Engineering Standard

SAES-K-502 31 August 2005

Combustion Gas Turbines

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Revised paragraphs are indicated in the right margin

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1 Scope

1.1 This Standard defines the mandatory minimum requirements for design, manufacture and installation of gas turbine packages for the applications of mechanical drive and power generation. This entire Standard shall not be attached to or made part of purchase orders.

1.2 The gas turbine package includes a base frame or a plate and accessory and auxiliary systems for starting, stopping, protecting, controlling and monitoring the gas turbine. The type of gas turbine shall be specified on the Data Sheet.

2 Conflicts and Deviations

2.1 Any conflicts between this Standard and other applicable Saudi Aramco Engineering Standards (SAESs), related Materials System Specifications (SAMSSs), Standard Drawings (SASDs) or industry standards, codes and forms shall be resolved in writing by the Chairman, Gas Turbines & Diesel Engines Standards Committee, Consulting Services Department, Saudi Aramco, Dhahran.

2.2 Deviation from this Standard shall be approved by the Chairman, Gas Turbines & Diesel Engines Standards Committee, Consulting Services Department, Saudi Aramco, Dhahran, and shall follow Saudi Aramco procedure SAEP-302.

3 References

The selection of material and equipment and the design, construction, 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 References

Saudi Aramco Engineering Procedure

SAEP-302	*Instructions for Obtaining a Waiver of a Saudi Aramco Engineering Requirement*

Saudi Aramco Engineering Standards

SAES-A-112	*Meteorological and Seismic Design Data*
SAES-B-006	*Fire Proofing for Plants*
SAES-B-068	*Electrical Area Classification*
SAES-J-505	*Combustible Gas and Hydrogen Sulfide in Air Detection Systems*

SAES-Q-005	*Concrete Foundations*
SAES-Q-007	*Foundations and Supporting Structures for Heavy Machinery*
SAES-Q-010	*Cement Based Non-Shrink Grout for Structural and Machinery Support*
SAES-Q-011	*Epoxy Grout for Structural and Machinery Support*

Saudi Aramco Materials System Specification

34-SAMSS-831	*Instrumentation for Packaged Units*

Saudi Aramco Standard Drawings

AD-036006	*Fuel Treatment Facilities for Combustion Gas Turbines – Typical Schematics*
AB-036322 Sht. 001	*Anchor Bolt Details – Inch and Metric Sizes*

Saudi Aramco Forms and Data Sheets

7305-ENG	*Equipment Noise Data Sheet*
8002-ENG & 8002-M-ENG	*Combustion Gas Turbine Data Sheet*

Saudi Aramco Product Specification

A-888	*Diesel*

3.2 Industry Codes and Standards

American Concrete Institute

ACI 318	*Building Code Requirements for Structural Concrete*

American Institute of Steel Construction

AISC	*Code of Standard Practice for Steel Buildings and Bridges*

4 Performance Requirements

4.1 Site Rated Temperature

The site rated temperature is defined as the site's highest recorded ambient temperature per SAES-A-112, and is used for determining the site rated power.

4.1.1 If heat island effect (ambient air heating generated by nearby site equipment) is present, then the above site rated temperature shall be increased by 5.5°C.

4.1.2 The site rated temperature applies to generator drive which are not connected to the grid. For generator drive connected to the national electrical grid, site rating shall be calculated at the average daily maximum temperature (hottest month).

4.1.3 A lower site temperature may be specified, for a power generation unit, if an exceptionally high ambient temperature is recorded at the site during short periods of time and its impact is acceptable and supported by value engineering studies. The lower site temperature information shall be submitted for approval by the proponent and the Gas Turbines & Diesel Engines Standards Committee, Consulting Services Department.

Commentary Note:

This site temperature is applicable only to the load equipment and not the auxiliary systems.

4.1.4 Minimum Temperature shall be the minimum site recorded ambient temperature per SAES-A-112.

4.1.5 The auxiliary systems shall be suitable for the lowest and highest site ambient temperatures

4.2 Site Rating Requirement

4.2.1 Since Manufacturers typically rate their gas turbines at ISO conditions, the Vendor shall provide and account for all correction factors including the effects of elevation, humidity (maximum humidity at site maximum temperature), and gearbox, transmission, and other losses, if any.

