THE 1968 INANGAHUA EARTHQUAKE AND ELECTRICTY SERVICES

H. C. Hitchcock, B.E. (Hons.) M.N.Z.I.E. M.I.E.E.

Including information supplied by -

W.H. Brown, Chief Engineer, Buller Electric Power Board
N.R. Langbein, Chief Engineer, Grey Electric Power Board
J.E. Coglan, Chief Engineer, Waimea Electric Power Board
D.S. Cannon, Electrical Inspector of Mines and Quarries

Electric power is carried into the area by the N.Z.Electricity Department over 66kV transmission lines as shown in Fig. 1, and supplied to the Electric Power Boards at Substations as indicated. Figure 1 also shows the estimated location of the epicentre of the main shock and its distance from the principle installations.

The main shock at 5.24 a.m. on 24 May 1968 interrupted supply over most of the northern end of the South Island and in some places in the North Island. Where this was due to false operation of Buchholz relays, supply was restored in a matter of minutes. It was three hours before temporary repairs and bypassing arrangements at Inangahua made power available at Waimangaroa and Westport and it was still later before supply could be provided in Inangahua itself.

N.Z.E.D. radio and telephone facilities initially provided the only links with the worst affected area, Inangahua, and were the means of conveying the evacuation order when the flood threatened. N.Z.E.D. staff and vehicles, carried out the evacuation of nearly 50 of the women and children.

The high voltage equipment involved was designed for 66 kV or in some cases 110 kV so that the detailed reports of damage are similar to those made after the Napier earthquake of 1931 (Ref. 1).

The effects of the earthquake can be summarised thus:

Transmission lines

The design of transmission line towers and terminal gantries is dominated by wind loading.

Earthquake loads on such structures are insignificant and the only real risk of failure is from disturbance to foundations. Fig. 2 shows how nearly this occurred in the Upper Buller Gorge near Lyell - at a point only 7.5 miles from the epicentre. The worse damage to towers themselves was on top of a ridge of poorly consolidated alluvial material near Dee Creek 2 miles north of Inangahua. The upper levels of the ridge were disintegrated with the violence of the shaking and the disturbance of the grillage footings was so great that an angle leg was fractured. Many towers were distorted to a lesser degree but none failed in service.

