MODEL 501-KH

# Allison GAS TURBINES

# INDUSTRIAL GAS TURBINE ENGINE

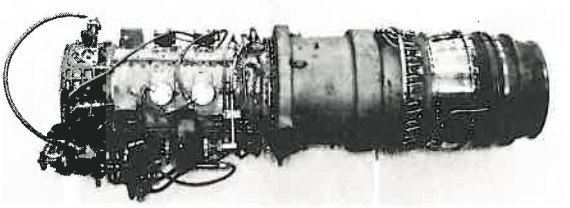
SPECIFICATION 935A

6 FEBRUARY 1989

# MODEL SPECIFICATION NO. 935A

1.0 APPLICABLE DRAWINGS

Installation 23038811



1.1 Overall Dimensions

| | |
|---|---|
| Length | 90.0 in. (2286 mm) |
| Height | 36.1 in. ( 917 mm) |
| Width | 32.2 in. ( 843 mm) |

1.2 Dry Weight

Basic Dry Weight 1270 lb. (576.1 kg)

2.0 DESCRIPTION The 501-KH engine is a single shaft gas turbine engine utilizing a 14-stage axial flow compressor; six combustion chambers within an annular combustor; a 4-stage turbine, of which the first stage is air cooled; and five main anti-friction pressure lubricated bearings. The compression ratio is approximately 9.3:1 at standard continuous rating conditions. Manifold flanges are provided on the outer combustion case for steam injection. The 501-KH engine is available in two configurations: (1) for operation with liquid fuel, (2) for operation with gaseous fuel. The specific fuel shall be reviewed by Allison prior to acceptance of the order. The fuel use shall be as specified in the purchase order.

3.0 PERFORMANCE

3.1 Ratings

3.1.1 Rating Conditions

| | |
|---|---|
| Ambient Temperature °F (°C) | 59 (15) |
| Ambient Pressure, S.L., psia (kPa) | 14.7 (101.4) |
| Engine Rotor Speed, rpm | 14,200 |
| Calculated Turbine Inlet Temp. (CTIT), °F (°C) | 1895 (1035) |

3.1.2 Rated Performance (see note 5.3)

| | NATURAL GAS[1] | LIQUID FUEL[1] |
|---|---|---|
| Power Output[2], hp (kW) | 5263 (3924) | 5106 (3807) |
| Specific Fuel Consumption, SFC[2], Btu/shp-hr (kJ/kW-hr) | 8876 (12558) | 9100 (12875) |

NOTES:

1. See section 3.3 for fuel definition and specifications.
2. Performance values are specified for new engine deliveries from Allison

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3.2 Estimated Performance Estimated performance is shown on Figures 1 through 27. Performance Characteristics are shown with no steam injection (dry), with 400°F (204°C) steam injection, and with 900°F (482°C) steam injection. The maximum allowable Calculated Turbine Inlet Temperature (CTIT) with steam injection is 1800°F (982°C). An IBM PC compatible performance program is available from Allison to calculate estimated performance at site specific conditions. The PC performance program output values for SFC do not include the production margin.

| | | |
|---|---|---|
| OPERATING LIMITS: | | |
| SHP vs TAMB | Figure No. 1 | |
| MAXIMUM COMPRESSOR DISCHARGE PRESSURE: | | |
| PS3 vs RPM | Figure No. 2 | |
| PERFORMANCE CHARACTERISTICS: | GASEOUS FUEL | LIQUID FUEL |
| SHP vs RPM (dry) | Figure No. 3 | Figure No. 15 |
| SHP vs RPM (steam injection) | Figure No. 4 | Figure No. 16 |
| WF vs RPM (dry) | Figure No. 5 | Figure No. 17 |
| WF vs RPM (steam injection) | Figure No. 6 | Figure No. 18 |
| WA vs RPM (dry) | Figure No. 7 | Figure No. 19 |
| WA vs RPM (steam injection) | Figure No. 8 | Figure No. 20 |
| W7 vs RPM (dry) | Figure No. 9 | Figure No. 21 |
| W7 vs RPM (steam injection) | Figure No. 10 | Figure No. 22 |
| TT7 vs RPM (dry) | Figure No. 11 | Figure No. 23 |
| TT7 vs RPM (steam injection) | Figure No. 12 | Figure No. 24 |
| PS3 vs RPM (dry) | Figure No. 13 | Figure No. 25 |
| PS3 vs RPM (steam injection) | Figure No. 14 | Figure No. 26 |
| STARTING CHARACTERISTICS: | | |
| TORQUE vs RPM | Figure No. 27 | |

3.2.1 Estimated Performance Conditions with Steam Injection

| | |
|---|---|
| Ambient Temperature °F (°C) | 59 (15) |
| Ambient Pressure, S.L., psia (kPa) | 14.7 (101.4) |
| Engine Rotor Speed, rpm | 14,200 |
| Calculated Turbine Inlet Temp. (CTIT), °F (°C) | 1800 (982) |
| Steam Flow lbs/sec (kg/sec) | 5.5 (2.50) |

