.g., from pipelines or marine vessels), an emergency power source shall be provided in addition to an UPS.

For metering systems in refrigerated butane service, the meter runs and piping to the prover shall be insulated in accordance with SAES-N-001.

6.1.5 Metering Automation and Control Systems

See Appendix A for automation and control requirements for pipeline and marine metering systems.

A flow-activated alarm signal indicator shall be supplied on the primary piping discharging from each relief system that bypasses a meter skid.

6.2 Rail Car and Refueler Loading (Distribution Operations)

Rail Car and Refueler loading systems from bulk plants and air fueling facilities shall be designed in accordance with 34-SAMSS-167.

6.3 Rail Car and Refueler Unloading (Distribution Operations)

Rail Car and Refueler unloading systems into bulk plants and air fueling facilities shall be designed in accordance with 34-SAMSS-168.

6.4 Aircraft Refueling, Defueling and Dispensing (Distribution Operations)

6.4.1 Meters

Positive displacement meters shall be utilized for all aircraft refueling, defueling and dispensing applications.

Meters in these applications may be furnished with a single pulse generator.

The use of single case meters is permitted.

Meters Copper and copper bearing alloy material shall not make-up more than 10% of the total wetted surface.

6.4.2 Meter Proving

See Section 7.2 for prover selection and design requirements.

6.4.3 Auxiliary Equipment

An air eliminator shall be furnished upstream of each meter.

If a filter is provided upstream of the meter, a separate strainer is not required.

Installation of a pressure transmitter for automatic pressure compensation is not required.

NOTE: Correction for the effects of pressure shall be accomplished by the flow computer using a constant pressure (preferable) or by use of a composite meter factor which includes such a correction.

6.4.4 Metering Automation and Control Systems

See Appendix C for automation requirements for aircraft dispensing and refueling meters.

6.5 Truck Loading (Distribution Operations)

The truck loading metering system and its control system shall be designed, fabricated, assembled and tested in accordance with 34-SAMSS-167.

6.6 Truck Unloading (Distribution Operations)

The truck unloading metering system and its control system shall be designed, fabricated, assembled and tested in accordance with 34-SAMSS-168.

7 Equipment Requirements

7.1 Meter Selection and Design Requirements

The number and size of meters shall be determined based on the process and operational data outlined in Section 5 and the requirements of the specific application as specified in Section 6.

7.1.1 Meter Selection

Turbine or positive displacement meters shall be used for all applications.

A turbine meter or positive displacement meter shall be selected based on the viscosity of the fluid to be measured and the criteria provided in API Manual of Petroleum Measurement Standards, Chapter 5.1, Figure 1.

In applications where both turbine meters and positive displacement meters are acceptable for the viscosity of the fluid, meter selection

shall be governed by the following guidelines:

- Turbine meters are recommended for applications where the metering operation is essentially continuous and where the meters will be proved routinely at intervals one month or less (e.g., pipeline deliveries and receipts; marine cargo loading and unloading). Helical blade type turbine meters may be used for liquids with viscosity equal to or greater than 180 centistoke.

- Positive displacement meters are recommended for applications where the measurement operation is intermittent or where the meters will be proved at intervals greater than one month (e.g., rail car and truck loading and unloading; aircraft refueling, defueling and dispensing; bunker fuel deliveries).

7.1.2 Turbine Meters

Turbine meters shall conform to 34-SAMSS-117 and API Manual of Petroleum Measurement Standards, Chapter 5.3.

A turbine meter shall be sized to operate between 40 and 100% of its maximum normal linear flow rate (capacity) after all relevant process data (e.g., viscosity, and specific gravity) has been considered.

A flow conditioning assembly (flow straightener) shall be provided for each turbine meter. See Section 7.3.8 for details.

7.1.3 Positive Displacement Meters

Positive displacement meters shall conform to 34-SAMSS-118 and API Manual of Petroleum Measurement Standards, Chapter 5.2.

Positive displacement meters with a nominal size of 6 inches or less shall be selected to operate between 20 and 85% of the manufacturer's maximum continuous flow rate (capacity). Positive displacement meters with a nominal size greater than 6 inches shall be selected to operate between 20 and 75% of the manufacturer's maximum continuous flow rate (capacity).

Unless otherwise specified for an application, each positive displacement meter shall be equipped to furnish dual channel pulse signals which are 90 degrees out of phase (dual pulse quadrature). Meter pulse signals shall be derived directly from the meter's main shaft without intervening gearing whenever a small volume prover will be used to prove the meter.

Commentary Note:

Direct drive pulse generators are preferred for all positive displacement meters.

7.2 Meter Prover Selection and Design Requirements

Base prover volumes shall be sufficient to allow the metered (and proving) volumes to be read to a resolution of 1 in 10,000.

Base prover volumes shall be expressed in the appropriate units at the reference conditions (temperature and pressure) in accordance with Section 5.2.

