Engineering features of the Lower Mangapapa hydro-electric power scheme

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Engineering features of the Lower Mangapapa hydro-electric power scheme, built and owned by the Tauranga Joint Generation Committee, particularly those features expected to be of most interest to engineers and executives of electricity supply authorities planning or operating their own stations.

Details of the civil engineering structures are given mainly from the point of view of future operation and maintenance. The mechanical and electrical plant are described in general terms and points of special interest are highlighted. An outline of the hydrological factors relating to reservoir and station output management is given.

Some comment is made on the background and profitability of the scheme.

1. INTRODUCTION

The Lower Mangapapa hydro-electric power scheme is a local authority station built and owned by the Tauranga Joint Generation Committee. The station is in the Kaimai Ranges on the Mangapapa River about 19 km by road from Tauranga, and is the second stage of the cascade development of the Wairoa River catchment (see Fig. 1). The station has a capacity of 6 MW and is expected to generate around 18 GWh of electricity per year. The scheme comprises:

- a 30 m high arch dam across the Mangapapa River about 4 km downstream of the Lloyd Mandeno power station
- a concrete-lined power tunnel 400 m long and 3 m in diameter
- a tunnel intake structure containing a bulkhead gate facility to permit de-watering of the tunnel and penstock
- intake screens and provision for a future screen rake, should this be found necessary - a steel penstock bifurcating to the two turbine delivery penstocks
- a power station situated on the Mangapapa River at the head of Lake McLaren
- one horizontal-shaft twin-turbine induction generating-set rated at 6 000 kW
- a 33 kV transmission line to the Wairoa switchyard.

Access is by sealed road across farmland below which the descent to the power station is steep and winding with gradients of up to 1 in 7. A branch road leads to the dam and intake.

The scheme was first conceived in its present form some 14 years ago as part of a study into hydroelectric development of the Wairoa River above the old McLaren Falls station. Work began on site on 19 July 1976. The first power was generated on 21 April 1979 and the station was handed over for commercial operation on 22 May 1979.

2. CIVIL WORKS

It is often taken for granted that civil works require little or no inspection or preventive maintenance, perhaps because there are no moving parts. However, even though civil works can be expected to have a longer life than plant items, inspection and maintenance are necessary and beneficial. This work should include not only obvious things like cleaning out roadside drains or slips and replacing the surface on metal roads but also such items as:

- scheduled repainting
- regular operation of hoists and other auxiliaries especially those exposed to the weather
- regular testing of all safety devices
- special work applicable to individual structures.

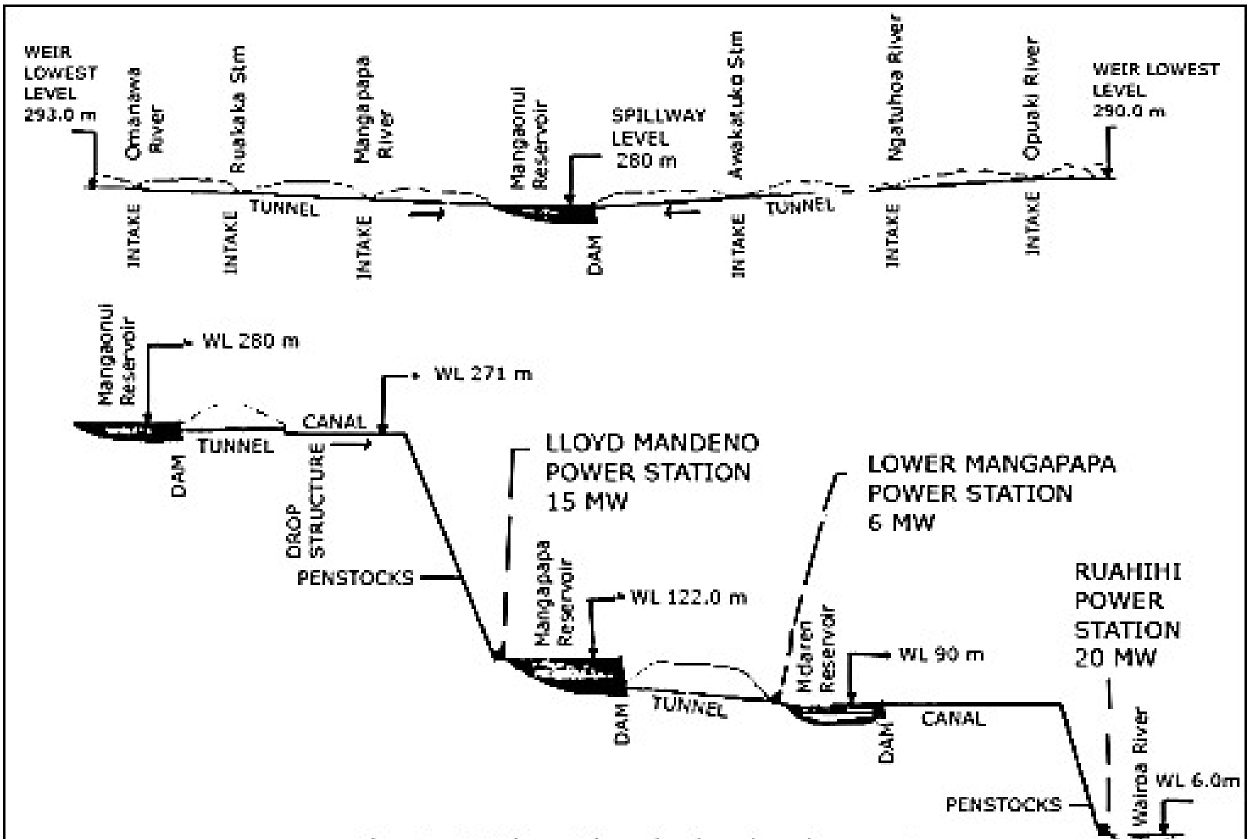


Fig. 1 -- Wairoa River hydro development

2.1 General arrangement

Figures 2 and 3 show the general arrangement of the scheme and powerhouse.