3.2.2 Estimated Performance with Steam Injection of 5.5 lbs/sec (2.50 kg/sec) at 900°F (482°C)

| | NATURAL GAS | LIQUID FUEL |
|---|---|---|
| Power Output , hp (kW) | 7966 (5940) | 7855 (5857) |
| Specific Fuel Consumption, SFC , Btu/shp-hr (kJ/kW-hr) | 6447 (9121) | 6456 (9134) |

3.2.3 Estimated Performance with Steam Injection of 5.5 lbs/sec (2.50 kg/sec) at 400°F (204°C)

| | NATURAL GAS | LIQUID FUEL |
|---|---|---|
| Power Output , hp (kW) | 8002 (5967) | 7873 (5870) |
| Specific Fuel Consumption, SFC , Btu/shp-hr (kJ/kW-hr) | 7018 (9929) | 7041 (9962) |

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3.3 Fuel (see also section 4.1 for additional requirements)

LIQUID FUEL: MIL-T-5624H, Grades JP-4 and JP-5
Allison EMS 64H and EMS66B
ASTM-D-1655-75T Jet A, A-1, and B
ASTM-D-2880 No. 1 GT
MIL-F-16884
Other fuels may be used with prior approval of Allison (see Installation Design Manual)

Required Inlet Conditions:

Pressure:
- o Not less than zero (0) psig (kPag)
- o 50 psig (345 kPag) max

Temperature:
- o Maximum: +130°F (54.4°C)
- o The fuel cloud, pour and freeze points shall be at least 10°F (5.5°C) lower than lowest ambient air and fuel inlet temperatures.

The fuel viscosity at the engine fuel shut off valve shall be not more than 10 centistokes at the lowest ambient air or fuel inlet temperature.

NATURAL GAS: Natural Gas with nominal heat content of 904 BTU/SCF LHV (35503 kJ/$m^3$), 0.6 specific gravity (Sp. Gr.) and Wobbe Index values of 1170 $\pm$ 130 BTU/SCF, (LHV/$\sqrt{\text{Sp. Gr.}}$) (45949 $\pm$ 5105 kJ/$m^3$, (LHV/$\sqrt{\text{Sp. Gr.}}$)). Inlet pressure at fuel valve 250 $\pm$ 5 psig (1724 $\pm$ 35 kPag). Engine will operate with a range of fuel heat content values - Wobbe Index values from 760 to 1575 based on BTU/SCF (29847-61855 based on kJ/$m^3$) with adjustment of the fuel control system and inlet pressure.

Sulfur content shall not exceed 0.55 lb/$10^6$ BTU (236 mg/MJ) or 22 lb/hr (10 kg/hr), whichever is less.

3.4 Oil Allison EMS-35J, EMS-45, EMS-53, or MIL-L-23699B Synthetic Oil. Allison EMS-38 Mineral Oil may be approved for limited use on special request. Also, see Para. 4.2.

Average Oil Consumption - 1/3 gallon (1.26 liter) per day

3.5 Estimated Sound Power Levels - Unsilenced

| Octave Band Center Frequency, Hertz | | | | | | | |
|---|---|---|---|---|---|---|---|
| 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
| Inlet Sound Power, db, re $10^{-12}$ Watts | | | | | | | |
| 110 | 113 | 116 | 119 | 121 | 124 | 124 | 133 |
| Exhaust Sound Power, db, re $10^{-12}$ Watts | | | | | | | |
| 130 | 134 | 135 | 135 | 132 | 130 | 127 | 124 |
| Case Sound Power, db, re $10^{-12}$ Watts | | | | | | | |
| 98 | 102 | 106 | 110 | 112 | 112 | 112 | 111 |

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3.6 Altitude-Temperature Limits for Starting and Operating

Altitude - Sea Level to 10,000 ft (3048 m)
Ambient Temp. - -40°F (-40°C) to +120°F (48.9°C)

3.7 Rotor Speed Operating Range

13800 to 14600 rpm

3.8 Gas Temperature Operating Limits, Calculated TIT (see Note 5.3)

| | |
|---|---|
| Continuous, dry operation | 1895°F (1035°C) |
| Continuous, with steam injection | 1800°F (982°C) |

3.9 Output Shaft Torque Limit

37,700 lb-in. (4260 Nm)

3.10 Shaft Horsepower Operating Limit Engine operation with steam injection shall not exceed the shaft horsepower limits specified on Figure No. 1. Line segment (1) on this figure is a torque limit and is not correctable to inlet pressure conditions. Line segments (2) and (3) are correctable to inlet pressure conditions.

3.11 Compressor Discharge Pressure Operating Limit Engine operation with steam shall not exceed the compressor discharge pressure limits specified on Figure No. 2.

3.12 Steam Flow Operating Limit The maximum steam flow permitted to be injected into the engine shall be 5.5 lb/sec (2.5 kg/sec) provided that engine compressor discharge limits shown on Figure No. 2 are not exceeded.

3.13 Steam Quality Steam shall be dry and unsaturated. Steam shall be free of solid, liquid and gaseous contaminants to the extent that a representative sample of steam and carry over contaminants when collected, condensed and cooled would pass the water quality requirements of Allison EMS 124 and/or EMS 120D Type III water for continuous water injection.