7.2.1 Meter Prover Selection

Provers shall be selected in accordance with the one of the following tables:

Pipeline and Marine Applications

Commodity	Meter Type	Conventional Pipe Prover			Small Volume Prover (1)		Master Meter
		Fixed Sphere	Portable Sphere	Piston(2)	Sphere	Piston(2)	
Crude Oil	Turbine	X	WA	--	WA	WA	--
	PD	X	WA	--	WA(3)	--	--
Gasoline, Kerosene, Jet A1, JP4, JP5, JP8, Diesel, Naphtha	Turbine	X	WA	--	WA	WA	--
	PD	X	WA	--	WA(3)	WA(3)	--
Bunker Diesel Fuel Oil	PD	X	WA	--	WA(3)	--	WA
Fuel Oil	PD	X	WA	--	WA(3)	--	--
Lube Oils, Lube Oil Blending Stocks	PD	X	WA	--	WA(3)	WA(3)	--
Butane, Propane, NGL, Natural Gasoline	Turbine	X	WA	X	WA	WA	--

Truck and Refueler Loading and Unloading Applications

Commodity	Meter Type	Conventional Pipe Prover		Small Volume Prover[1]		Tank Prover	Master Meter
		Fixed Sphere	Portable Sphere	Sphere	Piston[2]		
Crude Oil	PD	X	X	WA[3]	--	--	--
Gasoline, Kerosene, Jet A1, JP4, JP5, JP8, Diesel, Naphtha	PD	X	X	WA[3]	X[3]	WA	WA
Fuel Oil	PD	X	X	WA[3]	--	--	--

Air Fueling, Dispensing and Defueling Applications

Commodity	Meter Type	Conventional Pipe Prover		Small Volume Prover[1]		Tank Prover	Master Meter
		Fixed Sphere	Portable Sphere	Sphere	Piston[2]		
Jet A1, JP4, JP5, JP8	PD	X	X	WA[3]	WA[3]	X	X

X – Approved proving method.

WA – Proving method is acceptable only with the written approval from the Chairman, Custody Measurement Standards Committee.

Notes:

(1) Small volume provers shall be limited to applications where the flow rate is stable and free from pulsation.

(2) Piston provers are limited to applications where the liquids are free of particulates.

(3) Small volume provers shall be used only if the positive displacement meters are equipped with direct drive pulse transmitters.

Commentary Notes:

Tank provers are generally less desirable for the following reasons: 1) The proving process cannot be automated; 2) Errors may result from evaporation of the product during the proving process; 3) Personnel may be exposed to hazardous vapors.

A tank prover is not appropriate for proving meters in crude oil or fuel oil service because clingage to the walls of the prover may create errors in the proving result and these opaque liquids may coat the interior of the site glasses, making reading of the level difficult.

Master meters are generally less desirable for the following reasons: 1) The overall measurement uncertainty is greater because the meter factors are less directly traceable to the volumetric standard at a

recognized national standards agency [e.g., U.S. National Institute of Standards and Technology (NIST)]. 2) Each master meter must be calibrated at least as often as the operational meters for which it will be used. 3) A pipe or small volume prover is required to develop the calibration curves for each master meter.

A master meter is not appropriate for proving meters in heated liquid service because the conditions during the proving of the operating meter cannot be readily duplicated during the calibration of the master meter.

7.2.2 Conventional Pipe Provers

Pipe provers shall be either bi-directional or uni-directional in design. Bi-directional provers shall be furnished in accordance with 34-SAMSS-119. Uni-directional provers shall be furnished in accordance with 34-SAMSS-120.

7.2.3 Small Volume (Compact) Provers

Small volume provers shall conform to the requirements of 34-SAMSS-121 and API Manual of Petroleum Measurement Standards, Chapter 4, Proving Systems, Section 2, Displacement Provers, 3rd Edition, September 2003.

In case of using helical type turbine meter, double chronometry method shall be used per API MPMS Section 4.6.

7.2.4 Tank Provers

Tank provers shall conform to the requirements of API Manual of Petroleum Measurement Standards, Chapter 4.4 and 34-SAMSS-122.

Each portable tank prover shall be mounted on a trailer that meets the requirements of the U.S. Department of Transportation. A leveling jack shall be provided on each of the four corners of the trailer. Leveling jacks must be able to support the full weight of the tank prover and product.

Each portable tank prover shall be furnished with inlet hose adapter and outlet hose coupler for connection of the prover to the metering system; and tank truck, refueler or product return system, respectively. The adapter and coupler shall meet the requirements of API 1004.

7.2.5 Master Meters

7.2.5.1 Master meters shall be provided in accordance with API Manual of Petroleum Measurement Standards, Chapter 4.5.

7.2.5.2 Master meters shall be dedicated, double case positive displacement meters.

7.2.5.3 Master meters shall be portable in all applications except where used to prove or calibrate refueling, defueling and dispensing meters. Portable master meters shall be mounted on a wheeled trolley or other means of transportation.

7.2.5.4 Each master meter shall be sized to operate between 25 and 75% of the manufacturer's maximum continuous flow rate (capacity).

7.2.5.5 The size of the master meter shall be selected to permit proving or calibration of the operational meters over the full ranges of operating flow rates. In the case of aircraft fueling or defueling meters, the master meter shall also be sized to permit performing the dynamic slip test at 20% of the capacity for each operational meter.

7.2.5.6 Each master meter shall have repeatability and resolution specifications equal to or better than the meters to be proved.

7.2.5.7 Each master meter shall be equipped with a pulse generator that furnishes a pulse signal derived directly from the meter's main shaft (without intervening gearing). A pulse generator that employs a film-type disk with alternating etched opaque and transparent slots shall not be used.

7.2.5.8 Each master meter shall be provided with an electronic device with dual counters and a common timing gate. The dual counters shall accumulate at least 10,000 pulses from the operating meter and the master meter during each proving trial. In each case, the resolution shall be one whole pulse.

7.2.5.9 A means of indicating the instantaneous flow rate and average flow rate shall be provided with each master meter.

7.2.5.10 Provisions shall be made to develop product specific calibration curves using a pipe prover. Each curve shall cover the full range of operating flow rates for the respective meters to be proved.