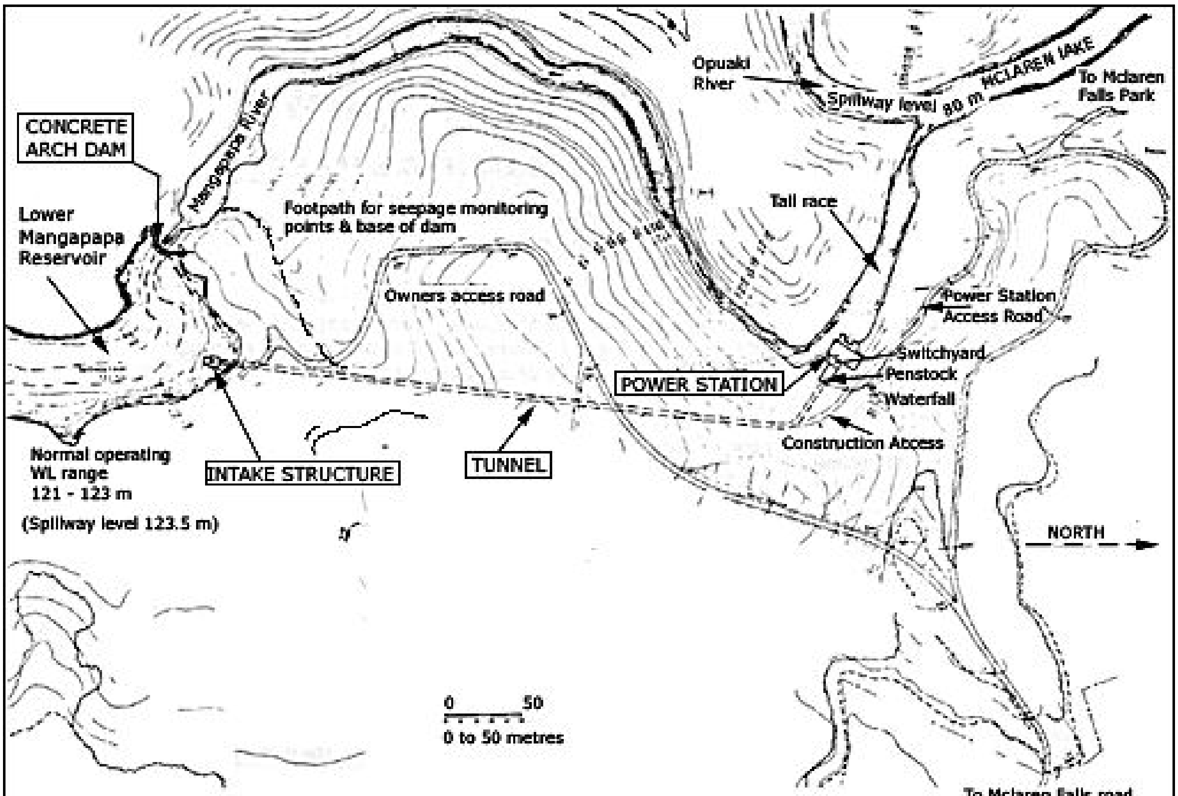


Fig. 2 General Arrangement of the scheme

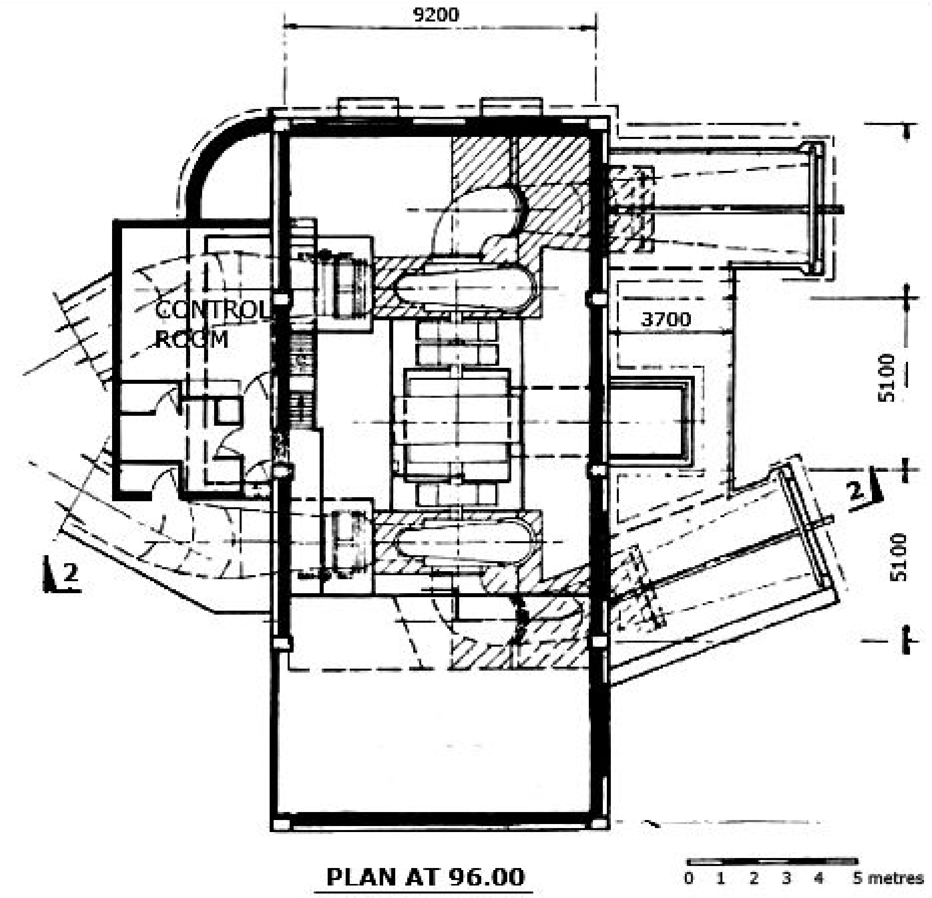


Fig 3A General arrangement of the power station

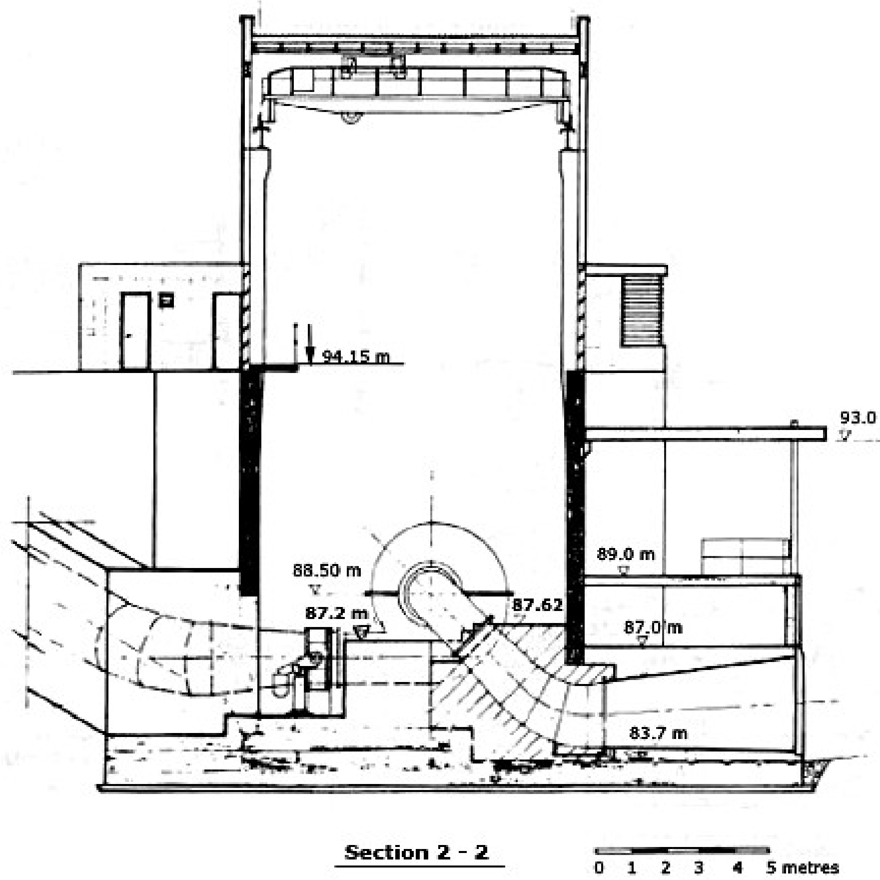


Fig 3B General arrangement of the power station

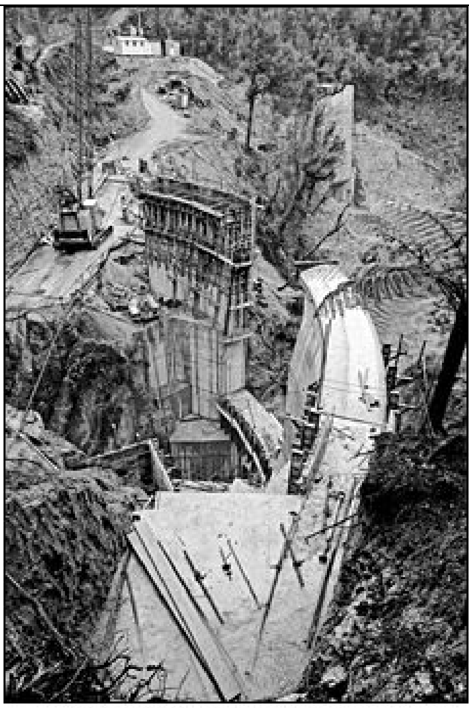
2.2 Reservoirs

The Mangapapa (upper) reservoir is confined in a steep-sided valley part of the shoreline of which is composed of loosely bonded slope detritus. This is subject to litoral erosion and for this reason the use of power boats for recreational purposes is prohibited. The owner uses a motor dinghy for maintenance inspections and a record has begun of shoreline changes.

