OHAAKI STATION STEAM SYSTEM

LEE, K.C., DesignPower New Zealand Ltd, Wellington, New Zealand
ANDERSON, A.R., Murray-North Ltd, Rotorua, New Zealand

ABSTRACT

Ohaaki Power Station is being constructed for the Electricity Corporation of New Zealand Ltd and is the second geothermal power station in the country. Steam-to-set for the first turbine is scheduled for November 1988 and full operation for June 1989. The installed generating capacity will be 116 MW(e).

The STEAM SYSTEM, as described in this paper, encompasses all the piping and associated equipment from the end of the supply mains from the steam field (a point about 75 m from the IP turbine house) up to the turbine inlets. This includes pipework up to 1600 DN (mm nominal size), expansion joints, isolating valves, bypass and vent valves, vent silencers, supports, platforms, acoustic and thermal insulation and the condensate drains system. This paper deals with the design and the design philosophy, the specifications, equipment, materials and the pressure control system.

INTRODUCTION

Ohaaki Power Station is located 30 km NE of Taupo in the North Island of New Zealand. It will be supplied with steam from the Broadlands geothermal field, which is of the wet hyper-thermal type (Ref 1). Unlike Wairakei Power Station, Ohaaki Power Station will reinject its separated water and condensate (Ref 2).

The basic design of the steam system was carried out by DesignPower NZ Ltd which is a subsidiary of the Electricity Corporation of NZ Ltd. The detailed design was carried out by Murray-North Ltd, NZ. The concept of the steam system is shown in Diagram 1.

The station has 4 turbo-generators: 2 high pressure (HP) back pressure sets of 11.5 MW(e) each and 2 intermediate pressure (IP) condensing sets of 46.5 MW(e) each. The HP sets have a nominal inlet pressure of 12.5 bar g and IP sets 3.5 bar g. The HP sets (AEI England) have been recovered from Wairakei where declining steam pressure has made them redundant. The IP sets are new Mitsubishi units.

OPERATION

A total design steam flow of 710 tonnes/hr will be delivered from the steam fields. During normal operation in the early years of the station life (when the HP system pressure will be relatively high) most steam from the steam fields will be supplied via the two incoming 750 DN HP lines (260 tonnes/hr each) and a lesser amount (190 t/h) via the 1000 DN IP line. The HP steam will all go to the two HP turbines. The HP exhaust steam will be stripped of condensate by means of vortex separators and discharged into the IP system. The combined IP flow (two HP turbine exhausts plus IP steam direct from the steam fields) will then go to the IP turbines and thence to the condenser.

As the fields decline in output with time, the HP steam pressure will fall. In order to maintain the IP pressure, an increasing proportion of the HP steam supply will be injected directly into the IP system via the two HP bypass valves.

When the steam system is in equilibrium during normal operation steam inflow from the steam fields will balance the steam outflow to the turbines (plus condensate loss). Trimming of the system pressures to achieve the design values during stable, steady-state operation will be done by adjusting the production of the steam fields.

STEAM PIPEWORK

In preparing the conceptual design various requirements were important. In particular:

