TURBINE GENERATOR AND AUXILIARIES

The turbine generator unit as supplied by the Westinghouse Electric Corporation is a two cylinder tandem compound condensing reheat turbine. At rated speed of 3600 rpm the unit is designed for 60,000 kw, 0.80 power factory, 75,000 kw maximum rating, when supplied with steam at 1450 psi gauge throttle pressure, 1000 Degrees F total temperature with reheat at 1000 Degrees F total temperature and 1.0" Hg absolute exhaust pressure.

Entering steam first passes through two hydraulically operated combination trip and throttle valves with integral steam strainers to multiple steam control valves in the two separately mounted steam chests.

Leaving the H.P. turbine, steam passes through the reheater, interceptor valves, I.P. and L.P. turbine to condenser.

The hydraulic control system is operated by pressure developed by the main oil pump mounted on the turbine shaft. Should the oil pressure drop to a predetermined value it is re-established automatically by a turbine driven auxiliary oil pump. This auxiliary pump furnishes oil pressure in starting until the turbine is up to speed and also in stopping the unit.

An emergency governor, independent of the main governor, is furnished to trip the turbine in the event of overspeeding. It may also be tripped by hand if desired.

A motor driven rotor turning device and motor driven oil pump are provided for slowly rotating the turbine rotor when the unit is being taken out of service or being started. Its purpose is to allow uniform heating or cooling of the rotor to minimize distortion.

A complete self-contained lubricating oil system is furnished. It consists of an oil reservoir of 3000 gallons capacity with strainer, the oil pumps previously mentioned, two oil coolers, necessary valves, gauges, thermometer and low oil pressure emergency protection devices.

The dimensions of the reservoir are 12'-0" x 7'-0" x 5'-6" high and one inch difference on oil level represents 52.5 gallons of oil. The operating capacity of the reservoir is 2,310 gallons. When shut down an additional 616 gallons are returned to it; 388 gallons do not return and the generator seal oil system contains 300 gallons. Thus the total charge of the turbine generator oil system is 3,614 gallons.

Gulfcrest "A" turbine lubricating oil furnished by the Gulf Oil Corp. was used in the turbine oil system.

The generator is direct connected to the turbine and is arranged for Hydrogen cooling from .5 to 30 psi gauge pressure.

Both main and pilot exciters are also direct connected to the main shaft. They are totally enclosed and self ventilated taking filtered air from the basement through a duct and discharging below the turbine room floor.

The turbine is designed for a steam pressure supplied to the throttle of 1520 psi gauge. However if, in an emergency, the throttle or admission valves are suddenly closed the permissible momentary pressure is 1740 psi gauge.

The temperature at the throttle valve shall not exceed 1000 Degrees F average, and shall not exceed 1015 Degrees F in maintaining this average except during infrequent abnormal operating conditions with maximum temperatures not in excess of:

1015 to 1025 Deg. F	5% of operating time
1025 to 1050 Deg. F	Swings of 15 minutes or less aggregating not more than 1% of operating time.

The unit will have sufficient turbine capacity to carry 75,000 kw when operating under steam conditions of 1450 psi gauge, 1000 Degrees F total temperature with reheat to 1000 Degrees F total temperature and condensing to 2-1/2" Hg absolute.

The unit is covered by Westinghouse Electric Company Contract No. G.D. BG 78800-TP with serial numbers and ratings as follows:

Turbine No. H.P. 5-A7080-1, LP 5A-7081-1, 60,000 kw, 3600 rpm, 36 stages
Generator No. 1-S-36-P-725, 75,000 Kva, 3600 rpm, 13,800 volts, 0.5 psig H2 press.
Main Exciter 225 kw, 3600 rpm, 250 volts
Pilot Exciter 2.5 kw, 3600 rpm, 250 volts

The approximate weights of the unit are as follows:

H.P.-O.P. Turbine Cylinder Cover	35,000 pounds
L.P. Turbine Cylinder Cover	30,000 pounds
L.P. Turbine Blade Ring (Upper Half)	34,000 pounds
H.P.-I.P. Turbine Rotor	25,000 pounds
L.P. Turbine Rotor	29,000 pounds
Generator Rotor	60,300 pounds
Generator Stator	242,450 pounds
Turbine exhaust chamber	76,000 pounds

Turbine

The turbine is designed with 36 stages and is the combination impulse-reaction type. It consists of a single flow high pressure, intermediate pressure element and a double flow low pressure element. These elements are enclosed in separate cylinders. The outer casing of the H.P.-I.P. casing is a chrome molybdenum steel casting. The low pressure casing is cast iron.