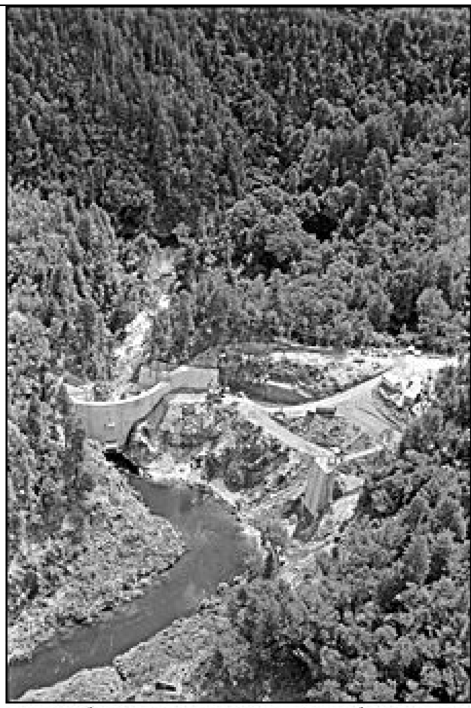
The public are free to make recreational use of the lower reservoir, Lake McLaren, which runs through the Tauranga City Council's Mclaren Park. However, boating is limited by an agreement between the owner and adjoining landowners. It restricts the public from landing on the shoreline except at the owner's boat ramp adjacent to the dam. Power boats are prohibited.

2.3 Arch dam

The concrete arch dam is founded on ignimbrite rock in a narrow gorge on the Mangapapa River and rises 2 m thick from its base at RL 101.25, tapering above RL 118 to a thickness of 1.5 m near the crest (RL 123.5). Mass concrete fills the gorge between the foundation at RL 94 and the foot of the dam. River diversion during construction was in a temporary pipe through an opening at the foot of the dam. Impounding was started by closure of this opening by a permanent bulkhead gate from a platform on the upstream face of the dam. The reservoir can be drained through the same opening if the need arises after first drawing down the water level to below RL 108 via the power tunnel and the turbines.



Lower Mangapapa Dam site
25 June 1978 *Photo: David de la Hyde*



Aerial View - Lower Mangapapa dam site
4 Mar. 1979 *Photo: David de la Hyde*

The dam abutments and foundations were grouted to seal and strengthen the rock which is very elastic in this area, a feature which made blasting for excavation curiously ineffective and difficult to perform.

Horizontal drains from the downstream country complete the foundation treatment and the regular observation of these for variations in drainage flows is an essential maintenance item. This maintenance includes periodic removal of any accumulated material which could affect their operation. There are a total of 75 such pressure-relief drains, streams, and underground springs. Measurement techniques vary from visual observation of very small "flows" (i.e. too small to form a running stream of water, but enough to cause permanent wetting at the "measuring" point), to bucket and stop-watch or vee-notch. Some are affected by the weather, but most have shown little variation since the dam was first impounded.

Regular dam maintenance also includes measurement of the horizontal movement of the dam crest and abutments. This is checked by reference to fixed remote station using EDM (Electronic Distance Measuring) equipment and ordinary precise optical survey techniques. Multiple observations obtain an apparent accuracy of the order of 0.1 mm in the position of individual markers.

2.4 Intake structure

The intake structure includes a two-leaf bulkhead gate which can be lowered under no-flow conditions to seal off the tunnel and penstocks from the reservoir, an operation which takes 30 to 40 min including preparatory work. Lifting is by 2-speed 2½ t electric hoist. Structural steelwork exposed to the weather is finish painted with chlorinated rubber.

No screen-raking mechanism has been provided, but provision has been made for one should experience show this to be necessary. A diver's inspection some 12 months after commissioning showed a small accumulation of natural wood debris at the foot of the screen and negligible quantities on the face of the screen. The screen bar spacing of 30 mm maximum between bars was fixed by the water right to prevent ingress of large fish into the power tunnel, and typically gives rise to a loss of head across the screens of the order of 300 mm. A land line and telephone provide communication between the intake structure and the control room in the power station.

The location of the tunnel intake and its shape and orientation were the subject of model testing performed by the consulting engineers in their Tauranga laboratory. The most important aspects of this were the avoidance of vortex formation and dangerous scouring eddies on the shores of the reservoir. The model testing was instrumental in making improvements to the original proposals and in simplifying the geometry of the intake bell-mouth.

2.5 Power tunnel and penstocks

The 3 m diameter concrete-lined tunnel leads into welded steel penstocks behind the powerhouse. The internal paint treatment on the penstocks and stud liner in the last 15 m of tunnel is coal tar epoxy. The penstocks are encased in concrete.

Access into the tunnel is via a manhole at the downstream end.

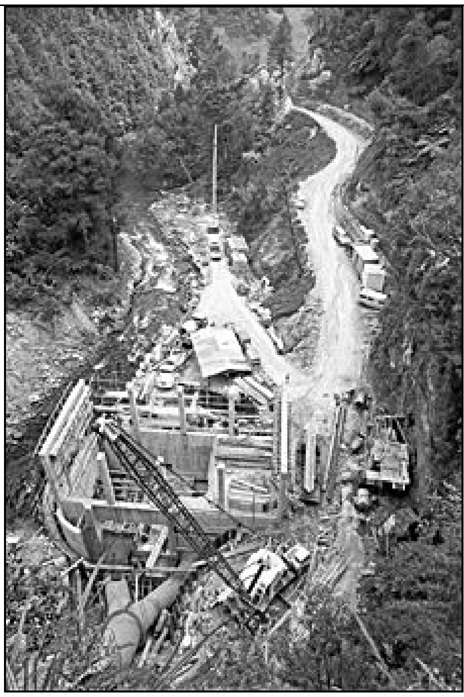
Tunnel inspections can be carried out only infrequently, usually when the station is shut down for general machine maintenance. Approximately one working day is required, allowing two hours or so for the actual inspection. Two hours are required for dewatering and four to five hours for refilling the tunnel. Re-filling is via a 200 mm valve and pipe on the intake structure. A log is supplied to record the observations made during the inspection. Some sliming on the tunnel walls was evident after four months from first filling and this makes inspections on foot more difficult especially in the steeper steel-lined sections. When de-watered, leakage into the tunnel is removed through the penstock drain in the powerhouse.