7.2.5.11 A globe or ball valve shall be installed downstream of each master meter for manual flow control.

7.2.5.12 A pressure gauge or transmitter, and an RTD/temperature transmitter or thermometer/thermowell shall be installed in the outlet piping within 1 m of the master meter.

7.2.5.13 Inlet and outlet hoses with quick connecting couplings, and a drain valve shall be provided.

7.2.5.14 Protection against vibration, dust and mechanical damage during transportation and handling shall be provided for all master meters.

7.3 Other Equipment

7.3.1 Temperature Instruments

Temperature transmitters shall meet the requirements of API Manual of Petroleum Measurement Standards, Chapter 7 and SAES-J-400.

Each transmitter shall be a microprocessor based smart unit that uses a platinum resistance temperature detector (RTD) as its primary element. The RTD shall be Pt100, four-wire design, with an alpha coefficient of 0.00385 per IEC 60751. The calibrated span of the transmitter shall normally be -18 to 65°C (0 to 150°F). The transmitter shall have a 4 to 20 mA DC output. The overall transmitter/RTD accuracy shall be ±0.2% of the calibrated span or better.

Thermometers supplied for tank provers shall be designed in accordance with ASTM E1 and meet the following requirements:

Range:	-1°C to 51°C (30°F to 124°F) or -1°C to 101°C (30°F to 214°F)
Scale Graduations:	0.25°C (0.5°F)
Accuracy:	±0.1°C (0.2°F)

Other thermometers shall have a range consistent with the process temperatures and an accuracy of ±0.25°C (±0.5°F) or better, and shall be graduated at increments not exceed 0.5°C (1°F).

The calibration of each thermometer shall be traceable to the temperature standard at a recognized national standards agency [e.g., U.S. National Institute of Standards and Technology (NIST)].

Each thermometer shall be furnished with an aluminum armor case with a diameter not to exceed 12.5 mm (½ inch).

7.3.2 Pressure Instruments

Pressure instruments shall be furnished in accordance with SAES-J-200.

Pressure transmitters shall be microprocessor based smart units with a reference accuracy of ±0.075% of calibrated span or better and shall be provided with over-range protection. Pressure sensor installation manifolds shall have vent, drain and test connections. Pressure gauges shall have an accuracy of ±0.5% of span or better. The range of each gauge shall be specified in accordance with SAES-J-200. Pressure gauges shall be glycerin filled.

7.3.3 Density Meters

7.3.3.1 Density meters shall be of the vibrating, straight-tube design and shall meet the requirements of API Manual of Petroleum Measurement Standards, Chapter 14.6 and 34-SAMSS-517.

7.3.3.2 Density meters shall have an accuracy of ±0.001 kg/L, repeatability of 0.0005 kg/L and a calibrated range of 0.300 to 1.100 kg/L.

7.3.3.3 Density meter readings shall be temperature and pressure compensated.

7.3.3.4 Each density meter shall be installed in a fast loop (slip stream) which draws liquid from, and discharges back to, the main stream. The density meter shall be oriented vertically with the flow upward through the instrument. The location of the fast loop inlet shall conform to the requirements of API Manual of Petroleum Measurement Standards, Chapter 8.2, Section 8.

7.3.3.5 The entrance to the fast loop shall consist of a probe with 45 degree chamfer or 90 degree short radius elbow inlet facing upstream and positioned in the center one-third of the piping upstream of the metering system. The probe design shall conform to API Manual of Petroleum Measurement Standards, Chapter 8.2, Section 11 and Figure 4, Design B or C, respectively.

7.3.3.6 A pump shall be furnished, to drive the fast loop with sufficient flow for proper operation of the density meter. The pump shall be located downstream of the density meter.

7.3.3.7 Isolation, vent and drain valves shall be provided to permit air calibration checks and cleaning of the density meter in situ, and maintenance of the density meter. Isolation valves shall be provided on the inlet and outlet of the fast loop (slip stream) to permit maintenance of the pump.

7.3.3.8 A temperature transmitter, test thermowell, and connections for a pycnometer shall be furnished between the density meter and pump. When pressure compensation of the density meter is required, a pressure transmitter shall also be furnished between the density meter and pump. A means shall be provided to detect and alarm a condition of low or no flow in the fast loop.

7.3.4 Automatic Sampling Systems

7.3.4.1 Automatic sampling systems in crude oil systems shall be flow proportional systems that meet the requirements of API Manual of Petroleum Measurement Standards, Chapter 8.2 and 34-SAMSS-525.

7.3.4.2 The sampling and associated equipment shall be designed, constructed and installed in accordance with SAES-Y-501.

7.3.4.3 Automatic sampling systems in natural gas liquids (NGL) service shall be flow proportionate, injection pump-type systems that meet the requirements of ASTM D3700.

7.3.5 Manual Sample Probe

Manual sample probes shall be designed in accordance with SAES-Y-501.

7.3.6 Strainers

7.3.6.1 Strainer bodies shall be carbon steel and shall be designed, constructed and tested in accordance with ASME PV SEC VIII D1. An ASME code stamp is not required.

7.3.6.2 Each strainer shall be sized to provide no more than 15 kPa (2 psi) pressure drop at the maximum design rate for the meter or group of meters when the basket is clean.

7.3.6.3 Strainers with nominal inlet and outlet size of 6 inches or less shall be equipped with a 304 stainless steel wire basket. Mesh sizes shall conform to the meter manufacturer's

recommendations. In the absence of specific recommendations from the meter manufacturer, the following table shall be used as a guideline for determining strainer mesh sizes.