Boiler water carryover shall not be permitted and may result in a substantial decrease in engine life.

3.14 Exhaust Emissions Based on factory tests, this engine when operating on specified liquid fuels, or on U.S. pipeline quality natural gas, is expected to meet Environmental Protection Agency Emissions Standards for New Stationary Gas Turbine Engines. (Ref. 40CFR60, Subpart G-G)

Local environmental regulations may require more stringent control of exhaust emissions than those specified by the U.S. EPA. See water injection option for control of $NO_x$ emissions.

Exhaust emissions and exhaust gas constituents for particular installation conditions will be established upon request.

3.15 Inlet Air Quality Based upon in house testing and operational experience inlet air quality has a direct effect upon the engine. It affects engine performance, compressor and turbine life, and the emission signature of the engine. For operational limits refer to the Installation Design Manual and contact Allison for advice.

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## 4.0 ENGINE SYSTEMS

### 4.1 Fuel System

LIQUID FUEL

Contamination Limit

- 8 grams/1000 gal (0.03 g/l) Solid Particles (Maximum)
- Particulate contamination must be no greater than that passed through a no bypass type filter which removes 95% of particles 10 microns or larger.

Biocide Treat

- 0.05% (by volume) max free water
- 200 PPM Max Total (20 PPM Max as Boron)

Trace Metal

- See Installation Design Manual for limits

NATURAL GAS

Contamination Limit

Free of liquid hydrocarbon droplets (including lube oil contamination from the gas compressor) 8 microns or larger, free of all solid particles 3 microns or larger, and free of ice forming moisture. See the Installation Design Manual for the complete definition of requirements.

Temperature Limits

At least 10°F (5°C) greater than the dew point or freeze point, whichever is warmer.

Supply temperatures greater than 130°F (55°C) require Allison approval and special hardware. Fuel metering valve electronics must not exceed 160°F (71°C).

### 4.2 Lubrication System - Dry Sump

External oil supply required.

| | | |
|---|---|---|
| Inlet Pressure: | | o 0 to 20 psig (138 kPag), operating<br>o 0 to 5 psig (34.5 kPag), non-operating |
| Inlet Temp., | max: | o 180°F (82°C) |
| | min: | o -25°F (-32°C) (EMS-35J)<br>o -40°F (-40°C) (MIL-L-23699 or EMS-53)<br>o +25°F (-4°C) (EMS-38) |
| Filtration: | | o 25 micron filter which removes 95% of particles 25 microns or larger. |
| Flow: | | o 4 to 6 gal/min. (15 to 23 l/min.) |
| Aeration: | | o 10 percent by volume, max. |
| Scavenge Back Pressure: | | o 30 psig (207 kPag), max. |
| Heat Rejection: | | o 1200 BTU/min (21101 W) max. at 180°F (82°C) Oil Inlet |
| Engine System Pressure: | | o 55 ± 5 psig (380 ± 34 kPag) |

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4.3 Engine Control System The engine is supplied with an electronic system that provides:

- o Start logic and sequencing
- o Fuel flow control during starting
- o Fuel metering for speed governing and turbine temperature limiting
- o Monitoring of engine speed and turbine temperature
- o Automatic shutdown and malfunction indication

4.4 Temperature Measurement System The temperature measurement system consists of 12 thermocouples, located at the turbine outlet, and an electronic control. Engine operator response is to a turbine inlet temperature (TIT) calculated by a portion of the electronic fuel control. Output voltage supplied as shown on the installation drawing for use with the customer indicator.

4.5 Ignition System The ignition system consists of an ignition exciter and two igniter plugs. Electrical requirements are shown on the installation drawing.

4.6 Starting System Starter and Starter drive pad not included. Starting torque required is shown on Figure 27.

5.0 NOTES

5.1 Acceptance Test Each engine shall be subject to an acceptance test. The test procedure, schedule, duration and performance determination method shall conform to Allison established commercial practice. The engine will be tested on a dry basis only (no steam injection).

5.2 The performance ratings and estimated performance curves shown are based on the standard conditions specified, without inlet duct or exhaust losses, with no loading of accessory drives, no air being bled from the compressor air bleeds, 14,200 rpm and with a 700 sq. in. (0.45 sq. m) exit area exhaust diffuser as shown on the installation drawing with no air gap between diffuser and engine.

5.3 The engine will produce, at a minimum, the rated power listed in paragraph 3.1.2 at a SFC no greater than that specified.

5.4 Any installation of the 501-KH engine shall be in accordance with the 501-KH Installation Design Manual and shall be subject to review by Allison.

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501-KH OPTIONS

See the Installation Design Manual and Installation Drawing for detail information regarding the available options.

DUAL FUEL SYSTEM OPTION

Engine fitted with fuel and power control components for operating with either liquid or gaseous fuel. Fuel switchovers can be made with the engine at any power level up to and including standard continuous power. Switchovers at power can be made in 14 seconds or less.

$NO_x$ EMISSION REDUCTION OPTION

A system is available to permit the introduction of water or other diluent into the engine for $NO_x$ reduction.