4.2.2 To ensure the proper sizing of the gas turbine, the following correction factors shall be used to convert ISO to Site rated power:

X1 = Site rated temperature correction factor**.

X2 = Eevation (minimum ambient pressure) factor**.

X3 = Mximum humidity factor**.

X4 = Inlet and exhaust losses correction factor (including inlet filters, inlet and exhaust silencers and inlet and exhaust ducts. The factor shall not be greater than 0.97 for simple cycle units. It may be less than 0.97 for co-generation or combined cycle units**.

X5 = Gearbox and transmission loss factor, if any**.

X6 = Deterioration and contingency factor:

= 0.90 for single and multiple shafts mechanical and generator drive units.

A7 = Auxiliary power (HP), if any (e.g., shaft driven auxiliary generator, main lube oil pump or atomizing air compressor, etc).

** Values to be provided by the Manufacturer.

SITE (HP) = ISO (HP)*X1*X2*X3*X4*X5*X6 – A7 (HP)

4.3 Peak Load

Peak load operation may only be requested as an option for power generation units not connected to the national electrical grid. For others, peak load operation is prohibited shall not be requested as an option

5 Design

5.1 Turbine

If the turbine cannot be hot restarted at any time after a trip, the end user organization shall be consulted for agreement to the restart limitations and interval.

5.2 Inlet Air System

5.2.1 The entry of hydrocarbon gases into the gas turbine inlet is prohibited and shall be prevented to avoid the possibility of unit runaway (loss of engine control due to hydrocarbon gases intake through the inlet and consequently uncontrolled combustion). To minimize the chance of such an incident, the gas turbine unit(s) shall be located upwind in relation to other plant equipment.

5.2.2 The air inlet shall be upstream of the exhaust stack in the prevailing wind direction.

5.2.3 The position and height of the air inlet and the exhaust stack shall be such that recirculation of hot exhaust gases into the air inlet cannot occur; this information shall be submitted review by the Chairman, Gas Turbines & Diesel Engines Standards Committee, Consulting Services Department.

5.2.4 The air inlet shall be outside of a three-dimensional fire hazardous zone as defined in SAES-B-006.

5.3 Exhaust System

5.3.1 The proposed location of the combustion gas turbine exhaust shall be submitted for review and approval by the Chairman, Gas Turbines & Diesel Engines Standards Committee, Consulting Services Department.

5.3.2 The discharge of the gas turbine exhaust gases shall be outside of a three-dimensional fire hazardous zone as defined in SAES-B-006.

5.3.3 The exhaust stack discharge shall be at least 3 m higher than any personnel platform or access within a horizontal distance of 7.5 m.

5.3.4 The exhaust stack shall discharge outside any classified electrical area as defined in SAES-B-068.

5.3.5 For COGEN or combined cycle units, the gas turbine exhaust may be accessed from the HRSG inlet plenum access door or manway. Personnel doors should have panic hardware.

5.4 Starting System

5.4.1 The type of starting system shall be determined for each project individually and shall be listed on the data sheets. The system may be one of the following:

- Electric motor
- Diesel engine
- Steam turbine
- Hydraulic motor
- Air expansion turbine
- Static Starter

5.4.2 Where electric power is reliably available, an electric motor is the preferred starter type

5.4.3 If a diesel engine generator is supplied for black start capability, it shall be dedicated for the gas turbine startups and other needs such as vital communication and lighting. The number of diesel engine generator shall be optimized based on the number of gas turbine units. This information shall be submitted review by the Chairman, Gas Turbines & Diesel Engines Standards Committee, Consulting Services Department.

5.5 Gas and Hydrogen Sulfide Detection System:

5.5.1 Gas and Hydrogen Sulfide detection outside the gas turbine compartment shall comply to SAES-J-505.

5.5.2 The gas and hydrogen sulfide detection system shall be capable of initiating a gas turbine unit trip using a two out of two voting system logic.

5.5.3 For units burning sweet gaseous fuel, one combustible gas detector shall be installed down wind of the fuel supply pipe flange, close to the turbine or the turbine compartment for packaged units. A second gas detector shall also be installed on the opposite side of the unit, as close as possible to the fuel manifold. This is to protect against fuel gas ingestion into the GT inlet due to supplied fuel leakage in the case of substantial gas leaks.