Ground water now emerging from the construction adit at the downstream end of the tunnel must be monitored as part of the maintenance programme. There were strong springs at a point some 60 m inside the downstream end of the tunnel during construction and these were not eliminated by the post lining grouting. They now appear at the upstream end of the adit adjacent to the bend in the tunnel.

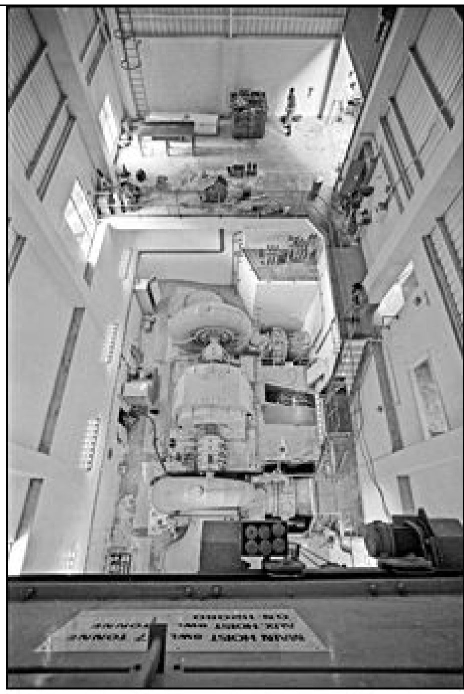
2.6 Power station

The power station was constructed "in the dry" in the bed of the Mangapapa River inside a circular steel sheet-pile cofferdam. The cofferdam was driven through a deep layer of boulders which were pre-cut by blasting before driving the steel sheet piles. The machine hall (below RL 94 -control room floor level) is of reinforced concrete and is designed to protect the machinery from floods up to RL 94. Above RL 94 the superstructure is formed from concrete block and pre-coated cladding on a steel framework. The interior surfaces, other than the ceiling, are unlined and have been painted. The ceiling has been insulated and lined with Gib-board as a defense against condensation.

Two-leaf bulkhead gates have been provided for each draft tube with an overhead monorail and chain block for handling. The gates are lowered with an independent lifting beam which disengages underwater to permit the second leaf to be placed on top of the lower. Once the bulkhead gates are in place, the draft tubes may be de-watered by an electric pump in the generator cooling-air duct and access gained to the turbine runners and draft tubes by removing the draft-tube exit bends.



Lower Mangapapa Power House
23rd February 1978 *Photo: David de la Hyde*



Lower Mangapapa Power House interior
17 March 1979 *Photo: David de la Hyde*

Information from the generator manufacture indicated that the exhaust generator cooling air could reach a temperature of 70°C. Over prolonged periods of generation at this temperature the mass concrete in the power station foundation in the vicinity of the air duct could be expected to expand, possibly leading to loss of turbine-runner clearances. To avoid this possibility, pan of the air duct and the bus chamber below the generator has been lined with a flameproof reflective insulating material installed with an air gap between the back of the insulation and the surface of the concrete. Duckboards have been provided for walking on this soft lining surface.

2.7 Access road
Construction of the access road has necessitated substantial cuttings in country that is in places unstable and falls of rock and slips can be expected from time to time, especially in wet weather.

3. PLANT AND EQUIPMENT

3.1 Arrangement
The generating plant comprises a horizontal shaft 6 MW induction generator supported by pedestal bearings and driven at either end by opposite hand but otherwise identical Francis turbines. A short, steel bifurcating penstock connects the tunnel upstream through butterfly valves to the two turbines.

3.2 Turbines and valves
The turbines, supplied by Titovi Zavodi Litostroj of Yugoslavia, are designed to be operated together to produce a combined shaft output of 6.25 MW at a net head of 32.8 m at 375 rev/min. Runaway speed is 900 rev/min..

The inlet butterfly valves are hydraulically operated and open and close automatically each time the plant is started or stopped. The valves are of the bi-plane type with rubber-ring seal. Each spiral casing is filled on start-up through a bypass gate valve and the main valve is opened only after pressure equalisation. Fail-safe closing on d.c. power failure or other faults is achieved by counterweight. Each valve is 1 500 mm in diameter.

The turbines themselves comprise fabricated steel spiral casings, moveable guide vanes, stainless-steel runners of outlet diameter 1 300 mm, carbon-ring shaft seals, air admission pipe-work for quiet running, etc.

3.3 Actuator

There is no need for speed-sensitive governing with an induction generator, and the guide vanes are opened and closed to raise and lower speed prior to switching in. They change load afterwards, by a simple hydraulic actuator. A position feedback from the guide vane linkages is by wire cable. Oil pressure is maintained at 25 bar by a 7.5 kW a.c. motor-driven pump with a d.c. standby. This oil system also supplies the butterfly valve actuators.

3.4 Generator

The 6 MW induction generator, supplied by Mitsubishi, Japan, is rated at 380 A at 11 kV and has a power factor at full load of 0.845. The rotor diameter is 1994 mm and the air gap 3 mm.

The guide bearings are of the journal type, forced-oil-lubricated from a lube oil unit. The pressure is maintained by an a.c. motor-driven pump with d.c. standby. A thrust bearing is provided to take full hydraulic thrust in either direction. There are no brakes. Cooling is open air with the hot air discharged downwards into a duct out of the power house.

A speed signal for use during switching-in, over-speed tripping and for indication is obtained from the output voltage of a permanent-magnet generator driven from the generator shaft by a nylon gear.
The generator windings are star-connected and the neutral point is earthed through a 1260 S2 reactance-free resistor.

3.5 Crane

A 37.5 t electric overhead traveling gantry crane is provided for plant assembly and maintenance. By comparison, the generator rotor weighs 27 t and the stator and pedestals etc, 35 t. It is impossible to "thread" the rotor into the stator when the latter is in place between the turbines and assembly of the generator was achieved with the stator supported on blocks above its bed plate, after which it was lowered on jacks. An auxiliary hoist is provided for light lifts.

3.6 Capacitor bank

An 1 l kV static capacitor bank is installed for power factor improvement. This is rated at 1090 kVAr and comprises six single-phase cans, each rated at 200 kVAr and 6990V, connected in two parallel stars with neutral points linked but unearthed. The dielectric is plastic film and paper, impregnated with Askarel.

The size of the capacitor bank was calculated at the design stage as the maximum permissible without running the risk of dangerous self-excitation of the generator during overspeed on loss of load. This was checked on site during commissioning.

The generator draws approximately 2 MVAr of reactive power when running at no load and rated speed, but by the time speed has risen to the trip setting of 120% - this occurs after about three-quarters of a second on loss of full load - the generator voltage, which initially decays exponentially in the usual way, has risen again - owing to self excitation - to about 110% of rated voltage of 12.1 kV. It will be noted that the capacitor bank has a rated line-to-line voltage of 12.1 kV - this was chosen on purpose - and that this is not exceeded.

The capacitor circuit-breaker is tripped by overspeed, overvoltage, overcurrent and out-of-balance protection as well as the generator/transformer differential group.

Advantage was taken of a small floor 2 600 mm above the generator floor and accessible by ladder to provide the necessary high-voltage security area. A concrete lip was poured around this area to retain the dielectric liquid in the event of a tank rupture.

3.7 Switchgear and transformation

Connections from the generator terminals were made in copper bus from the air duct under the machine to the 11kV Switchgear cubicle and from there by cable to the capacitor bank and out to the generator transformer. Figure 4 is a line diagram.