Both casings are split on the horizontal centerline to form bases and covers, with the nozzle chest cast integral with the high pressure cover.

The two cylinders are supported in such a manner as to allow axial and vertical movement due to expansion but not transverse movement. They are joined together by a member rigid axially and transversely but flexible in the vertical direction. Movement is so guided that proper alignment of unit is caused all conditions of operation.

Turbine Rotor

The two cylinder rotors are made from solid alloy steel forgings and are joined together by a solid coupling. A solid coupling also joins the L.P. cyl. rotor to the generator rotor. Each rotor is carried by two main bearings. A separate stub shaft bolted to the outer end of the high pressure turbine rotor, carries the thrust bearing collar, oil impellers, and the overspeed trip body.

Blading

The impulse element consists of two rows of rotating blades and a single row of stationary blades. The rotating blades are pinned to the rotor. The stationary blades are secured in their retaining ring by a "T-root" type of fastening. The blades are shaped to form their own shrouds.

The rotating blades are secured to the rotor by T-shaped grooves and the stationary blades are held in straight sided grooves by a series of short keys. The shrouding is riveted to the blade ends. Close radial clearance with the shrouding is obtained by use of thin seal strips mounted in the casing or rotor.

In the low pressure turbine the last stage rotating blades are mounted on the rotor discs by the "side entry" (Buttress thread) type of fastening. The rotor discs are shrunk on and keyed to the main body of the rotor. The row of blades preceding the last stage at each end of the L.P. turbine is attached by the "straddle double T-root" type of fastening. The stationary blades in the last two stages are made without roots. Blades are grouped and a base on to each group. These base sections are held in the cylinder groove by a "T-root" fastening.

The low pressure stage blades are protected against entrained moisture erosion by renewable stellite strips silver soldered to each blade. The entrained moisture is also removed from blading by being thrown, due to centrifugal force, into removal troughs in casing surrounding blading, and drained away.

Main Bearings

The turbine main bearings are of the self aligning, spherical-seated pressure lubricated type. The shells are of cast steel, split horizontally, and lined with high grade tin base babbitt. Seal strips at each end of bearing prevent escape of oil vapor along shaft. Oil drain holes are provided to drain oil away.

Thrust Bearing

A Kingsbury type thrust bearing is used to absorb any unbalanced axial forces acting on the rotor and maintain the correct axial position of rotor in relation to the stationary parts of the turbine.

Leveling blocks divide the load equally among the several segments of the bearing surface. These segments, being free to tilt, allow a wedge-shaped film of oil to form between them and the revolving thrust collar. The bearing is lubricated by forced circulation of oil through it.

Throttle Valve

Two oil operated throttle valves are provided with removable steam strainers. These valves cannot be opened until oil pressure is established in the lubrication system and then only if handwheels are in the open position. The valves automatically close of the oil pressure is released or when the overspeed trip mechanism functions.

Steam Chests

A steam chest is mounted on each side of the high pressure turbine. Each chest contains three single seated plug type valves each of which feeds a certain nozzle bank to the first stage. Each valve is positioned by its servo-motor.

Governor

The speed of the unit is normally controlled by the main constant speed governor. The governor is actuated hydraulically. The governing oil pump receives a limited amount of oil from the main oil pump. This governing pump, mounted on the turbine shaft maintains a pressure which varies as the square of the speed, thus giving a positive governing medium. A pressure transformer magnifies the relatively small pressure changes produced by the governing pump into larger and exactly proportioned pressure changes. The latter actuate the servo-motor relay which controls the position of the servo-motor piston. The governor is equipped with hand and motor operated speed changers.

