

Technical Scope

The following describes the complete steam turbine generator system.

Turbine-Generator

The system will consist of a moisture separator, steam turbine, speed reducing gear and generator mounted on a common steel base and a complete generator protection and automatic control system, with a 480 V generator breaker. The control system will be in a separate control panel enclosure.

DESIGN CHARACTERISTICS	
Steam supply pressure	615 psia
Steam supply temperature	740°F
Steam exhaust pressure	130 psia
Steam flow rate	60,000 lbs/hr
Generator type	Synchronous
Electric power output	1,485 kWe
Power factor	0.80 lagging
Voltage	480 V

This packaged turbine-generator will be comprised of the components listed below.

Steam Turbine

Steam pressure drop from 615 psia / 740°F to 130 psia will be converted into mechanical power via a steam turbine with the performance characteristics identified below.

	DESIGN
Turbine Inlet Pressure	615 psia ¹
Turbine Inlet Temperature	740°F
Turbine Exhaust Pressure	130 psia
Turbine Exhaust Temperature	510°F
Steam Flow	60,000 lbs/hr
Turbine Output at Rated Flow	1,590 kW _s
Turbine Speed	5,485 RPM

This turbine will be capable of operating at the transient conditions specified in the Black & Veatch specification for this project (up to 165 psia exhaust pressure and up to 750°F inlet temperature). However, power output will necessarily vary as operating conditions deviate from the rated conditions.

¹ Note that actual turbine inlet steam will be 612 psia at rated conditions due to the pressure drop across the separator. Turbine power shaft power output will be 1,588 kW_s at this lower inlet pressure. Power output at the generator terminals will be 1,485 kWe as shown in the previous table.

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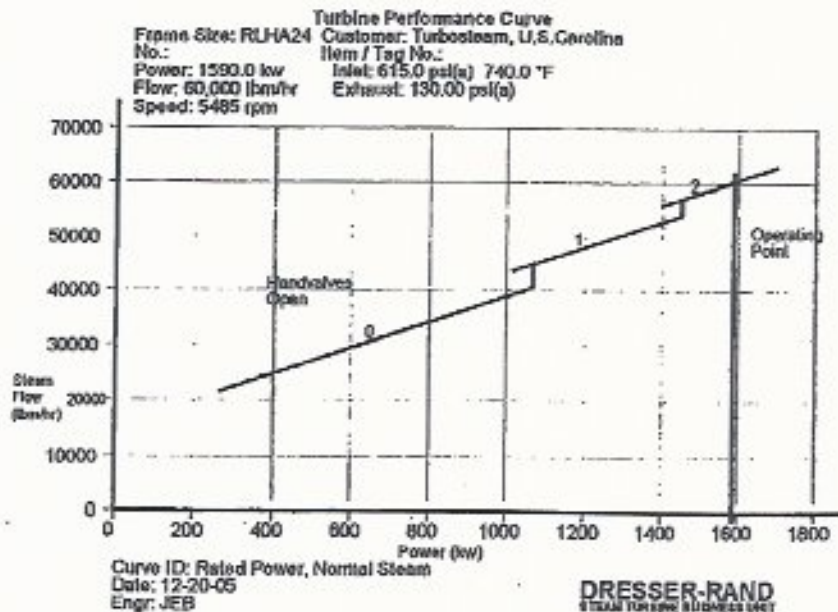
To satisfy these conditions we have selected a Dresser Rand RLHA 24 horizontally split, single-stage, single-valve, axial flow, backpressure unit with a 6-inch inlet connection, and a 10-inch exhaust connection. The turbine includes the following features:

1. Two journal sleeve bearings
2. Carbon ring type seals
3. Trip and throttle valve with internal steam strainer
4. Pneumatic governor valve actuator
5. High exhaust pressure construction
6. Blanket lagging
7. Manual handvalves for part load efficiency
8. Resistance temperature detection (RTDs) in each bearing for alarm and trip

The turbine presented above is designed precisely for the steam conditions presented in the bid specification. The steam flow that the turbine is designed for represents the best match with regards to nozzle configuration and the turbine described above.

Testing and inspection for the turbine will be carried out at the manufacturer's shop in Millbury, Massachusetts in accordance with NEMA Standard SM-24.

Figure One: Turbine Performance Curve



Synchronous Generator

The turbine will drive a synchronous generator with the following design characteristics:

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Generator Mfg.	Marathon
Rating:	1,490 kWe
Temperature rise by resistance:	105° C at 40° C Ambient
Bearings:	Ball, with grease lubrication
Insulation:	NEMA Class F
Full load efficiency:	95 % @ 1,490 kW
Power factor:	0.80 lagging
Voltage/Phase/Frequency:	480 Volts / 3 phase / 60Hz
RPM:	1,800 RPM

Resistance temperature detectors (two per phase, one per bearing) will be provided for temperature monitoring, alarm and trip via the control system. This generator will have a brushless exciter and a solid-state voltage regulator, which will automatically control voltage, reactive power or power factor. Space heaters will be provided to prevent moisture absorption by the generator windings. VPI insulation has also been included. The generator has an open drip proof (ODP) enclosure with an air inlet containing washable filters that will capture particulates between 20 and 50 microns. A differential pressure switch will activate a warning indicating when the filters need to be washed. We have chosen this enclosure due to the cost associated with requesting a WPII enclosure in this smaller size range.