Product	PD 3" & 4"	Turbine 3" & 4"	Turbine > 4"
Premium Gasoline	60	40	20
Jet A-1, Kerosene, JP4, JP5, JP8	60	40	20
Diesel	60	40	20
Fuel Oil	40	n/a	n/a
Crude Oil	40	40	20

Commentary Note:

This standard does not address aviation fuel quality requirements. More stringent mesh sizing or filtration may be required to meet aviation fuel quality specifications.

7.3.6.4 Strainers with nominal inlet and outlet size of greater than 6 inches shall be furnished with a rolled 304 stainless steel perforated plate basket with 5/16-inch diameter holes on 3/8-inch staggered centers.

7.3.6.5 Strainers with nominal inlet and outlet size of 6 inches or less may be equipped with either a swing bolt, hinged-type closure (preferable) or a flange-type closure (alternative). Strainers with nominal inlet and outlet size of greater than 6 inches shall be equipped with a swing bolt, hinged-type closure.

7.3.6.6 Strainers with nominal inlet and outlet size of 6 inches or less shall be provided with a differential pressure indicator. Strainers with nominal inlet and outlet size greater than 6 inches shall be provided with a differential pressure indicating transmitter.

7.3.7 Air Eliminators

Air eliminator sizing and design shall be determined based on the type of problem anticipated (e.g., entrained air vs. air pockets or slugs).

All air eliminators shall have a soft-seated check valve in the vent line, and shall be vented to a safe location.

Air eliminator bodies shall be carbon steel and shall be designed, constructed and hydrostatically tested in accordance with ASME PV SEC VIII D1. An ASME code stamp is not required.

7.3.8 Flow Conditioning Assemblies

Flow conditioning assemblies with straightening elements shall conform to the requirements of API Manual of Petroleum Measurement Standards, Chapter 5.3

Flow conditioning assemblies shall be flanged-type and consist of three sections. Two sections shall be installed upstream of the meter (minimum total length of 10 diameters). One section shall be installed downstream of the meter (minimum length of 5 diameters). Each pair of flanges between the respective sections, and between the upstream and downstream sections and the meter, shall be match numbered and doweled to ensure proper alignment.

Straightening elements shall be the flanged-type and constructed from 304 stainless steel.

7.3.9 Block Valves

Gate valves shall conform to 04-SAMSS-001 and ball valves shall conform to 04-SAMSS-051.

7.3.10 Double Block and Bleed Valves

Double block-and bleed valves shall be of the expanding plug type design and shall meet the requirements of 04-SAMSS-041.

7.3.11 Digital Set-Stop Valves

Valves shall be hydraulically operated from the pressure in the process line to which they are connected, and shall be fitted with flow restricting valves in both of the sense lines, to regulate valve stroke times.

Valves shall be provided with both upstream and downstream solenoids for valve control. Solenoids and mode of operation shall be compatible with the output requirements of the selected electronic preset controller.

The valve shall fail closed upon loss of power to the solenoids and upon loss of hydraulic pressure.

7.3.12 Control Valves

Control valves shall meet the requirements specified in SAES-J-700 and 34-SAMSS-711.

The control valve provided downstream of each pipeline meter and meter prover shall be globe type valve and sized to accomplish the following objectives:

- Maintain the flow rate at a selectable value between 10 and 100% of the meter's normal linear capacity. If a common prover is provided for different size meters, the control valve downstream of the prover shall be sized to control the flow rate at any value between 10% of smallest meter's normal linear capacity and 100% of the largest meter's normal linear capacity.
- Maintain the minimum back pressure required downstream of the meter and prover to prevent cavitation in the meter.

The minimum back pressure required for each turbine meter shall be equal to or greater than each of the following requirements:

$$Pm = 2 * \text{Delta P} + 1.25 * Pe$$

$$Pm = 20 \text{ psig}$$

where:

Pm = Minimum back pressure 5 diameters downstream of the meter (psig)

Delta P = Pressure drop across meter at its maximum normal linear flow rate (psi)

Pe = Absolute equilibrium vapor pressure of the fluid at the maximum operating temperature (psia)

The minimum back pressure required for a positive displacement meter shall be greater than each of the following requirements:

$$Pm = 5 \text{ psi} + Pe$$

$$Pm = 20 \text{ psig}$$

where:

Pm = Minimum back pressure 1 m downstream of the meter (psig)

Pe = Absolute equilibrium vapor pressure of the fluid at the

maximum operating temperature (psia)

7.3.13 Check Valves

Check valves shall be spring actuated, double single disk valves that meet the requirements of SAES-L-108.

7.3.14 Valve Motor Operators

Electric motor operators shall meet the requirements of 34-SAMSS-718.

Limit switches shall be provided to permit local and remote indication of valve position.

7.3.15 Thermal Relief Valves

Thermal relief valves shall conform to the requirements of SAES-J-600 and SAES-L-140.

7.3.16 Adjustable Frequency Drives (AFD's)

Low voltage adjustable frequency drives shall meet the requirements of SAES-P-116.

8 Testing and Inspection

8.1 Piping and piping components shall be hydro-tested in accordance with ASME B31.3 or ASME 31.4 and 01-SAMSS-010 prior to the application of internal coating, external paint and insulation.

8.2 Metering system components (meters, valves, provers, sampling systems, etc.) shall undergo tests as specified in the relevant Saudi Aramco Material Supply System specification.

8.3 Each complete metering system shall be flow tested as part of the Factory Acceptance Flow Test (FAT) at the Vendor's facility and witnessed by the concerned organizations in accordance with SAEP-21 or SAEP-50, as applicable. This test shall ensure the system meets all functional and operational requirements. The Vendor shall provide simulators that perform the functions of any missing components.