If the turbine speed at full load increases to approximately 3630 rpm the secondary governor or pre-emergency governor takes control of the servo-motors. This governor operates similarly to the main governor. It is provided with a hand speed changer. If the turbine speed rises an additional 2%, control oil pressure will rise and close the governing valve completely. When speed drops to below 3630 rpm the main governor automatically re-assumes control.

Emergency Overspeed Trip

The emergency trip is entirely separate from and independent of the main governor. When the overspeed point, about 10% above normal, is reached, the centrifugal force of the trip body overcames its opposing compression spring and trips the oil release valve. This removes the oil pressure holding the throttle valves open and they instantly close.

Simultaneously high pressure oil is admitted to the governor servo-motors thus closing the steam chest governing valves. Also with the emergency trip operating, the interceptor valve will close. The valves may also be tripped by hand. Once tripped, the trip must be set by hand after speed has been reduced to slightly above normal speed or lower.

Throttle Pressure Regulator

Inlet steam pressure is prevented from dropping below desired limit by the throttle pressure regulator. Here control oil pressure changes resulting from steam pressure changes actuate the governor servo-motors. The steam chest valves thus close on decreasing steam pressure limiting steam flow the amount necessary to maintain the desired minimum steam inlet pressure.

Steam Flow Limit Control Valves

High pressure oil is reduced to an adjusted pressure in this valve. It is admitted through a ball check valve to the secondary governing system. In the latter system a decrease in control oil pressure opens the steam inlet valves. When this pressure decreases to allow maximum steam to the turbine, the limit control valve oil passes the check and takes control of the governing valves to prevent further opening.

Low Vacuum Tripping

In the event of turbine exhaust dropping to too low vacuum will be shut down by the low vacuum trip. Here a bellows with exhaust pressure on it is spring balanced. Decreasing vacuum operates a plunger which hydraulically causes the overspeed trip valve to close the throttle valves. A solenoid, remotely energized, may operate the plunger to stop the machine. A Mercoid pressure switch gives an alarm on the turbine board showing that the over speed trip valve has opened due to low vacuum.

Interceptor Valves

The two interceptor valves are normally open, passing steam from the reheater to the I.P. turbine. When the turbine speed is increased to 3700 rpm the auxiliary governor control oil pressure operates the interceptor control valve to partially close the interceptor valve to hold speed at 3700 rpm. At further increase in speed, the control oil will cause the interceptor valve to quickly close. Handwheels are provided for manual operation.

Interceptor Bypass Valve

This valve can be manually opened to bypass steam from the high pressure turbin to the intermediate turbine to prevent overheating of the exhaust end of the turbine. It is normally closed. If open and the emergency overspeed trip operates, a Mercoid switch on the latter's linkage energizes a solenoid mounted on the bypass valve to close it.

Diaphragm Leakage Dump Valve

The inlet of this valve is connected to the labyrinth seals leak-off chamber in the diaphragm between the high pressure turbine exhaust and intermediate pressure turbine inlet. The valve is normally closed. When the interceptor valve colses, it opens the dump valve by air, bleeding the labyrinth seal leak-off to the condenser.

Low Oil Pressure Trip

This trip will shut down the turbine on loss of pressure in the high pressure oil or bearing oil pressure system. An abnormal decrease of either pressure will operate the over-speed trip vlave to close the throttle and governing valves.

Rotor Position Meter

This meter show the relative axial position of the thrust runner with respect to the thrust bearing support. Excessive movement of the rotor will cause an alarm to be sounded on the turbine board.

Turbine Shaft Vibration Meter

The shaft vibration measuring equipment records the amplitude of vibrations at various points along the turbine shaft near the bearings thus serving as a warning for such unusual operating conditions as would cause changes in the vibration amplitude.

Oil System

Oil pressure for the hydraulic control system is furnished by the turbine drive auxiliary oil pump is starting, and by the main oil pump when the unit approaches normal speed. The main oil pump is a centrifugal pump impeller mounted on the turbine shaft. It has pressure on the suction of 10 to 30 psig and discharges at from 120 to 150 psig at normal operating speed. A portion of the oil from the pumps is reduced in pressure to 10-12 lbs by a fixed orifice and flows through the oil cooler and to the bearings. Another portion goes to an ejector where it is discharged along with additional oil from the oil reservoir to the oil pump inlets, thus keeping a positive head on their suctions.