An early decision was made not to fit taps to the generator transformer. Because the machine is an induction generator, there is a nominal voltage fall from the 33 kV line terminal to the 11 kV bus during generation, apart from transformation. Whereas with the static capacitor bank in service and the generator

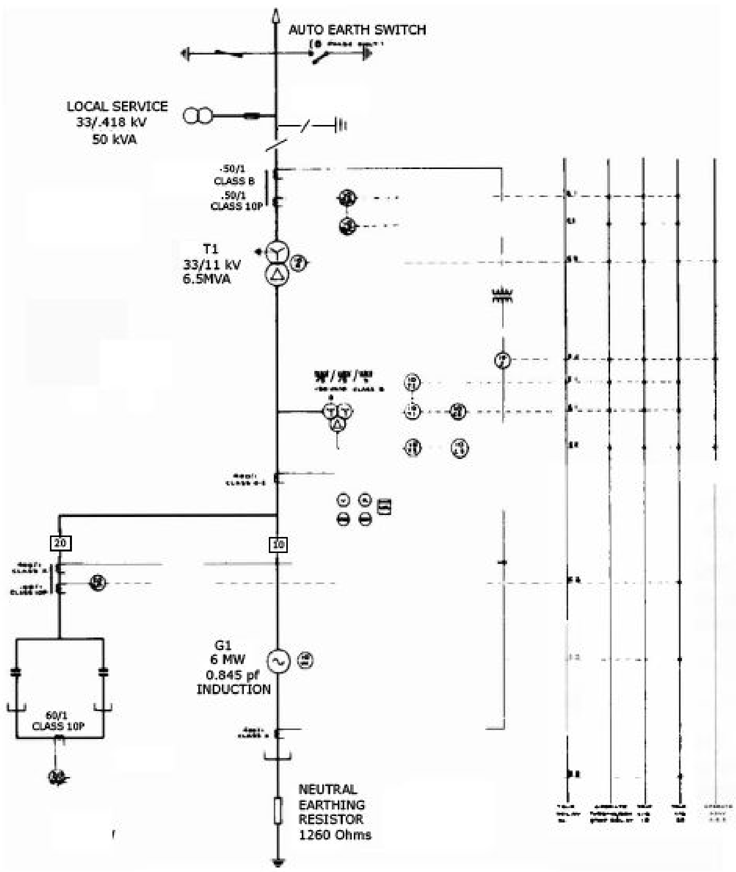


Fig. 4 - Relay and Instrument diagram

out of service, there is a nominal voltage rise. At the fixed transformation ratio of 33/11 kV and a 33 kV system voltage of 34 kV at the New Zealand Electricity substation, the 11kV bus voltage at Lower Mangapapa can be shown to vary between 101.3% and 106.4% of the nominal rating of 11 kV.

The transformer itself is rated at 6.5 MVA and would be over-loaded at full generation without the capacitor.

There is no 33 kV switchgear apart from an isolating switch: transformer and generator/transformer differential trips operate an auto earth-switch to trip the remote line breaker.

3.8 Controls.

The plant is arranged for semi-automatic starting and stopping from the main control panel in the control room or over the remote control link referred to below. Manual control is possible from the machine floor for use during testing, trouble-shooting, maintenance, and in emergencies.

On the receipt of a "start" command the semi-automatic control mode starts the auxiliaries, runs the set up to speed and switches it in as the speed descends slowly through synchronous speed. Raising and lowering of load is then achieved by other pushbuttons. Shutting down from no load and emergency shutting down are also provided. The capacitor bank is controlled independently.

Controls are operated from a 110 V lead-acid battery with a normal floating voltage of 119 V. This battery also provides power for the d.c. oil pumps referred to above. A separate 24 V battery powers the remote control link.

3.9 Cooling water and drainage

Cooling water for the bearing lube Oil and actuator oil head exchangers is taken from the penstock via a duplex cartridge filter. Because of the small flows, the supply remains on when the machine is shut down. A supply is also taken to the carbon-ring shaft seals to prevent ingress of untreated water between the seals and shaft.

Station drainage is from the No. 1 butterfly valve pit by an ejector jet pump designed for the purpose. A standby a.c. electric motor-driven pump is provided.

3.10 Other services

A local service supply is taken from a 50 kVA 33 kV/415 V transformer. Incandescent emergency lighting operated from the station battery is provided in the control room, on the stairs, and in each butterfly valve pit.

Fire-fighting measures comprise first-aid fire-fighting equipment and "halon" gas cylinders for the main control panel and 11 kV switchgear cubicle. These cylinders are arranged for automatic discharge on actuation of smoke detectors. Another smoke detector in the generator air duct monitors outlet air.

Earthing is to lugs in the power station wall, welded to the structural steel, which serves as the earth electrode.

4. TRANSMISSION

Transmission is at 33 kV by overhead line for 4 km to the Wairoa switchyard. The conductor is 220 mm^2 aluminium where new sections have been built but in other parts, the existing McLaren Falls power station line has been used. Transmission from the Wairoa switchyard is by three 33 kV circuits to Greerton substation and from there to the N.Z.E. Tauranga substation and Tauranga E.P.B. and Tauranga C.C. load centres. The lines were designed and built by the Tauranga Electric Power Board.

5. INDUCTION GENERATOR SOLUTION

The fact that this generator is an induction machine deserves special mention. Tenders were called for induction sets but tenderers were invited to offer synchronous machines as an alternative. At the same time, firms tendering for the Ruahihi generators were asked to state the extra cost of providing synchronous sets for that station with a rated power factor of 0.8 instead of 0.9.

In the event, the costs were found to be as follows:

- Tender comparison figure for most favoured synchronous set	$1 434 000
- Less tender comparison figure for induction set chosen	(1 036 000)
- Less extra cost for 0.8 p.f. generators at Ruahihi	(81 000)
- Less extra cost for the transformers at Ruahihi	(18 000)
- Less capacitor bank and switchgear	(10 000)
– Add for extra control equipment costs with a synchronous set	8 000
Net advantage of induction set	$297 000

At a saving of around $300 000 the induction set was the obvious choice and its simplicity and robustness are added advantages. So far as the authors know, this is the largest induction generator in the world.

6. OPERATION AND MAINTENANCE

6.1 Remote control

The station is normally operated unattended by remote control from the Mclaren Falls power station. The remote-control link uses a pilot-wire circuit to convey analogue indications of reservoir water level, line current, station megawatts and megavars, voltage and alarm and trip indications as well as start, stop, raise bad, lower load and emergency stop controls. It is intended to remove the remote control point to the Tauranga Electric Power Board's system control-room in Spring Street in the near future.

6.2 Water management

The water right for this station permits normal reservoir operation between a level 0.5 m below the dam crest (spillway) level of RL 123.5 m and RL 121 m. Draw down below RL 121 m requires the prior permission of the local catchment commission. Operation above RL 123 will occur only in floods or when the machine is not available to discharge the river flow and prevent spillage over the dam. Between RL 121 and RL 123, the reservoir stores approximately 21 MWh and between RL 123 and RL 123.5 a further 8 MWh.

Discharge from this station at full gate and at a net head of 32.8 m is 21.8 cumecs. By comparison, the river inflow into the Mangapapa reservoir at full output from the Lloyd Mandeno station is of the order of 12 cumecs and discharge from the McLaren reservoir through the Ruahihi station (under construction) with the latter at full output will be of the order of 28 cumecs. Storage capacities between the normal operating limits (2 m range) in the Mangaonui (upper) and McLaren (lower) reservoirs including associated canals are 9 MWh and 71 MWh respectively.