5.6 Emissions

5.6.1 Equipment noise levels shall be less than 85 dB(A) at a distance of one meter from the unit at 1.5 meter height above ground. The Vendor shall advise whether acoustic treatment will be required to meet this noise requirement

The equipment shall not generate noise in excess of 90 dB(A) after noise control methods have been implemented. If the noise level will exceed this limit, the Project Manager shall submit a completed Form 7305-ENG, Equipment Noise Data Sheet, to Environmental Protection Department (EPD), and shall obtain a waiver in accordance with SAEP-302.

5.6.2 If the exhaust emission level exceeds the allowable limits, the Project Manager shall obtain a waiver in accordance with SAEP-302 from the Environmental Protection Department (EPD).

5.7 Auxiliaries and Driven Equipment

For mechanical drive gas turbine packages, the following are applicable:

a) The driven load (pump, compressor), the load gearbox (if applicable), and the load couplings shall be supplied in accordance to Saudi Aramco standards.

b) 34-SAMSS-831: applicable to the instrumentation and wiring outside the gas turbine, fuel control valves, and control system enclosures.

6 Gas Fuel System

The following paragraphs along with the applicable Saudi Aramco standards (e.g., piping, K.O. Drum, etc.) define the requirements of the gas turbine gas fuel treatment system. Drawing AD-036006 provides the general guidelines for this system. The proposed fuel system schematic shall be submitted for review and approval by the Chairman, Gas Turbines & Diesel Engines Standards Committee, Consulting Services Department.

6.1 Emergency Isolation Valve

6.1.1 An emergency isolation valve shall be installed in the gas supply line at the plot limit.

6.1.2 The plot limit emergency valve shall automatically trip on the gas knock out drum high high liquid level proceeded by high liquid level alarm, and shall also be capable of being manually tripped. Automatic unit trip shall be based on a 2 out of 3 voting system to eliminate trips due to false readings.

6.1.3 The valve shall be operated by means of an electric motor (M.O.V.) or by air (A.O.V.) and shall be of a "Fail Safe" design with a manual override.

6.1.4 Multiple supply branches shall each be equipped with an emergency isolation valve upstream of the particle/coalescing filter.

6.2 Pressure Control Valve

6.2.1 A pressure control valve shall be installed downstream of the plot limit emergency isolation valve located upstream of the knock-out drum.

6.2.2 For multiple branch layouts with individual units requiring different supply pressure ranges, each branch shall be equipped with a pressure control valve, upstream of the particle/coalescing filter.

6.3 Knock-Out Drum

6.3.1 A knock-out drum shall be provided for the maximum expected gas consumption of the plant. The knock-out drum shall be installed downstream of the plot limit's emergency isolation and pressure control valves. A single knock-out drum is required for multiple branch layouts. Knock-out drum bypass shall be provided to be used for maintenance purposes.

6.3.2 The knock-out drum shall have automatic drain valves and an easily accessible level indicator sight glass. This arrangement is necessary to

protect the drum from being flooded.

6.3.3 High level alarm and shutdown settings per 6.1.2 shall be provided.

6.4 Particle and Coalescing Filters

6.4.1 A combined particle/coalescing filter shall be installed close to the gas turbine, for each unit downstream of the knock-out drum.

6.4.2 The filters shall be of its vendor proven design. Screw type mounting of the particle or coalescing filter cartridges is not acceptable. Filter drum inspection manholes shall be provided.

6.4.3 Bypass valves shall not be provided for the filters.

6.4.4 The particle filter shall have the following particle removal efficiency as a minimum:

- For sizes 3 microns and above : 100%
- For sizes 0.5 to 3 microns : 99.5%

6.4.5 In addition to the fuel gas composition, flow, temperature and pressure as specified in the data sheets, the coalescing filter/separator shall be sized to satisfy the following requirements:

- Liquid droplets carryover : 50 ppmw
- Liquids to be removed : condensate, oil, water.
- Droplets removal efficiency:

  0.5 to 8 micrometers : 99.5%

  8 micrometers and above : 100%

6.4.6 Coalescing filters shall have automatic drain valves and an easily accessible level indication sight glass. This arrangement is necessary to protect the filters from being flooded.