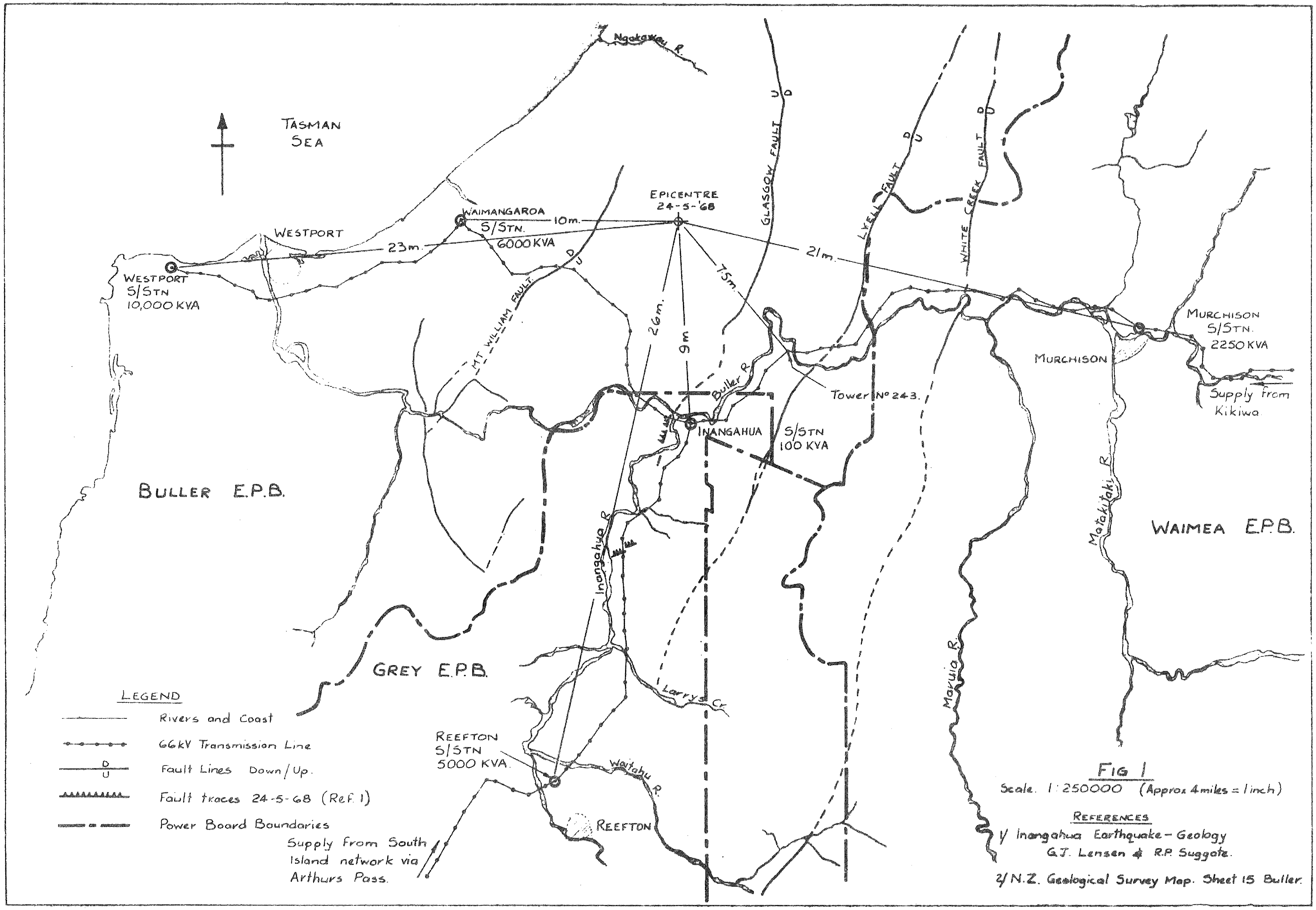


Fig 1

Scale. 1:250000 (Approx 4 miles = 1 inch)

References

1/ Inangahua Earthquake - Geology G.J. Lensen & R.P. Suggate.

2/ N.Z. Geological Survey Map. Sheet 15 Buller.

Substations

Inangahua Substation (Fig.3) was 9 miles from the epic
but was in the zone of maximum ground damage and shaking.

In the small control building the station battery and
control, relay and communications panels were overturned be
of inadequate fastening.

In the outdoor switching station the lattice steel swi
structure was undamaged and its foundations undisturbed as
bulk oil type circuit breakers and their foundation slabs.
of the 66 kV insulator stacks in the airbreak switches were
off because jumpers did not have enough slack to allow for
movement between the steel structure and adjacent equipment
broken insulator stacks swung down on the ends of the jumpe
damaged the transformer neutral bushing and the support ins
for the power line carrier coupling capacitors.