Plant factors for the three stations are:

- Lloyd Mandeno	68%
- Lower Mangapapa	45%
- Ruahihi	<u>48%</u>
- combined	<u>55%</u>

Generation scheduling is carried out within this framework to eliminate unnecessary spillage, ensure adequate water availability at each station at times of peak demands, and to ensure generation at the points of greatest turbine efficiency at other times.

The importance of careful hydraulic management cannot be stressed too strongly. Unnecessary generation at full output, for example, when generation at, say, 85% flow would have been acceptable, will result not only in a fall in turbine efficiency of about 6% but also in a drop in net head of just under 2%, a total drop in energy conversion efficiency of 8%.

6.3 Attendance at station

Attendance at the station is necessary before re-storing after a mechanical or electrical trip. This was a policy decision taken at the design stage, although electrical re-setting features have been built into the plant to allow remote resetting in the future if desired.

Daily attendance at the station, preferably while the plant is running, is also recommended for routine checks and preventive maintenance.

6.4 Maintenance recommendations

Each plant supply contractor was required to provide detailed maintenance instructions for his plant. These were coordinated and an overall maintenance guide and plant manual was prepared for the station by the consulting engineers. Records of all contract specifications, manuals, drawings, tests and related reports have been included in this manual for future reference purposes. The manual includes details of test procedures for all alarms and trips, dewatering procedures, and general remarks on paintwork, galvanising and the care of tools. It is currently being extended to cover maintenance and inspection of the civil works.

7. COSTS

The cost of the completed work is given in Table 1.
The cost per kilowatt is $1 130 and this can be shown to compare favourably with other stations.

TABLE I

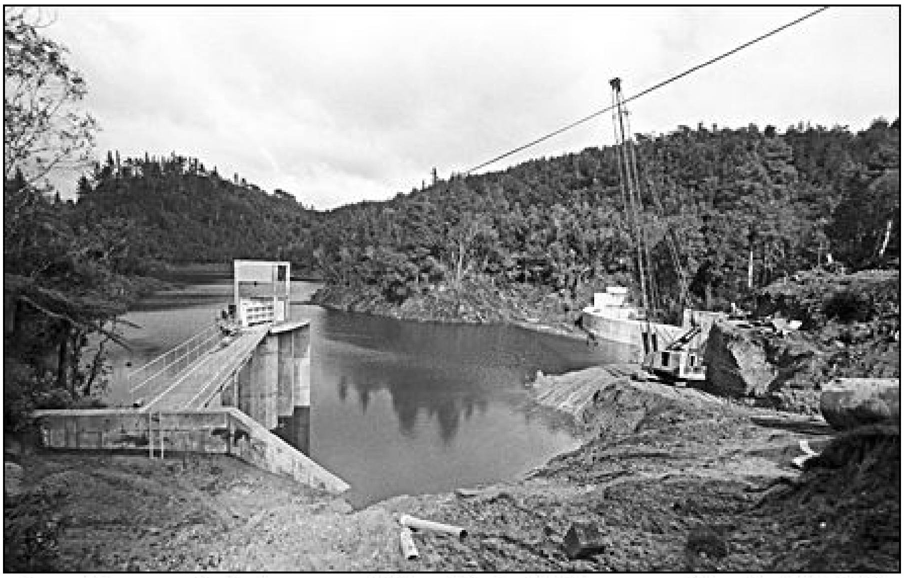
	$
Investigations	90 000
Roading	140 000
Dam and intake	1 477 000
Reservoir clearance	60 000
Tunnel	969 000
Power station	1 175 000
Tunnel liner, penstocks, gates, screens, hoists	125 000
Turbines and valves	671 000
Crane	72 000
Generator	509 000
Transformer	55 000
Capacitors	7 000
Control equipment	43 000
Site electrical work	76 000
Lloyds inspection	11 000
Transmission*	13 000
Remote controls*	20 000
Land purchase and compensation*	45 000
Raising loans' 25000	
Interest during construction*	570 000
Engineering fees and expenses including commissioning	630 000
	$6 783 000

*Provisional

8. CONCLUSION

This paper was written primarily to describe the engineering features of the scheme with special reference to maintenance and operation, but the authors feel it is also appropriate to remind readers generally that small hydroelectric schemes are worth pursuing.

This scheme was known to be marginal on straight economic grounds but as part of a series of three stations it was considered desirable. Although there were increases in the costs of construction, the results of the first year's operation were better than had been forecast. The station is expected to make a small loss over the next three to four years but, in the long term, there can be little doubt that it will afford the owner a worthwhile return.


Lower Mangapapa Intake Structure and Dam - 25 April 1979 *Photo: David de la Hyde*

9. ACKNOWLEDGMENTS

Thanks are due to the Tauranga Joint Generation Committee for permission to publish this paper, to Mandeno Chitty and Bell Ltd. for use of their drawings and to David Hyde of the Tauranga Electric Power Board for the photography.

Use of information from the paper quoted below is gratefully acknowledged: MANDENO, L and PATTERSON L.S. (1972): Mangapapa hydro-electric project *Trans E.S.A.EI. 42.*

DISCUSSION ON THE PAPER:

ENGINEERING FEATURES OF THE LOWER MANGAPAPA HYDRO ELECTRIC POWER SCHEME:

CHRISTCHURCH 1980

MR D J BINNS (Ashburton Electric Power Board, President ESAEI)

In introducing the authors said that the paper was a topical one in view of the current interest in small hydro electric stations and that this scheme had been engineered by a firm of long standing in the field. He was sure the paper would be of interest to all members especially those contemplating small hydro development.

THE AUTHORS

. In presenting the paper asked members to correct the plant factor figures given in Section 6.2 to read:

Lloyd Mandeno	55%
Lower Mangapapa	34%
Ruahihi	41%
Combined	45%

The average combined output of the three stations was estimated to be 162 GWh from the total installed capacity of 41 MW.

They thought that members would be interested to know that the control equipment specification allowed for programmable solid state or relay equipment to be offered and that at the time, the latter solution was selected on a price basis.

Since submitting the paper they had come across an article published in March 1980 in Mitsubishi Advance describing a 16.5 MW 2-pole induction generator commissioned in April 1979 and so the Lower Mangapapa set is not the worlds largest induction generator as claimed!

If they were designing the station again they would probably add a 11 kV isolator at the transformer terminals to provide the visual break necessary for work to be carried out on the 11 kV system without opening the 33 kV isolator or shutting down the 33 kV system.

MR P M R BROWNE (Tauranga City Council)

Said that operating experience with the station since commissioning 16 months ago had been very satisfactory. There had however been some trouble with the turbine carbon ring seals and in the last month or so, corrosion of a type suggesting possible galvanic attack had been discovered in the seal housings. He thought this could be due to shaft currents circulating through the seals at each end of the shaft. He said that the question of whether or not the station delivered its predicted annual energy output of 18 GWh depended of course on the weather.

MR E W GRAHAM (Tauranga Electric Power Board)

Congratulated the authors on a well presented paper. He supported Mr Browne's remarks that operating experience with the station had been good. In fact, he said, the semi-automatic controls were so simple to operate that there had been a degree of "operator resistance" to manual starting and stopping on the odd occasion when this had been used at the station.

He pointed out that the authors' remark about the desirability of an 11 kV isolator stemmed mainly from the presence of the manually controlled but normally unattended Omanawa Falls Station on the line since shutdowns were complicated by the fact that an operator had to be sent out to this station during switching operations.