Level indicators with alarms and manual drain valves are not acceptable.

Differential pressure devices with alarm and shutdown settings across the filter shall be provided.

6.5 Superheater

6.5.1 A fuel gas superheater shall be installed downstream of the Coalescer Filter, to prevent a condensate mist carryover or hydrate formation. The

gas turbine manufacturer shall provide the required superheater output fuel gas temperature.

6.5.2 The superheater must be sized for the total expected gas consumption of the unit under all operating conditions.

6.5.3 The superheater shall have a built-in temperature detection device to alarm and cut-off the heater when high temperature is detected inside the heater. Temperature devices downstream of the heater shall not be used instead.

6.6 Strainer

A fuel gas strainer with a differential pressure gauge shall be provided upstream of the gas supply connection to the turbine fuel delivery interface flange. The strainer shall be purchased together with the combustion gas turbine from the turbine Manufacturer. The internals of this strainer shall be corrosion resistant stainless steel.

6.7 Blow-down Pipe

6.7.1 A blow-down pipe connection to the flare with an automatic valve shall be provided. The pipe shall be located downstream of the strainer, and upstream of the gas supply connection to the turbine on-base fuel skid.

6.7.2 The blow-down pipe shall be used for purging and warming up the fuel system until the fuel gas entering engine reaches the manufacturer's required superheated temperature to ensure that the fuel gas is free of liquid droplets prior to entering the turbine. The blow-down valve is to be closed just prior to engine startup.

6.7.3 The blow-down pipe shall also be used to vent to flare during emergency shutdown of the unit.

6.8 Gas Fuel Piping

6.8.1 Gas supply/distribution piping shall be stainless steel, full penetration butt-welded, and hydrotested.

6.8.2 All piping between the gas fuel superheater and the fuel gas on-skid connection flange shall be insulated to ensure that the heat loss into the surrounding is minimal to prevent condensate mist carryover or hydrate formation.

6.8.3 Horizontal piping sections shall be installed sloped towards the knock-out drum to allow drainage. All low points shall be provided with valved drain connections and all high points shall have valved vent connections.

6.9 Double Block and Bleed Valves (DBBV)

Commentary Note:

The DBBV arrangement is to quickly vent to flare much of the gas trapped close to the gas turbine unit, between the individual gas turbine unit fuel emergency isolation valve and the gas turbine manufacturer supplied fuel control valve, during an emergency shut down condition. This arrangement is to ensure that engine runaway is prevented.

6.9.1 Double block and bleed valve (DBBV) arrangement shall be provided for each gas turbine unit. That is, a second emergency isolation valve shall be installed as close as possible to the gas turbine unit.

6.9.2 For units with on-skid double–block and bleed arrangement, the second shutoff valve just outside the unit is not required.

6.9.3 A vent to flare using a fast acting automatic type valve shall be provided just upstream of the particle/coalescer filter.

6.9.4 Refer to the Standard Drawing AD-036006 for the block and bleed arrangement.

7 Liquid Fuel System

7.1 Diesel, per Saudi Aramco Product Specification A-888, is the preferred fuel oil for combustion gas turbines with dual fuel systems.

7.2 For liquid hydrocarbon fuels, the extent and method of liquid fuel treatment shall be determined for each project individually and shall depend on the fuel quality (grade) and the requirements of individual turbine make and type. Proposals by the Vendor for burning liquid fuel shall detail the fuel treatment required. Proposals shall be submitted through the Company or Buyer Representative for review and approval by the Chairman, Gas Turbines & Diesel Engines Standards Committee, Consulting Services Department..

8 Installation

8.1 The power generator train shall be mounted on one common foundation. The mechanical drive train can be mounted on multiple foundations. The foundation(s) shall be in accordance with SAES-Q-007. Cement based grout shall be in accordance with SAES-Q-010. GT Vendor standard epoxy based grout is also acceptable.

8.2 Anchor Bolts

8.2.1 Anchor bolts shall be in compliance with Standard Drawing AB-036322 (The AB-036322 requirement of SAES-Q-005 shall be considered inapplicable for anchor bolts). It is the responsibility of the foundation design engineer to verify the capacity of any vendor furnished or detailed anchor bolts.