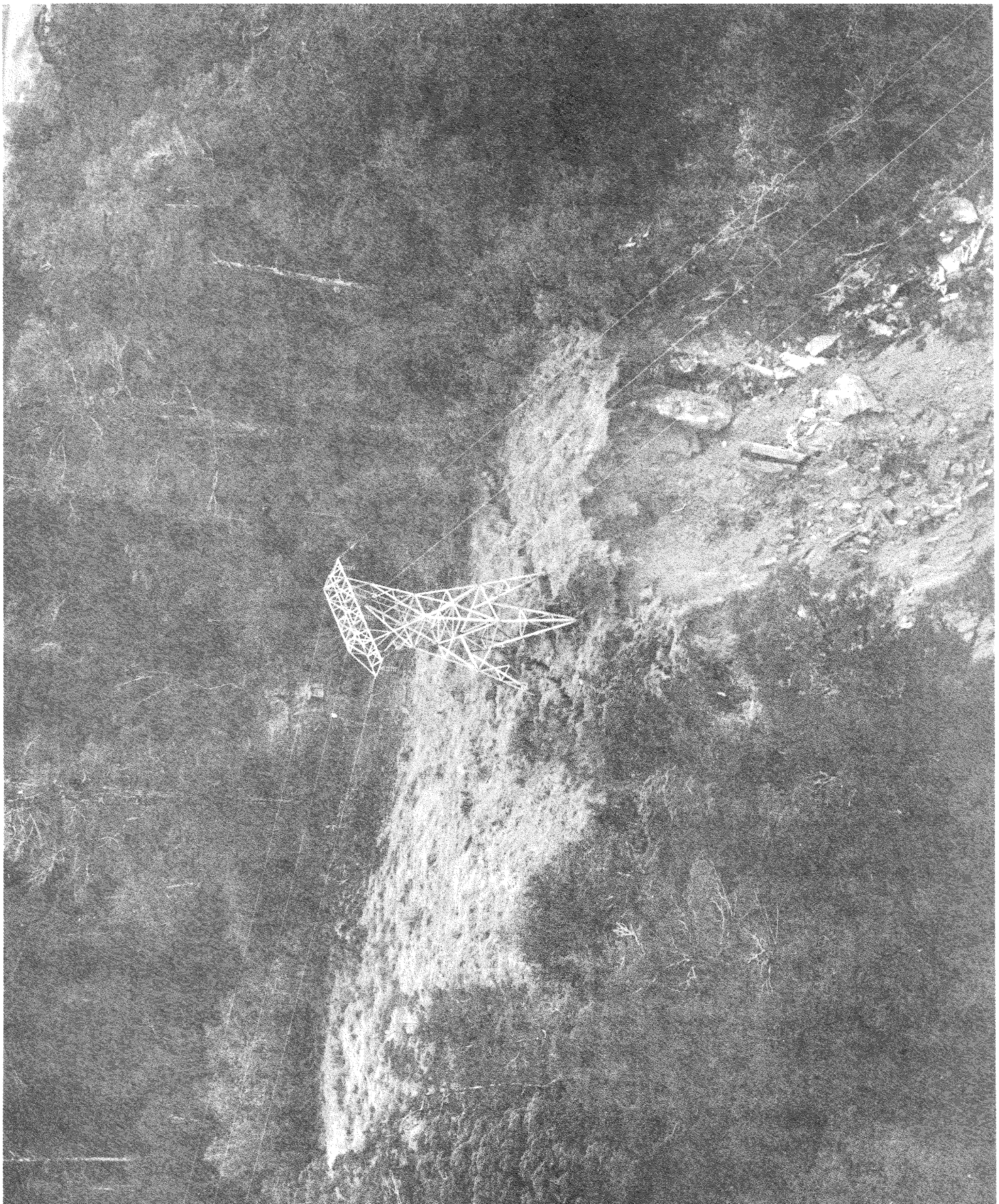
The small permanent staff at the substation were howev
able to carry out sufficient repair work to bypass the inop
circuit breakers and allow through transmission of power to
resumed about three hours after the main shock.

The six departmental houses and the depot building wer
severely shaken. In contrast, the control building of the
same general construction but with a smaller "weight to bra
strength ratio" showed no sign of distress. Four of these
were of weatherboard construction with non-continuous concr
foundations and had just had their tiled roofs replaced wit
corrugated iron (in accordance with the Department's policy
not using concrete tiles in hard frost areas) but in spite
relief of roof weight they were so strongly shaken that sto
and refrigerators were thrown about and overturned, hot wat
cylinders broken from their connecting pipes and even a bow
lighting fitting torn from the ceiling.

At Reefton Substation 26 miles from the epicentre the
flanged wheel transformers had each moved their 4 fixing cl
gripping the head of the rail with the pressure from two 3/
bolts), by about 1½ inches.

In contrast, nearby wooden houses with piled, non-cont
foundations, were undamaged (though some of the contents we
thrown to the floor) and in the reinforced concrete block d
building not a single item was displaced from shelves or wo

At Murchison Substation 21 miles from the epicentre th
no trace of earthquake disturbance whatever, although only
from the Murchison Post Office where .3g max. ground accele
was recorded. This substation stands on rising ground acr
river where foundations are very firm and this undoubtedly
the severity of ground surface shaking.