The oil reservoir has a 3000 gallon capacity and is vented to prevent accumulation of oil vapors.

Two Westinghouse oil coolers are furnished and are interconnected by a three-way valve. They are designed for 400 gpm cooling water at 95 Degrees F temperature and 2 lb pressure drop with maximum water pressure of 125 psig.

A pressure switch in the bearing oil line gives an alarm at the turbine board in the event of low bearing oil pressure. A float switch in the oil tank also gives an alarm at the turbine board for high or low oil level.

Thermocouples are installed for recording at the turbine board oil temperatures at all bearings and the oil coolers with an alarm provided to signal excessive temperatures at any point.

Turning Gear Oil Pump

A motor driven pump supplies lubricating oil pressure when the turning gear is in use. Also it is automatically started by a pressure actuated switch if the turbine driven auxiliary oil pump fails to maintain the required bearing oil pressure. However, it will only supply sufficient oil for shutting down the unit. The switch controlling the pump is normally in "auto" position where the pump starts at oil pressure drop to 35 psig. The pump will not stop automatically on increased pressure. The control switch must be returned to "off" position to stop the pump and then to "auto" to allow the pump to start under control of pressure switch.

Motor Driven Rotor Turning Gear

This rotor turning device consists of a high speed and low speed motor and suitable gear train and is used to rotate the unit during periods of temperature changes in starting or stopping the turbine generator. A pinion engages with a gear machined in the turbine generator coupling spacer ring and disengages when steam is admitted to turbine and its speed becomes greater than that of the turning gear.

The low speed turning gear motor will rotate the unit at 4 rpm for start-up and shutdown. The high speed turning gear will rotate the unit at 29 rpm.

The turning gear cannot operate until the bearing oil pressure has been established. In addition to bearing oil pressure being established the low speed turning gear motor must be running before the high speed motor can be started.

Seals

To prevent escape of oil along the shaft from the bearing housings a series of seals are installed in a split ring which is bolted to the bearing housing. These flat thin labyrinth seal strips fit the shaft with a very close clearance and are held in position by soft steel caulking rings. Oil wiped off the shaft by these seals drains back to the bearing housing.

Axial and radial seal strips are used to reduce interstage steam leakage to a minimum. The radial strips are mounted in the cylinder and the rotor and the axial strips in the cylinder. All are accurately machined to maintain uniform clearances. They are held in place by soft steel caulking strips and are removable for replacement.

At the inlet end of the high pressure turbine the balance seals are the same as installed to prevent interstage leakage. The inner gland seal rings are segmented and carried in a gland ring and held against the rotor by strap springs. The seal strips and their rotor lands have a close running clearance and are staggered in height to give a zig-zag path for the steam leakage resulting in an effective seal.

The seal rings in the diaphragm separating the high pressure turbine exhaust and intermediate pressure turbine inlet are segmented spring backed, and have "T" roots fitting in the diaphragm. The sealing edges are accurately machined to form a close running fit with rotor lands again staggered in height to necessitate a zig-zag path for the steam.

Water Glands

Water glands are installed where the turbine rotor passes through the casing. The seal is essentially an impeller pump pumping water at a pressure greater than the pressure against which the gland is sealing. The impeller is mounted on the rotor and has labyrinth seals to minimize water leakage. The water flow is throttled to pass just enough to prevent vaporizing.

Lagging

The turbine parts enclosing high temperature steam are insulated with non-conducting material and where exposed above the floor line are protected by sheet metal jackets.

Performance

Based on receiving steam at 1450 psig and 1000 Degress F total temperature reheating to 1000 Degrees F total temperature and exhausting at 29" hg vacuum and with full steam extraction for feedwater heating, the unit is guaranteed to generate 75,000 kw at unity power factor with a steam flow to throttle of 511,500 lb per hour or 6.82 lbs of steam per Kilowatt hour.

Expected steam rates at partial loads are shown on Curve H-2261 and correction factors for pressure or temperature other than above are shown on Curves H-2262, H-2263, and H-2264.