He thought Mr Keith might care to describe the arrangements for dewatering the reservoir. He was interested in the author's opinions on the possible siltation of the reservoir.

MR R C W HOWES (Dunedin City Council)

Congratulated the authors on a most interesting paper. He bad noticed the discrepancy between the plant factor and the station output given in the paper. Assuming the 34% plant factor to be correct he asked whether NZE had had any comment at the scheme approval stage in relation to their guidelines on local authority stations. He noted that the gate at the tunnel intake could not be closed under flow and was not therefore a guard gate and asked what consideration had been given to possible failure of a valve or penstock.

Had the roof insulation proved effective? He noted that the turbine and generator bad been supplied separately and from different parts of the world. Had there been any problems in adopting this policy. The clearance between rotor and stator was only 3 mm; to what extent would the machine have to be dismantled in order to carry out winding cleaning?

MR G W LATHAM (Bay of Plenty Electric Power Board)

Asked what fire protection measures had been taken for the generator enclosure. He queried the reason for manually resetting protection relays and asked how long it would take operating staff to reach the station. Hand any special precautions been taken in respect to cooling water and seal water supply?

MR H L HOY (Walroa Electric Power Board)

Found the paper comprehensive despite its brevity. He appreciated the fact that although it was intended to describe the engineering features, some space was given to supportive description and he congratulated the authors. Having recently enjoyed a tour of the whole Tauranga scheme, a number of the points in the paper were more readily appreciated from seeing the site. The craggy and vertical nature of the country and loose surface presented their own difficulties leading to the need to prohibit the use of power boats on the Mangapapa Reservoir. A pity, but accelerated shore erosion can mar the excellence of an amenity brought about by man's interference with nature. Public acceptance of man's interference also suffers. It would be of interest to learn of difficulties encountered in shaking off opposition to flooding a river valley, probably only every visited by Mr Lloyd Mandeno himself.

He was aware from the 1979 Auditor General's report that the constructed cost of the Mangapapa arch dam exceeded the estimated by about twice. Could the authors indicate the cause of this? It was surprising that very little wood debris had collected at the intake after a year of operation. He imagined that a considerable amount of vegetation clearing was necessary before filling the lake and the contractors must have done a good Job. Concerning the main civil engineering structure, the dam movement is stated to have been checked with the use of EDM (Earthquake Duration Metering) equipment. Whose responsibility does it become to analyse the information provided and would the installation of an earthquake alarm be considered of value? Following an earthquake of whatever intensity, is there a stated procedure to be followed? By whom is examination of the structure carried out, who is responsible for the integrity of the dam, and who for instance would be able to require the reservoir to be dewatered.

Inside the power house, the provision of AC drive for operation hydraulics was appreciated, with DC as standby only. The same with bearing lube oil. Upon AC motor failure, was he correct in thinking that plant shut-down would be initiated, so that the DC standby would have only one function - emergency shut down? The P.F. Correction capacitors used Askarel which today is regarded with some disfavour due to its toxicity and extreme danger during arcing. What facilities are available for handling and disposal? What physical protection is there in the event of tank rupture? Turning to fire protection, automatic discharge of smothering gas will be initiated by smoke detectors. What indication might an attendant obtain that the halon fire protection gas was present; what should he do if it is. How long must he hold his breath to get out of the station? Finally, the station earth is bonded to the structural steel. Could the authors inform members of the success or otherwise of the connection?

MR 0 G KLLIS (Otago Central Electric Power Board)

Questioned the authors on the desirability of using a static capacitor bank to provide reactive power for the generator. His Board had recently considered this alternative in the case of a scheme they were investigating and had decided that the alternative of providing greater synchronous generating capacity was to be preferred.

MR J M MOORE (Egmont Electric Power Board)

Spoke on behalf of Mr A R Davis who regretted not being able to attend the discussion. "The paper gives a description of the main engineering features of a recently completed small hydro scheme, but its value to the institute and to supply authority engineers is more than that; it reminds us that small schemes have a place in the total energy scene and that they are worth pursuing. There are many locations throughout the country where a little engineering ingenuity aimed at collecting and diverting water could produce a worthwhile quantity of electrical energy.

The Lower Mangapapa scheme is just part of the composite development of the Wairoa River Catchment which was conceived many years ago by the late Mr Lloyd Mandeno. "I believe that in a sense the authors, in presenting this paper, are paying a tribute to a man who was an enthusiast for the small scheme and was an engineering pioneer."

He had three questions for the authors. At the beginning of the paper it was stated that the station had a capacity of 6 MW and generates 13 GWh. p.a. His calculations gave a plant factor of about 35% whereas later in the paper it was stated that the plant factor was 45%. Could the authors please confirm which is the correct figure and if it was the lower one, was there any difficulty in persuading NZ Electricity that this was sufficient compliance with their operating guidelines? In Section 6.4 reference is made to maintenance recommendations. Could the authors indicate the different trades involved in the maintenance of the station and the time involvement in say, man hours for daily maintenance, weekly maintenance and for longer term overhaul? What is the annual cost of all maintenance? With reference to the recreational use of the lakes, how is the activity controlled? Was there any form of reserves Board or user Committee or other organisation set up to monitor the various activities and to prevent conflict of one type of use with another? Was there any difficulty policing the restrictions which had been placed on the use of the lakes?

MR L E RASMUSSEN (Poverty Bay Electric Power Board)

Asked whether the capacitor bank could have been situated in the switchyard and would they care to comment on the decision to locate the bank within the powerhouse.

MR K G STEWART (Taupo Borough Council)

Noted that with the storage provided there appeared no reason why the machine could not be operated at its best efficiency and wondered why a two-turbine set had been adopted. At 375 rpm he would not expect the machine bearings to require forced oil lubrication. Could the authors explain the need for this provision or was it just a consequence of the tender selection? As the intake screens were at low level and no provision had been made for routine cleaning, how would the operators be aware of screen blockage? Had the engineers considered out-of-balance loading on the generator and the possible need for negative phase sequence protection? Did the authors not think a solenoid valve on cooling water would have been desirable to save water wastage?

MR KEITH (IN REPLY)

Thanked the meeting for the interest shown. Mr Graham had asked about reservoir dewatering and siltation. The reservoir could be dewatered by discharging water through the turbine with the Lloyd Mandeno Station shut down. The water remaining below tunnel invert level would then be drained through the opening in the base of the dam which had been used for river diversion during construction and which was normally closed by a bulkhead gate. Access for fitting lifting tackle and for lifting the gate could be obtained by boat after dewatering through the turbine. Once the gate in the dam was opened, generation at Lloyd Mandeno could be resumed.

The 55 year old Lake McLaren reservoir downstream of the station had silted to a considerable degree in its upper and middle reaches. This had not affected the McLaren Power Stations' intake directly although at extreme draw down increased flow velocities tended to draw silt into the water and cause difficulty in the power station cooling water intakes. The Lower Mangapapa Reservoir has a catchment only a third that of Lake McLaren and siltation was consequently expected to be correspondingly reduced.

Mr Howes and Mr Moore had asked about NZED's attitude to the station plant factor. As far as the authors were aware, NZED had been satisfied with the applications made and had granted the licences to generate without comment on this aspect. Mr Keith thought it probable that they would have more regard for the overall plant factor of the whole development than for the individual stations.