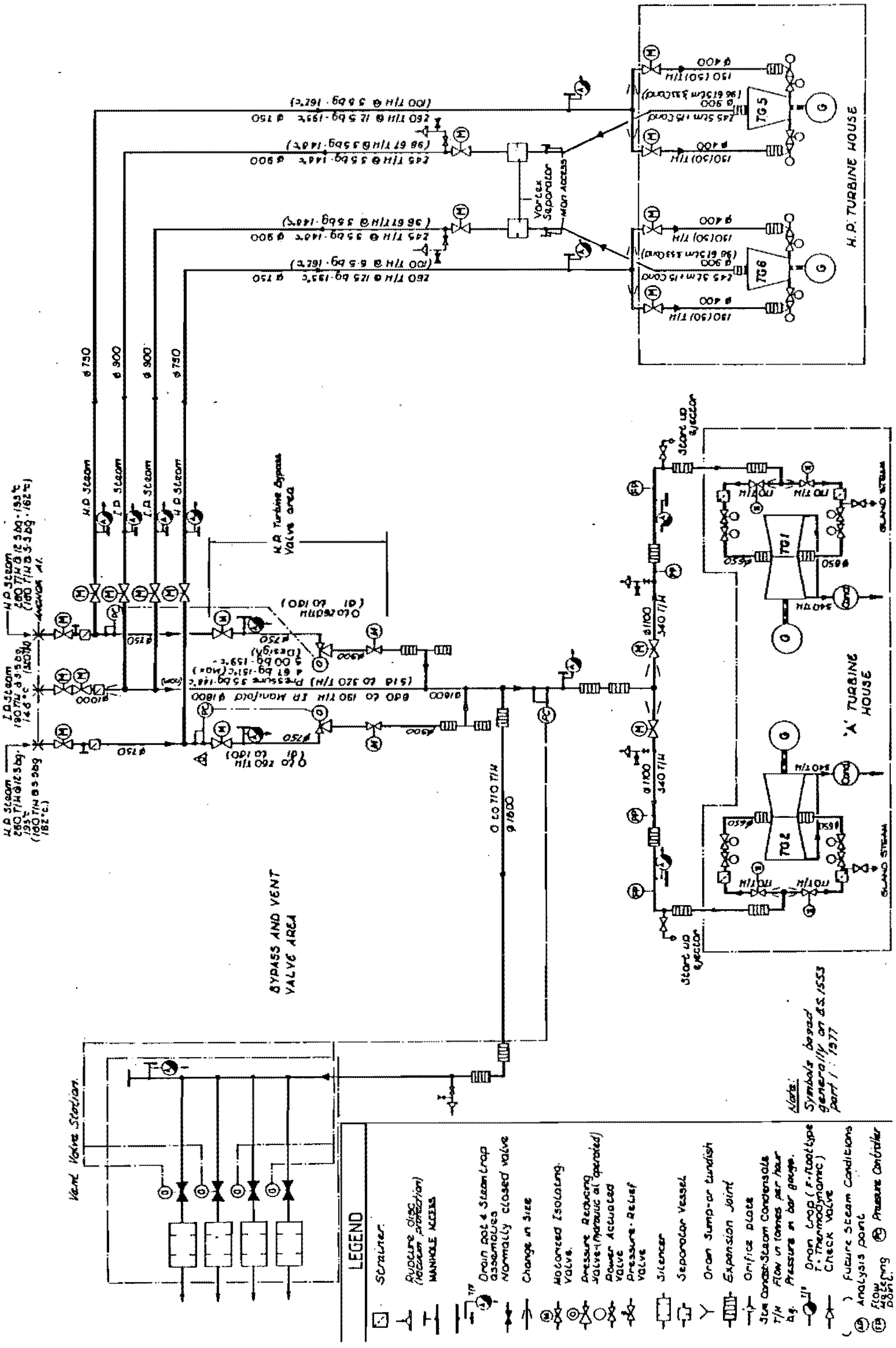
a) The system had to enable a continuous flow to be drawn from the steam fields regardless of the station operating requirements. The system had, therefore, to be able to cope with virtually instantaneous changes in turbine demand and to be able to vent part or all of the steam flow to waste for extended periods.
b) The system had to be able to maintain design pressure in the IP system as a first priority (since the majority of the generating capacity is in the two IP sets).

These requirements were met by designing the control system as described below. The piping was arranged to achieve the best balance possible of the following:

1) An arrangement with the minimum of large pipe and fittings.
2) Natural flexibility to absorb thermal expansion where practicable.
3) Horizontal and, to a lesser extent, vertical restraints to ensure the integrity of the system under seismic conditions.
4) Substantial flexibility between major sections of the piping to ensure that different parts could move out of phase without damage in an earthquake. This has been largely achieved by using expansion joints in suitable configurations.
5) Pipe sizing which limits friction losses to economic levels and keeps velocities and noise within acceptable levels.

The pipework, some being large diameter (up to 1600 DN) and thin wall, required very careful detail design. Support attachments, for example, were individually designed to ensure unacceptable pipe wall deformations and stresses did not occur.