Generator

The base rating of the generator is 60,000 kw with 0.5 psig hydrogen, 80% power factor, 75,000 kva, 13,800 volts, wye connected, 3 phase, 60 cycle, 0.90 short circuit ratio, 3600 rpm, with class B insulation. The generator is totally enclosed and is cooled by hydrogen which is circulated by blowers mounted on the generator rotor. The hydrogen cooler is a two-section closed circulation type mounted in the generator casing. The cooling system is designed for up to 30 psig operating pressure.

Based on continuous operation at rated load, voltage and frequency the following results will be obtained in accordance with ASA Standards:

Maximum temperature rise	Deg. F (and means of temp. measurement)
Armature	60 (detector)
Field	85 (resistance)
Collector Rings	85 (thermometer)

The generator capacity of 13,800 volts, 60 cycles will be:

Hydrogen Pressure psig	Load Kw	Power Factor	Kva	Excitation amps	Excitation volts
0.5	60,000	0.80	75,000	800	194
15.0	69,000	0.80	86,250	880	213
30.0	75,000	0.80	93,750	920	223

The calculated reactances based on 75,000 kva and 13,800 volts are as follows:

Synchronous Reactance	124%
Transient Reactions	14.5%
Subtransient Reactance	9.3%
Negative Sequence Reactance	9.3%
Zero Sequence Reactance	6.0%

Provisions are made for synchronous condenser operation of the generator. Capacities as such are 60,000 kva at 13,800 volts, zero power factor, overcited at 0.5 psig hydrogen pressure, approximately 70,000 kva with 15.0 psig hydrogen pressure and 77,000 kva with 30 psig hydrogen pressure, other conditions remaining. See Curve H-2266.

Stator (Armature)

The generator stator frame is a welded structure fabricated from steel plate.

The laminated stator core is provided with radial gas vents for cooling both windings and core. Flexible mounting minimizes the effect of double frequency vibration inherent in two-pole machines.

The armature coils are transported internally so that induced eddy currents are reduced to a minimum. Insulation is of the Class B Type.

Rotor

The rotor is a single steel forging with radially machined slots for the windings. Ventilating passages are provided through the rotor for circulating hydrogen.

The rotor is designed for a temperature rise not to exceed 85 Degrees C above an ambient of 40 Degrees C. The winding resistance at 75 Degrees C is 0.242 ohms.

Collector Rings

Collector rings of tool steel are located beyond the outboard bearing. A spiral groove on the wearing face gives improved brush performance by allowing air entrapped under the brush to escape giving better contact with ring and cooler brush rigging.

Shaft Seals

Seals are provided to prevent leakage of hydrogen from the generator. These seals are supplied with oil at a higher pressure than that of the hydrogen. To prevent contamination of the hydrogen by air or moisture and contamination of main bearing oil by hydrogen the seal oil passes through defoaming tanks and a vacuum tank where such impurities are removed.

A seal oil pump feeds oil through the seal oil coolers to the shaft seals at a pressure of 10 psi above machine gas pressure. Failure of pressure from this pump will cause the seals to be supplied from the main bearings. Controls (run-stop) are at the motor with indicating lights at the turbine board.

Generator Neutral Grounding

The neutral of the generator is grounded through a 50 kva, 14,400-240/480 volt distribution transformer with secondary resistor rated 29 kw, 200 amp, 145 volt, 0.725 ohms.

In parallel with this resistor is a type LAV relay with 16 volt pick-up which will operate and sound an alarm at the generator panel. This will indicate a ground on any part of the 13.8 kv system including generator, bus, high side of station service transformer, low side of main transformer, and potential transformers.

Hydrogen Cooling

The hydrogen gas is circulated by rotor fans through the generator in a closed system. The absorbed heat is removed from the gas in the finned tube coolers through which water is circulated. The two coolers are located on the stator frame within the cylindrical casing.

Cooling water is supplied from the main circulating water by the hydrogen and oil cooling pump. Water requirements are 840 gpm at 95 Degrees F inlet temperature with water pressure drop of 11 ft through the cooler.

The hydrogen supply is a manifold suitable for connection to banks of two commerical (2000 psi) cylinders each of 194 cubic feet capacity. Two regulators are provided beyond the manifold. One regulator is manually operated for filling the machine with gas. The other is an automatic regulator which prevents gas pressure in the generator housing from falling below .5 psig.