8.2.2 Equipment shall be installed on mounting plate(s), and the direct attachment of equipment feet to the foundation using the anchor bolts shall not be permitted. Mounting plates shall be of sufficient strength and rigidity to transfer the applied forces to the foundation.

8.2.3 Anchor bolts and embedded items shall be set accurately, using templates provided by the equipment manufacturer, if applicable, within the tolerances specified in the AISC Section 7.5, Code of Standard Practice, unless specified otherwise on the vendor drawings.

8.2.4 The design of anchor bolts shall be in accordance with the requirements of Appendix D of ACI 318.

8.2.5 The minimum anchor bolt diameter shall be 20 mm (¾"), except when specified otherwise by the vendor for small equipment or for the anchorage of small miscellaneous steel items such as; ladder supports, small piping supports, handrail anchorage, stair stringers, small platforms, etc.

8.2.6 Anchor bolts subject to uplift or vibration shall be equipped with an additional nut to serve as a lock nut, to ensure against loosening.

8.2.7 Minimum clear distance from anchor bolts or anchor bolt sleeves to edge of concrete shall be 100 mm. Metallic sleeves are not allowed and anchor bolts shall not be in contact with reinforcing steel.

8.2.8 Anchor bolts shall have 3 mm as a corrosion allowance in addition to the coating required by the Standard Drawing AB-036322.

8.2.9 Post-installed anchor bolts shall not be used for new construction without prior written approval. Approval Request shall be submitted through the Company or Buyer Representative for review and approval by the Chairman, Gas Turbines & Diesel Engines Standards Committee, Consulting Services Department. When approved for use, the post-installed bolts shall be designed per ACI 318, Appendix D and in strict compliance with the manufacturer's recommendations.

Revision Summary

31 August 2005 Major revision.

Appendix I – Definitions

For the purposes of this standard the following definitions apply. Other unidentified definitions shall be per API616.

Droop: A droop governor, or governor regulation, is one which biases its setpoint down as load increases. This speed bias makes the machine reluctant to increase load at a given governor setting which improves the ability of the unit to share load stably with other droop governor units. As the steady state speed varies with load (PP), the speed governor controls the speed of the power turbine within a prescribed range (droop)

Design Condition: The point at which normal operation is expected and optimum efficiency is desired. This point is usually the point at which the vendor certifies that the heat rate is within the tolerances stated in this standard. Parameters used to determine the normal operating point include speed, site conditions, emissions, and fuel composition.

Base Load: The Vendor's defined output load that the gas turbine is required to produce at site rated conditions while achieving an operating life of over 20 years and the OEM recommended Time Between Overhaul (TBO).

Isochronous: Isochronous operation maintains speed constant despite change in load level, to maintain the frequency of the generator output.

Island Mode Operation: When the gas turbine driven generator is operating alone disconnected from other power sources either due operability or the lack of other power sources.

Maximum continuous speed: The maximum speed (revolutions per minute) at which the manufacturer's design will permit continuous operation.

Minimum allowable speed: The lowest speed (revolutions per minute) at which the manufacturer's design will permit continuous operation.

Operating Range: The load and/or speed ranges that the unit is expected to be operated within, at the site expected conditions.

Overspeed limit: The maximum speed limit that the shaft are permitted to reach safely.

Peak Load: The power output when firing at a temperature above base load firing temperature as specified by the Manufacturer. Peak load operation capability is intended only for limited or emergency use.

Site Rated Power: The output shaft power developed by the gas turbine when it is operated at site rated: firing temperature, speed, inlet air temperature, minimum inlet pressure, auxiliary system losses including inlet and exhaust duct losses, exhaust pressure, and normal fuel

composition. (Net shaft horsepower (HP) for mechanical drive units, or net generator output in MW for power generation units).

Site Rated Firing Temperature: The turbine inlet total temperature, measured at a location immediately upstream of the first-stage turbine nozzles, required to meet site rated power conditions.

Wobbe Index: The Wobbe index is a gauge of the OEM allowable range of change in heating value. It is the ratio of the Lower Heating Value (LHV) of the fuel gas divided by the square root of the product of relative density (with respect to air at ISO conditions) and the absolute temperature, T, of the fuel gas:

$$W = \frac{LHV}{(G \times T)^{0.5}}$$ G is gas specific gravity