8.4 A Site Acceptance Test (SAT) similar to the FAT shall be performed after the metering system is permanently installed at the field location. Refer to SAEP-21 or SAEP-50, as applicable.

8.5 Each pipe, small volume and tank prover shall be calibrated by the waterdraw method in the vendor's shop prior to the FAT in accordance with SAEP-36. Prover calibrations shall conform to API Manual of Petroleum Measurement Standards, Chapters 4, 11 and 12.

8.6 In crude oil applications, a water injection test shall be performed for each automatic sampling system prior to placing the system in service. The test shall be conducted in accordance with API Manual of Petroleum Measurement Standards, Chapter 8.2.

8.7 Functional tests shall be witnessed and approved by Saudi Aramco or their approved representatives.

9 Shipping Requirements

All necessary repairs, replacements or modifications to hardware, firmware, and software, shall be completed by the Vendor and approved by the SA Inspector prior to shipment.

The Vendor shall be responsible for ensuring the equipment is properly prepared for shipment, including, but not limited to, the requirements specified hereafter.

9.1 General

All equipment and internals being shipped shall be braced and temporary supports shall be provided, if required, to prevent damage during shipment.

Equipment shall be marked with water-soluble materials that will not attack or damage the equipment at either ambient or operating temperatures. Marking materials shall be free of lead, sulfur, zinc, cadmium, mercury, chlorine and all other halogens.

Markings for export shall conform to the requirements specified on the purchase order.

9.2 Fabricated Equipment

9.2.1 Internal Protection

The internals of all piping, fabricated and assembled equipment shall be completely cleaned and dried to the satisfaction of the Saudi Aramco Inspector.

A non-toxic vapor phase corrosion inhibitor (CORTEC VpCI-309 or VpCI -307, or equivalent approved by the Supervisor, Corrosion Technology Unit, Materials Engineering and Corrosion Control

Division) shall be applied to the internal surfaces of all piping, fabricated and assembled equipment.

Commentary Note:

Vendors are cautioned to allow sufficient lead-time for the purchase and delivery of the vapor phase corrosion inhibitor. Lack of planning by the Vendor will not constitute justification for a waiver of this requirement.

The application rate for the inhibitor shall be 1 kg/m³ of equipment.

The inhibitor shall be blown through the equipment using air with a dew-point that is the lower of the following: 1) -1°C or 2) 5°C below the lowest ambient temperature to be encountered in shipment from the point of manufacture to the final destination. Application of the inhibitor shall continue until the powder can be seen blowing out of the opposite end of the equipment.

Following application of the inhibitor, equipment openings shall be sealed vapor tight with steel covers in accordance with the requirements for external protection.

9.2.2 External Protection

All external surfaces shall be prepared and coated in the shop with the complete Saudi Aramco coating system (primer and final coatings) as specified in SAES-H-001. If the specified Saudi Aramco approved coating is unavailable or unusable at the Vendor's site, an alternative coating system may be used with the concurrence of the Supervisor, Corrosion Technology Unit, Materials Engineering and Corrosion Control Division.

All bolts and nuts shall be coated with a temporary protective coating (MIL C16173, Grade IV, or Denso paste or equivalent).

Permanent blind flanges or covers shall be installed with the gaskets and bolts required for service.

The faces of open, flanged connections shall be coated with a temporary protective coating (MIL C16173, Grade IV, or equivalent) which can be easily removed prior to equipment installation. Following application of the protective coating, each connection shall be fitted with a neoprene gasket, and vapor tight steel cover. The cover shall be held in place by a minimum of four equally spaced bolts.

9.3 Electronic and Electrical Equipment

The Vendor shall determine if electronics and instruments are susceptible to damage from shock, weather or extremes of temperature during shipment. If required, such items shall be removed after the functional test and shipped separately.

Electronic equipment shall be prepared and protected for shipment in accordance with the manufacturer's recommendations. As a minimum, the equipment shall be fitted with a vapor phase inhibitor emitter (CORTEC VCI-101, VCI-105, VCI-110 or equivalent).

Electrical boxes shall be fitted with vapor phase inhibitor emitters (CORTEC VCI-101, VCI-105, VCI-110 or equivalent).

10 Documentation

Project drawings shall conform to the requirements of SAES-J-004 and SAES-J-005.

Project documentation shall be developed, reviewed, approved and distributed in accordance with SAEP-21 or SAEP-50, as applicable.

Documentation for metering system equipment shall be furnished in accordance with the purchase order(s) and relevant material specifications.

Each strainer and air eliminator shall be assigned a tag number. A data sheet that specifies the maximum operating pressure and other design data shall be provided for each strainer and air eliminator.

Revision Summary

4 December 2012	Major revision.
26 September 2013	Editorial revision to change the primary contact persons.

Appendix A – Pipeline and Marine Metering Control Systems

This appendix describes the requirements for metering and control systems for pipeline and marine applications. Other system architectures and equipment that provide the same functionality and level of redundancy may be specified with the concurrence of the Chairman, Custody Measurement Standards Committee. Examples of possible alternative designs or equipment which may be acceptable include, but are not limited to:

- Specification of a separate flow computer for meter proving calculations.
- Specification of Distributed Control System (DCS) to perform the functions of the metering supervisory computers.
- Specification of DCS hardware to perform the functions of the programmable logic controllers.

Commentary Note:

Approval of alternate designs and/or equipment by the Chairman, Custody Measurement Standards Committee is required to ensure that all functional requirements are met.