Diagram 1: System Diagram of Ohaaki Power Station Steam System



The piping was designed to comply with ANSI/ASME B31.1 Power Piping Code, with design pressures of 17 bar g (HP) and 5 bar g (IP). The seismic loading conditions were chosen in accordance with a NZ code (Ref 5) and correspond to a 150 year return period earthquake. The seismic design factor is 0.6.

The pipe supports systems have been designed to ensure the natural period of the piping is less than 0.1 seconds thus minimising dynamic response effects. Hydraulic dampers have been widely used.

CONDENSATE DRAINS SYSTEM

A comprehensive drains system has been provided to collect and remove condensate from the steam system under all conditions and dispose of it in an environmentally acceptable manner.

During normal operation, condensate in the piping system is collected in drain pots which are fitted with baffles to ensure highly efficient operation (Refs 3 & 4). Vortex separators and interstage drains vessels collect condensate from the HP turbines exhaust pipes and interstage drains respectively.

All condensate is piped to open drains vessels which are fitted with cooling water sprays. The sprays quench flash steam to prevent the continual discharge of visible vapour and lower the condensate temperature to a level safe for the FRP discharge pipeline to the hotwell. From the hotwell the condensate is reinjected with the excess water from the cooling tower.

Normally condensate will be discharged from steam traps at 104 °C and a pH of 6.9. In the open drains vessels the condensate will be cooled to 77 °C, with a pH of 5.8 to 7.0.

During shutdown, air will be admitted into the steam pipes to replace the condensing steam and prevent a vacuum occurring. Most of the condensate will be evaporated by the hot pipes during shutdown. There will be condensate trapped at low points and enclosed spaces eg. valve intergate areas, which are provided with drain lines for gravity draining to open culverts.

INSULATION

Two insulation systems are being installed: thermal and acoustic. The thermal system consists of one layer of fibreglass insulating material and cladding. The acoustic system consists of two layers of fibreglass insulating material, one intermediate cladding and one outer cladding. The acoustic system is installed on piping in the proximity of the control valves. All cladding is 1.2 mm thick aluminium except on bends, which have FRP cladding.

The thickness of the thermal insulation varies with the size of the pipe and its duty; from 25 mm on 50 DN steam and condensate piping to 65 mm on 1600 DN steam piping. The thickness of acoustic insulation is 2x65 mm in all cases. All pipe fittings except bends are insulated with 50 mm thick fibreglass in non-contact insulation boxes.

PRESSURE CONTROL

The principal functions of the pressure control system are to control steam pressures during transient/short term disturbances and to protect the IP system from over-pressure. The causes of disturbance may be relatively minor, such as small load changes, or major, such as a turbine trip.

Both the bypass valves and the vent valves controls incorporate feed forward elements. In the event of an HP turbine trip the bypass valve for that machine will automatically open to maintain the HP flow by diverting it directly into the IP system. In the event of an IP turbine trip the vent valves will receive a signal from the turbine trip circuitry and will open rapidly to relieve the steam directly to atmosphere.

The HP system has the same design pressure (17 bar g) as that of the steam field pipework. Over-pressure protection of the HP system is provided by the safety valves in the steam field.

The IP vent valves have the dual functions of pressure control and over-pressure protection. During normal operation the vent valves will be controlled by the IP pressure controller, which will modulate the valves as required. Generally the vent valves will be closed and the controller will only be able to act to reduce the IP pressure.

The vent valves will also function as safety valves, to protect the IP system from over-pressure. The initiation will be by means of a "2 out of 3" pressure switch system. The vent valves have been arranged for fail-safe operation, in that loss of electric or hydraulic power causes them to open. The system is not self-resetting and is arranged to ensure the vent valves can only be closed after manual resetting of the controls. The capacity of the vent valves is such that 3 of the 4 valves have sufficient capacity to vent the full flow from the steam fields. Hydraulically operated valves were specified to achieve the required speed of operation.