A hydrogen control panel is provided on the turbine board to indicate temperature pressure and purity of hydrogen in the generator and to furnish visual and audible alarm for any abnormal conditions.

The annunciator system gives both alarms for the following conditions:

No.	Indicates
1	Hydrogen Density-High or Low
2	Hydrogen Pressure-High or Low
3	Hydrogen Bottle Pressure-Low
4	Water Detector-High
5	Hydrogen Temperature-High
6	Seal Oil Pressure-Low
7	Seal Oil Pump-Off
8	Defoaming Tank Level-High
9	Hydrogen Side Level-Low

See generator board for description of operation.

Carbon dioxide is used to remove air or hydrogen from the casing. A common manifold is provided for four standard CO2 cylinders of 440 cu ft capacity each.

Their control is manual.

The static gas volume is 1700 cu ft. The following quantities of CO2 and H2 are required for the various conditions:

	Standstill	Running
Purging air with CO2	1.5 vol.	2 vol.
Purging CO2 with H2	2.5 vol.	3.5 vol.
Purging H2 with CO2	2 vol.	3 vol.
Raising H2 pressure from .52 to 15 psig	1 vol.	1 vol.

When the generator is properly maintained, the hydrogen consumption will not exceed 100 cu ft per day when operating at .5 psig pressure, 300 cu ft per day at 15 psig pressure and 600 cy ft per day at 30 psig pressure.

The hydrogen seal oil pump and hydrogen seal vacuum pump have selector switches at their respective motors with the seal oil pump having red and green indicating lights on the turbine board. The vapor extraction is controlled by jog station at motor and control station (Stop-Start) and red and green indicating lights on the turbine board. The hydrogen density blowers are controlled on the hydrogen panel.

Exciters

The main exciter, direct connected to the generator shaft, is rated 225 kw, 250 volts, d-c shunt wound. It is the semi-enclosed, self ventilated type taking air through an air filter in the basement and discharging it below the turbine room floor.

The direct connected exciter is augmented by a spare exciter with provisions to transfer under load. See description under Excitation Operation.

Pilot Exciter

The pilot exciter, direct-connected to the main exciter shaft, is rated 2.5 kw, 250 volts d-c, compound wound. It is also the semi-enclosed, self-ventilated type with ventilation included on the main exciter system.

EXCITATION

Normal excitation for No. 8 Generator is obtained from a direct connected main exciter whose field is excited by a direct connected pilot exciter.

The main exciter field may be regulated either manually, by means of a motor operated rheostat, or automatically by means of a General Electric GFA-4 regulator. The pilot exciter is self excited.

Indication, under normal operation, of the generator field current and voltage and the pilot exciter voltage is at main control board panel No. GT-4F for No. 8 Generator and No. 8 Bank. Main exciter current indication is at the Spare Exciter Panel O-F.

In case of failure of normal excitation, No. 8 Generator excitation may be obtained from the motor driven spare exciter which serves as a spare for No. 6 and No. 7 Generators as well. The spare exciter field is separately excited from Battery No. 3 and may be regulated either manually by means of a motor operated rheostat or automatically by transfer of the generator GFA-4 voltage regulator. The spare exciter motor operated rheostat may be controlled either from the spare exciter or generator control panels. These rheostat control switches are placed in parallel. Control of the main exciter motor operated rheostat is transferred to the spare exciter panel by means of a transfer switch, for the corresponding generator, located on the spare exciter panel.

Under excitation from the spare exciter, indication of generator field current and voltage is at the generator panel. Spare exciter current and voltage are indicated at the spare exciter control panel.

Loss of Field Protection

Either loss of generator field or accidental opening of the field breaker will trip the generator differential lockout relay which in turn will trip the machine off the line, transfer station service to the emergency source and shut down the boiler.

Exciter Transfer

The procedure for transfer of generation excitation from the main to the spare exciter for any of Generators N. 6, 7, and 8 is as follows:

1. At the Spare Exciter Panel:
   a. Start spare exciter drive motor.
   b. Close spare exciter field breaker and raise spare exciter voltage by means of motor operated rheostat.