A.1 General

All flow computers, auxiliary counters, indicating lights, etc. shall be mounted in a cabinet designed and constructed to meet the requirements of 34-SAMSS-820 and 34-SAMSS-821.

A.2 Architecture

1. The system shall be designed such that a single equipment failure will not result in loss of control or degrade the functional capabilities of the system. This requirement does not apply to field equipment such as transmitters and I/O modules unless specified as redundant or dual.

2. The metering control system shall be arranged in functional blocks. The functional blocks used to construct the system are flow computers, programmable logic controllers (PLC's) and metering supervisory computers (MSC's).

3. Redundant flow computers shall be furnished for each meter, or group of parallel meters.

4. The A and B pulse transmitter channels from each meter shall be connected to the primary and secondary flow computers in a crisscross fashion. For each meter, the signal from pulse transmitter A shall be wired to the pulse input A of the primary flow computer and pulse input

B of the secondary flow computer. The signal from pulse transmitter B shall be wired to the pulse input B of the primary flow computer and pulse input A of the secondary flow computer.

5. Redundant PLC's, each with its own processor, power supply, and communications, shall be provided to operate all metering systems MOV's. Redundant I/O is not mandatory.

6. Redundant MSC's shall be provided. Each MSC shall include a graphical user interface (GUI) to the metering system for operator interface. Each GUI shall provide operator control selection, report printing, alarming, metering and system graphics, data archiving, and trending capabilities.

7. The MSC's shall have no direct interface to field devices.

8. Redundant communication links shall be provided between the flow computers and the MSC's with either link selectable at each MSC. A similar arrangement of dual communication links shall be provided between the pair of PLC's and the MSC's. The MSC's shall be masters, and flow computers and PLC's shall be slaves on their respective communication ports.

9. If an automatic sampling system is provided as part of the metering system, a single communications link shall be provided between the PLC and the sampling system controller.

10 Redundancy must be established between flow computers, PLCs and MSCs at their level using a direct communication link.

11. For direct interconnection of metering equipment at distances of 15 m or less, RS-485, RS-422, RS-232-C or Ethernet interfaces are permitted. For direct interconnection distances greater than 15 m, RS-485, RS-422 or Ethernet shall be used. Industry standard protocols (e.g., MODBUS, MODBUS Plus, OPC, TCP/IP, or other standard protocol) shall be used for communication between system components or the metering system and higher level computer system.

12. All communication links in the system shall support error correction and multiple retries.

13. A discrete (on/off) output for operation of the prover 4-way valve or interchange shall be hardwired from each flow computer to a common set of PLC inputs. The prover detector switches shall be hardwired to the flow computers.

14. The system shall permit the addition of meters simply through the purchase of flow computers (if required), PLC I/O cards and reconfiguration of the MSC's, PLC's and flow computers, as applicable.

15. In the event of failure in the MSCs, the primary flow computer in combination with PLC shall be able to perform proving.

A.3 Programmable Logic Controllers

1. Redundant PLC's shall be provided to operate all metering system MOV's.

2. Each PLC shall meet the requirements of 34-SAMSS-830.

3. The PLC shall provide logic functions and sequential control for the following operations:

- Valve line-up in preparation for and after meter proving
- Opening and closing meter runs.
- Operation of the prover 4-way valve or interchange.

4. The PLC shall provide Open/Stop/Close logic with completion alarm timers, Remote/Local status, and the ability to reverse travel before completion of a command for each MOV.

5. The PLC shall include interlock logic for sequential control of the metering system MOV's. The logic provided shall include, but not be limited to provisions for preventing the following:

- Opening of the prover inlet valve on more than one meter run at a time
- Closing of a meter run outlet valve prior to opening of the prover inlet and outlet valves
- Closing of a prover inlet or outlet valve prior to opening of the meter run outlet valve

6. The PLC shall set an alarm flag if an MOV is operated locally.

7. The PLC shall refuse a sequential operation and set an alarm flag if any of the affected valves is in the LOCAL position.

8. In response to a “Prove Meter Run” command from the MSC, the PLC shall sequence the valves for proving as follows:

- Open prover outlet MOV.

- Open prover inlet MOV for the meter to be proved.
- Close the meter run outlet MOV.

9. If a bi-directional prover is provided, the PLC shall "home" the prover sphere in the left chamber (as observed from the chamber end of the prover) by operating the prover 4-way valve after configuration of the MOV's for proving.

10. In response to a command from the primary flow computer, the PLC shall initiate operation of the prover 4-way valve or interchange. The PLC shall monitor the status of the prover during proving, including the 4-way valve limit switches if a bi-directional prover is provided. The status shall be made available to the MSC via the communications link

11. Upon receipt of a command from the MSC, the PLC shall reconfigure the metering system MOV's using the following sequence:

    - Open the meter run outlet MOV.
    - Close the prover inlet MOV for the meter proved.
    - Close the prover outlet MOV.

12. The PLC shall sequence the valves for an "Open Meter Run" command from the MSC as follows:

    - Ensure the prover inlet MOV on the meter run is closed.
    - Open the inlet MOV for the meter run.
    - Open the outlet MOV for the meter run.

13. The PLC shall sequence the valves for a "Close Meter Run" command from the MSC as follows:

    - Ensure the prover inlet valve on the meter run is closed.
    - Close the meter run outlet MOV.
    - Close the meter run inlet MOV.

14. Following the completion of proving, the PLC shall command the 4-way valve to open to a relaxed position

15. The PLC shall have an input from each strainer differential pressure transmitter and set an alarm flag if the differential pressure switch or the transmitter is activated.