Speed Reducing Gear

A Lufkin single reduction parallel shaft speed reduction gear will be used to transmit 1,590 kW shaft power with a 1.3 AGMA service factor (minimum) from a turbine speed of 5,485 RPM to a generator speed of 1,800 RPM. This unit will have split sleeve babbitt lined bearings on the high-speed shaft and anti-friction type roller bearings on the low speed shaft. Resistance temperature detectors will be included on each drive bearing for temperature monitoring, alarm and trip via the control system. The speed reducing gear will have its own integral forced oil lubrication system that will also provide lube oil to the turbine bearings.

Moisture Separator

Although the superheated steam provided to the turbine inlet should not contain any entrained moisture, we include a steam separator to prevent occasional water slugs from damaging the turbine. The separator will be a Circle S Dry-Flo (or equivalent), and is to be installed in the steam piping upstream of the turbine inlet. It will cause a pressure drop prior to the turbine-inlet of 3 psi @ 63,000 lbs/hr flow.

Turbine Generator Skid

A common steel base will be provided for the turbine, speed reducing gear and generator. The turbine and gear will be coupled by a Lovejoy flexible disc spacer type coupling, which will be dynamically balanced to a maximum of AGMA 10. The generator and gear will be coupled with a Lovejoy gear-type coupling with a 1.5 service factor. Coupling guards will be provided.

The turbine, speed reducing gear and all skid-mounted accessories, piping and wiring will be assembled on the base at Turbosteam's shop.

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Skid piping will include all piping necessary to collect condensate drains, steam leak offs and instrument air to single field connection points. Manual globe valves will be installed in condensate drain lines for startup condensate removal.

Skid wiring will include all conductors and conduit necessary to consolidate terminations for all skid instrumentation and control devices in a common terminal box.

An on-skid air-cooling system will be provided to maintain proper lubrication oil temperature for the turbine and gear.

480 V Generator Circuit Breaker

An electrically-operated insulated case circuit breaker will be provided complete with voltage and current transformers for metering, synchronizing and protective relaying. The circuit breaker will be draw-out type, rated for 480 V, 60 Hz., 3,000 A, 65 kA interrupting capacity and will be housed in a free-standing indoor enclosure.

Turbine Generator Control System

The turbine generator protection and control system is summarized below. A more complete description, including operator actions required to start, synchronize, operate and shut down the system is included in Appendix 3.

The turbine generator protection and control system will provide automatic system startup, synchronizing, operation and controlled shutdown.

Alarms and automatic tripping will occur for abnormal conditions. These will be listed on the operator interface until cleared and acknowledged. First out indication will be provided. Appendix 3 includes a complete list of alarms and trips.

The turbine generator protection and control system will include the following components mounted in a NEMA 12 enclosure:

1. A programmable logic controller (PLC)
2. An operator interface terminal (OIT) with color touch screen
3. Communications for interfacing with the existing plant DCS
4. A Stacktach dual channel tachometer with independent overspeed trips
5. A GE Multilin Generator Protective Relay for generator protection, monitoring and metering
6. A voltage regulator with automatic VAR/power factor control
7. Automatic synchronizing devices consisting of:
 - a. Synchronization enable switch
 - b. Voltage and frequency meters for the bus and generator voltages
 - c. Synchroscope and synchronizing lights
 - d. Synchronism check relay

The full complement of synchronizing devices is provided even though synchronizing is automatic. Communication via Modbus or Data Highway is available to allow connection for complete remote monitoring of all turbine generator performance metrics.

Temperature Monitoring System

The temperature monitoring system is designed to protect critical components and alert the operator in the event of a malfunction. A pre-trip warning alarm level and a system trip level are set for each monitored point. The system includes monitoring and display for the following points:

- Turbine and Generator Journal Bearings (1 RTD per bearing)
- Speed Reduction Gear Bearings (1 RTD per drive bearing)
- Generator Stator (1 RTD per phase, 1 spare per phase)
- Generator Bearings (1 RTD per bearing)

Utilities Required

Control Air

80-150 Psig, 30 SCFM maximum (short duration), clean, dry, filtered to 5 microns

Electric Power (circuit capacities listed – demand is less)

1. Generator space heater – 15 A at 120 V single phase
2. Control and protection system – 15 A at 120 V single phase
3. Control panel convenience receptacles and interior light – 15 A at 120 V single phase
4. Lube oil cooling fan – 15 A at 240 V single phase

Lubrication Oil

30 Gallons VG32 light turbine oil required by the gear lubrication system