MATERIALS

The corrosive geothermal environment created some difficulties for the designer. For components inside closed piping systems there are no particular problems during normal operation and carbon steel is a perfectly acceptable material for pipe and pipe fittings. However, geothermal condensate exposed to air becomes very corrosive and suitable high alloy steels are required in situation where this can occur. The bellows of expansion joints, wherein condensate can collect during shutdown and cannot be readily removed, is an example of items needing substantial corrosion resistance.

The piping material is to API standard 5L, grade B or ASTM standard A106 grade B. ERW, SAW and seamless constructions were permitted. The vortex separators were designed to the ASME Boiler & Pressure Vessel Code, Section VIII, Division 1, and the vessel body material is ASME SA

516 grade 55. The vortex separators and the IP piping interior have been coated with Apexior No.1 paint for corrosion protection.

Flanges are to ANSI B16.5 for sizes up to 600 DN and API for larger flanges. The flange material is ASTM A105 or A216-WCB. The flanges are generally welding neck, raised face with serrated concentric finish. Pipe fittings were specified to ANSI B16.9 and the pipe fitting material is ASTM A105, A106-B, or A234-WPB.

RHS sections have been used for the pipe support structural steelwork, which is galvanised to AS 1650. The platforms grating and handrail material is aluminium.

EQUIPMENT AND SPECIFICATIONS

Six major specifications were produced for the steam system:

1) Pipework and supports, 2) Control valves, 3) Expansion joints,
4) Isolating valves, 5) Drains systems, 6) Insulation.

Because of the size and the unusual nature of the application, much of the equipment is outside manufacturers normal, standard product ranges. Potential suppliers were therefore contacted at an early stage in the design process to ensure that the specified requirements for valves and expansion joints were reasonable and achievable. The specifications were functional specifications and no pretender qualifications were required.

The control valves are Valtek valves manufactured by Automatic Accessories Ltd, Melbourne, Australia. The HP bypass valves are right angle globe valves with 600 DN bottom inlet and 600 DN horizontal outlet. The body material is ASTM A106-B. The IP vent valves, also 600 DN, are of the in-line globe type with bodies of ASTM A216-WCB material.

The control valves were designed to meet ANSI B16.34. The seats are hard-faced with Stellite 6. The valves have a turndown ratio of 20:1 and have linear characteristics. The HP bypass valves leakage rate was specified to ANSI B16.104 Class II and the IP vent valves to Class IV.

Each HP bypass valve has a minimum specified capacity of 228 tonnes/hr at 2 bar pressure drop and 318 t/h at 8.9 bar drop. The four IP vent valves were specified to have a minimum total capacity of 781 t/h at 2.9 bar drop, and three valves to have a minimum of 864 t/h at 3.1 bar drop.

The hydraulic oil supply was specified to API 614 with some amendments. Both the bypass and vent valves are required to respond to emergency venting within 2 seconds.

Each IP vent valve discharges steam to the atmosphere via a vent silencer. The vent silencers are designed and manufactured by Works Services, Wairakei, NZ. Each silencer is 3.3 m in diameter and 10 m high. Steam flows through an annular area filled with scoria. The silencers are made of corrosion resistant corten plate coated with protective paint.

The expansion joints were supplied by two manufacturers: Bachmann and Hyspan, both of USA. Most of the expansion joints are of single hinge type. The largest single expansion joint is the 1600 DN tie universal type which is more than 5 m long. The design was specified to the standards of the Expansion Joint Manufacturers Association, Inc. The expansion joints have removable internal sleeves. The bellow material is Inconel 625 (UNS N06625) for the steam system and Avesta 254SMO (UNS S31254) for the drains system.

Large isolating valves up to 1100 DN were supplied by Valvotecnic SA of Switzerland. These valves are full bore, flexible wedge gate type, with bypass valve and electric actuator. Body seats have Stellite 12 hard-facing and wedge seats have Stellite 6 hard-facing. Valves on the HP system are rated to ANSI B16.34 Class 300 and on the IP system to Class 150. The minimum stroking speed is 4 mm/sec for Class 300 valves, and 4.5 mm/sec for Class 150.

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