16. The PLC shall continuously run a self-diagnostic routine and shall set an alarm flag if it fails.

17. Each PLC's program and data memory shall have a battery backup with a minimum retention time of two weeks.

18. Each PLC shall have a minimum of two serial or Ethernet communication ports capable of supporting industry standard protocols (e.g., MODBUS, MODBUS Plus, OPC, TCP/IP or other standard protocol) for communicating with the MSC's.

19. In the event the sequential logic is not complete, an appropriate alarm should be annunciated if a sequence failed to complete within the specified time, the lineup shall be returned to its original state prior to any new command being accepted

A.4 Metering Supervisory Computers (MSC's) and Associated Peripheral Equipment

The Metering Supervisory Computers (MSC's) shall be provided to meet 34-SAMSS-851.

Redundant MSC's shall be furnished to support the metering system. The MSC's shall be interconnected to provide data transparency in their operation to the metering system. Any changes in one MSC shall automatically be updated and displayed in the other MSC. Acknowledgement of alarms on one MSC shall cause them to be acknowledged on the other MSC.

If a desk type TFT-LCD (Thin Film Transistor- Liquid Crystal Display) is provided, the vendor should supply the desk, if requested

A.5 Flow Computers

The flow computer shall be provided to meet 34-SAMSS-841.

A.6. Reports

A.6.1 The following Meter Proving Report Formats and Procedures shall be provided in accordance with 34-SAMSS-851:

- Proving Report for Bi-Directional and Uni-Directional Sphere Provers - Refined Products (Metric Units)
- Proving Report for Bi-Directional and Uni-Directional Sphere Provers - Refined Products, Naphtha and Lube Oils (USC Units)
- Proving Report for Bi-Directional and Uni-Directional Sphere Provers - Crude Oil (USC Units)

- Proving Report for Bi-Directional and Uni-Directional Sphere Provers – Natural Gasoline, Butane, Propane, and NGL (USC Units)
- Proving Report for Small Volume Provers
- Meter Factor Control Procedure

A.6.2 The following Meter Ticket Formats and Procedures shall be provided in accordance with 34-SAMSS-851:

- Meter Ticket - Refined Products (Metric Units)
- Meter Ticket - Refined Products, Lube Oils and Naphtha (USC Units)
- Meter Ticket - Crude Oil (USC Units)
- Meter Ticket – Natural Gasoline, Butane, Propane and NGL (USC Units)
- Meter Ticket Calculations

A.6.3 The Rounding Conventions shall be in accordance with 34-SAMSS-851.

A.6.4 The following Miscellaneous Reports shall be in accordance with 34-SAMSS-851:

- Delivery/Receipt Summary Report – Refined Products (Metric Units)
- Delivery/Receipt Summary Report – Crude Oil, Refined Products, Naphtha and Lube Oils (USC Units)
- Delivery/Receipt Summary Report – Natural Gasoline, Butane, Propane and NGL (USC Units)
- Delivery/Receipt Summary Report, Composition Supplement – NGL (USC Units)
- Meter Calibration Report – All Liquid Hydrocarbons (Metric or USC Units)
- Non-Transaction Activity Report – All Liquid Hydrocarbons (Metric or USC Units)
- Hourly Report –Refined Products (Metric Units)
- Hourly Report – Refined Products, Naphtha, Lube Oils, Crude Oil (USC Units)
- Hourly Report – Natural Gasoline, Butane, Propane, NGL (USC Units)

Appendix B – Automation Requirements for Rail Car and Refueler Loading Meters

This appendix describes the basic automation requirements for required for rail car and refueler loading meters.

B.1 Preset Controllers

Each meter shall be furnished with an electronic preset controller the meets the requirements of 34-SAMSS-847.

Electronic preset controllers having multiple meter capability may be used provided that control of the meters is independent from one another.

Each preset controller shall provide Level B pulse security as defined in the API Manual of Petroleum Measurement Standards, Chapter 5.5 using the dual inputs provided by each assigned meter.

B.1.1 Software

Each electronic preset controller shall calculate volume totals for each meter in accordance with API Manual of Petroleum Measurement Standards, Chapter 12.2, and the applicable API/ASTM tables specified in Section 5.

In performing volume calculations, each preset controller shall use linearized meter factors derived from at least 4 pre-configured meter factors and corresponding flow rates.

B.1.2 Inputs

The electronic preset controller shall be wired and configured to receive the following input signals as a minimum:

- Frequency inputs for the A & B pickup coil from each meter.
- A temperature input for each meter controlled by the preset controller.
- A pressure input for meter controlled by the preset controller (if specified).
- Two local interlock permissive.

System shall support the later addition of additive injection pump status and volume data.

B.1.3 Outputs

The electronic preset controller shall be wired and configured to allow outputs for the following:

- Digital set-stop valve(s), solenoid operation (two solenoids per valve)
- Pump start permissive
- Raw (unaltered) meter pulses from each pick-up coil of each meter for remote and local meter proving

System shall support the later addition of additive injection pump, start signals.

B.1.4 Communication

An RS-485 communications interface shall be provided.

It shall be possible to connect multiple units together on a single multi-drop RS-485 communication link.

Through this interface it shall be possible to upload and download the entire operating configuration of the electronic preset controller from a portable computer (IBM Compatible), or through the Terminal Management System.

Information available for upload over the communication link to the Terminal Management System shall include but not be limited to:

- All dynamic data
- I/O status
- System configuration/diagnostics data
- Data input by the driver/operator

System shall be capable of accepting the download of information from the Terminal Management System. This shall include but not be limited to:

- System configuration data
- Driver / operator prompts
- Driver / order / transaction data

B.1.5 Data Retention

Delivery ticket data from the last 20 transactions shall be retained in non-volatile memory, for later recall by the Terminal Management System or through the local display and keypad.