In reply to Mr Howes' comment on the lack of a guard gate the engineers had regarded the penstock and station pipe work as sufficiently secure to make a guard gate at the intake unnecessary in this instance. In the event of a failure in the valve mechanism the flow could be shut off using the turbine wicket gates. The roof insulation had proved effective in preventing condensation drips onto the machine floor in cold weather. Dividing the main machinery into separate contracts did introduce an element of contractual risk but there had been a considerable financial gain. In the case of Lower Mangapapa, on balance, there had been a substantial gain to the owner in the action adopted.

Mr Hoy had asked about environmental matters. The question of shore erosion might have been overstated. Some erosion had occurred, but experience at the other reservoirs had indicated that in the long run erosion could be expected to be fairly limited. There had been no opposition to the flooding of the river valley. The arch dam had cost considerably more than estimated due to the degree of open jointing found in the foundation on excavation. This had necessitated additional excavation, concrete and grouting. The right abutment had also to be strengthened by reinforcing with steel rods installed across joint lines. The additional work in strengthening and grouting had come towards the end of the construction period and escalation had added appreciably to the cost. The additional work also appeared significant in comparison with the original cost because the structure was of small volume, only 3000 m of concrete, and the additional treatment became a major proportion of the work. The authors apologised to Mr Hoy for using the contraction "EDM" instead of saying what they meant. EDM was intended to mean "electronic distance measuring". The owners are responsible for the integrity of the dam and for the necessary inspections during its life. No earthquake alarms were installed. Following severe earthquake, damage to the structure or its foundations would be ascertained by observing increases in leakage and movements that had occurred. Dewatering of the reservoir could be effected as described above if considered necessary.

Mr Moore had asked about policing the restrictions on recreational use of the reservoir. The Tauranga City Council Parks Department administered recreational use of reservoirs and lake environs were open to the public on behalf of the joint owners. No difficulties had been encountered in the year and a half since the scheme had been completed.

In reply to Mr Stewart the two turbine arrangement had not been a requirement but had come about because that had been the most economical machine offer even allowing for the additional costs in penstock and power house. It was not particularly preferred to a double discharge turbine horizontal shaft arrangement and as Mr Stewart had noted there was no advantage in this case in having two turbines.

MR WILSON (IN REPLY)

To Mr Browne said that the problem he reported of corrosion in the seal housings was an interesting one. There were a number of possible causes and further Investigation was warranted. Insulation was provided under the bearing pedestals in the usual way, but in retrospect, it was obvious that the carbon seals bearing on each end of the shaft could provide a circulating current path through the foundations. It should be possible to fit insulation into the seal assembly if found necessary.

To Mr Graham he said he was pleased to hear the operators found the controls simple to use. There were in fact only 5 generator controls - Start, Stop, Raise Load, Lower Load and Emergency Stop. Switching-in was achieved simply by taking a voltage signal from the PMG and using this to switch a voltage relay to close the circuit breaker within the limits of ± 2i% of synchronous speed. Setting up at the time of commissioning was checked with a hand held tachometer. There was little mechanical shock on switching-in.

He confirmed to Mr Howes that the placing of orders for the turbines and generator with separate companies had resulted in a big saving and had raised no special problems in this instance. However, he supported the point that divided responsibilities created an element of risk. With a vertical set, for example, a vibration problem, if it arose, might be disclaimed by both suppliers, possibly leaving the purchaser without a financial remedy.

The point about the small air gap (3 mm) was an interesting one. However, since the rotor was cylindrical, not salient pole, cleaning would largely be confined to the end windings and should be able to be achieved manually and with compressed air without any dismantling beyond the removal of end covers.

To Mr Latham he said that open air cooling had been chosen for the generator on the grounds of simplicity and low cost. Fire quenching in the generator enclosure was therefore impractical because of the large volume of gas which would be required. The provision of dampers to enclose the space in the event of fire had been considered but not adopted since the generator was largely built of non-combustible materials anyway and had a high resistance earth.

The policy decision in favour of manual re-setting of protection relays was taken on the basis that the relays would not be operated unless an abnormal condition existed and that in such a case a visual inspection was desirable, prior to re-starting. It took the duty operator about 10 minutes to reach the station.

No special precautions had been taken in respect of cooling and seal water apart from providing a filter. The water was non-aggressive and did not contain many suspended solids. The authors did think however, that there were good reasons for taking cooling and seal water from an independent source rather than the penstock if this could be arranged on other projects.

Mr Hoy had asked if failure of an AC motor drive would shut down the plant. The answer to this was no, but an alarm was raised to alert the operator to the condition. The plant would run on the standby DC drive.

No special facilities were provided for handling or disposal of Askarel in the event of a capacitor tank rupture. However, steps had been taken to contain the fluid as explained in the paper. The bank was a small unit comprised of 6 cans, and the authors considered the risk of failure and potential damage to be slight.

Operation or malfunction of a smoke detector element was indicated to operating staff by the extinguishing of a light on the detector. The operator should then proceed on the basis that Halon gas had been discharged, until he was able to establish otherwise. If gas is present, the first step is to wait for it to disperse, then to investigate the cause of discharge. The gas is not toxic but is an asphixiant. It would be possible to get out of the control room on one "breath", or to get clear of the 11 kV switchgear panel on the machine floor.

The author's experience with earth electrodes comprised of a building's structural steelwork was that this method was a very satisfactory one and in almost every case had given better results than driven electrodes.

To Mr Ellis, he pointed out that the capacitor bank at this station supplied only a part of the generator's reactive power requirements, the remainder coming from synchronous generating capacity on the system. The bank was a small one on a comparatively large machine. A 12 kV rating had been chosen on purpose to provide an extra margin against over-voltages due to self-excitation and the bank had been bought in two parts in case it was found necessary to reduce its size. This had not been necessary. The bank was cheap and effective - much cheaper per kVAr than the provision of extra reactive output on the Ruahihi machines had been.

Time did not permit a full answer to be given to Mr Moore on the maintenance question. Mr Wilson referred Mr Moore instead to the Plant Operating and Maintenance Manual which his firm had prepared and in which a detailed preventive maintenance programme had been laid out, comprising daily, weekly, monthly and other checks. Unplanned maintenance was carried out with whatever labour was required or available.

To Mr Rasmussen he said that there was no reason why the capacitor bank could not have been located in the switchyard, other than the fact that he had not seen the presence of this bank within the power house as a significant problem.

He said Mr Stewart was correct in supposing that forced oil lubrication was not specified but was simply the system offered (and insisted on, actually) by the supplier.

A differential pressure device was provided in the intake to warn operators of screen blockage.

The need or otherwise for negative phase sequence protection to eliminate the risk of overheating ob unbalanced loads had been considered. The decision not to fit it was based on prior operating experience which showed the 33 kV subtransmission system voltages to be well balanced. In addition, the temperature rise of the generator when on load appeared to be well within the specified limits and there was therefore a margin to spare for faults.

At the time the station was designed, calculation showed a cooling water shut-off valve and control interlocks to be unjustified but it could be an analysis today would give a different answer.

On behalf of the authors he thanked the members for the interest taken in the paper, which had been most gratifying. They should also like to express their appreciation to the Association for the opportunity to present the paper.

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A W A R D

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WHEREAS the Award of the Electric Supply Authority Engineers' Institute of New Zealand Incorporated may be made ....

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and

PURSUANT to the recommendation of the Awards Committee adopted by the Institute in annual meeting in Christchurch on 23 September 1980

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and

JEFFREY WEBSTER WILSON, M.E., B.Com., C.Eng., M.I.E.E., M.I.E.E.E., M.N.Z.I.E.,

Directors

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