B.1.6 Operating Parameters

It shall be possible to set operating parameters and control limits within the unit, as required to support safe operation. This shall include but not be limited to such items as maximum flow rate per meter, low flow start, normal and ramped shutdown flow rates.

It shall be possible to stop flow at any time, by depressing the stop button on the electronic preset controller. Interruption of flow by this method shall not cause the transaction counters to reset, and it shall be possible at any time to restart the flow by depressing the start button once again.

Configuration of external shutdown logic shall be the responsibility of Saudi Aramco, unless otherwise noted.

B.1.7 Dynamic Data

Status of the load in progress shall be shown during the loading operation. This shall take the form of an incremental or decremental counter in conjunction with the total batch size.

It shall be possible to call up other displays during a loading operation without affecting the load in progress. Display shall automatically return to the status of the load in progress after a pre-defined period of inactivity.

B.1.8 Configuration Data

It shall be possible through the local keypad, to access and change all configuration and calibration data contained within the unit.

Protection against unauthorized changes to configuration and calibration data shall be provided in the form of a keylock or passcode.

B.2 Meter Tickets

The following information shall be furnished on the bills of lading and/or other accounting documentation associated with the volumes loaded:

General Information

Plant
Date and Time
Customer or Contract Hauler (as applicable)
Account Number
Driver Identification
Trailer Identification
Load/Unload Bay Number
Transaction Number
Product
Total Gross Standard Volume Delivered/Received (L or U.S. gal)

Information for Each Meter

Meter Number
Ticket Number
Product
Opening Meter Reading (L or U.S. gal)
Closing Meter Reading (L or U.S. gal)
Indicated Volume Delivered/Received (L or U.S. gal)
Gross Volume Delivered/Received (L or U.S. gal)
Gross Standard Volume Delivered/Received (L or U.S. gal)
Average Temperature (°C or °F)
Density (kg/m³ at 15°C, or deg API at 60°F)
Average Flow Rate (L/min or U.S. gal/min)
Average Meter Factor

B.3 Meter Proving

Meter proving operations, calculations and reports shall be in accordance with API Manual of Petroleum Measurement Standards, Chapters 4.8 and 12.2, and the applicable API/ASTM tables specified in Section 5.

Appendix C – Automation Requirements for Rail Car and Refueler Unloading and Aircraft Refueling, Defueling and Dispensing Meters

This appendix describes the automation requirements for rail car and refueler unloading, and aircraft refueling, defueling and dispensing meters.

C.1 Preset Controller

Each meter shall be furnished with an electronic preset controller the meets the requirements of 34-SAMSS-847.

C.1.1 General

Each preset controller shall perform the following operations:

- Correct volumes to standard temperature and pressure using the applicable API/ASTM tables specified in Section 5.
- Meter factor linearization using at least 4 meter factors and corresponding flow rates.

C.1.2 Inputs

The preset controller shall be wired and configured to receive the following input signals as a minimum:

- Frequency input(s) for the pickup coil from each meter
- Temperature input from an RTD

C.1.3 Outputs

The preset controller shall have the output of raw (unaltered) meter pulses from each pick-up coil of each meter for remote and local meter proving.

C.1.4 Data Transfer (Refueling, Defueling and Dispensing Meters)

If transfer of measurement data to a Terminal Management System is required, the preset controller shall be provided with a secure means for doing so (e.g., magnetic card, memory module, etc.).

C.1.5 Data Retention

Delivery / receipt ticket data from the last 20 transactions shall be retained in non-volatile memory for later recall by the Terminal Management System or through the local display and keypad.

C.1.6 Operating Parameters

It shall be possible to stop flow at any time, by depressing a stop button. Interruption of flow by this method shall not cause the transaction counters to reset, and it shall be possible at any time to restart the flow by depressing a start button once again.

Configuration of external shutdown logic shall be the responsibility of Saudi Aramco, unless otherwise noted.

C.1.6 Dynamic Data

Status of the transaction in progress shall be shown on the local display, in the form of an incremental counter.

It shall be possible to call up other displays during operation, without affecting the transaction in progress. Display shall automatically return to the status of the transaction in progress after a pre-defined period of inactivity.

C.1.8 Configuration Data

It shall be possible through the local keypad, to access and change all configuration and calibration data contained within the unit.

Protection against unauthorized changes to configuration and calibration data shall be provided in the form of a keylock or passcode.

C.2 Meter Tickets

The following information shall be furnished on the bills of lading and/or other accounting documentation associated with volumes loaded or received:

<u>General Information</u>

Plant

Date and Time

Customer or Contract Hauler (as applicable)

Account Number

Driver Identification

Trailer Identification
Load/Unload Bay Number

Transaction Number
Product
Total Gross Standard Volume Delivered/Received (L)

Information for Each Meter

Meter Number
Ticket Number
Product

Opening Meter Reading (L)
Closing Meter Reading (L)
Indicated Volume Delivered/Received (L)
Gross Volume Delivered/Received (L)
Gross Standard Volume Delivered/Received (L)

Average Temperature (°C)
Density (kg/m³ at 15°C)
Average Flow Rate (L/min)
Average Meter Factor

C.3 Meter Proving

Meter proving operations, calculations and reports shall be in accordance with API Manual of Petroleum Measurement Standards, Chapters 4.8 and 12.2, and the applicable API/ASTM table(s) specified in Section 5.