At Waimangaroa Substation 10 miles from the epicentre the 16½ ton flanged wheel transformers moved by 2 to 3 inches bending the holding straps and in one case shearing a 3/4 inch bolt.

The 3" x 3" x 3/16" angle frames supporting circuit breakers were distorted and one flange of one leg cracked.

At Westport Substation 23 miles from the epicentre the 11½ ton transformers hammered their friction grip wheel wedges out of place by about 2 inches.

Distribution

Retail distribution of electric power in the area affected by the earthquake is undertaken by the Electric Power Boards indicated in Fig. 1.

Damage experienced by these authorities resembled that caused by the Napier earthquake (Ref.1) many service connections damaged but little damage to house wiring, some clashing and damage to 400/230 V and 11 kV lines, poles leaning over, or carried out of alignment or allowed to sink deeper (by up to 3 ft) by slumping of roads or embankments or by slips.

The two Boards with small hydro generating plant (Buller and Waimea) reported some damage to civil engineering works and the two Boards supplying the coal mining areas (Buller and Grey) reported very heavy increase in electricity demand 15% - 20% when consumers turned to electric heating because of broken chimneys.

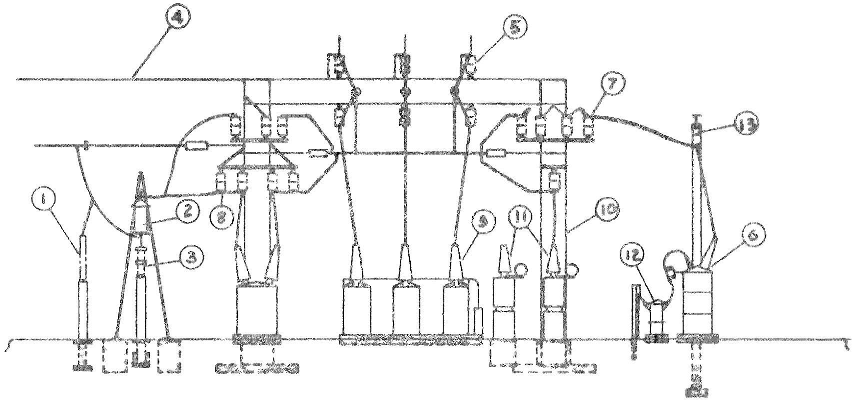
Coal Mines

No damage to electrical equipment was reported even in workings about 8 miles from the epicentre. It has been noted previously (Ref. 2) that ground shaking is relatively less severe underground (though no less terrifying). Another factor was that electrical installations underground were neither massive nor extensive.

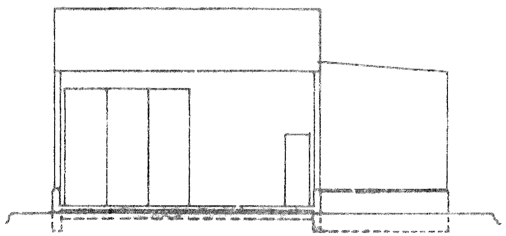
Summary

(1) Anti-earthquake design of transmission lines consists primarily of selecting tower sites least likely to be affected by earthquakes. The advice of a geologist was sought in selecting routes for deviations made necessary by ground failures in the Buller Gorge.

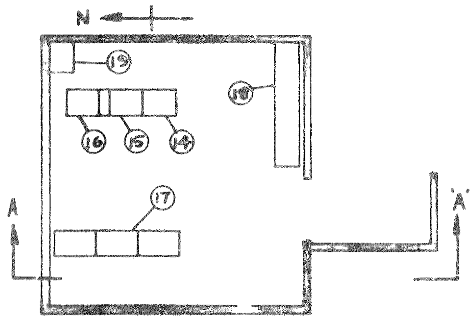
(2) The damage to battery and control panels emphasizes that earthquakes design must attend to minor detail with great care if major provisions are not to be nullified.



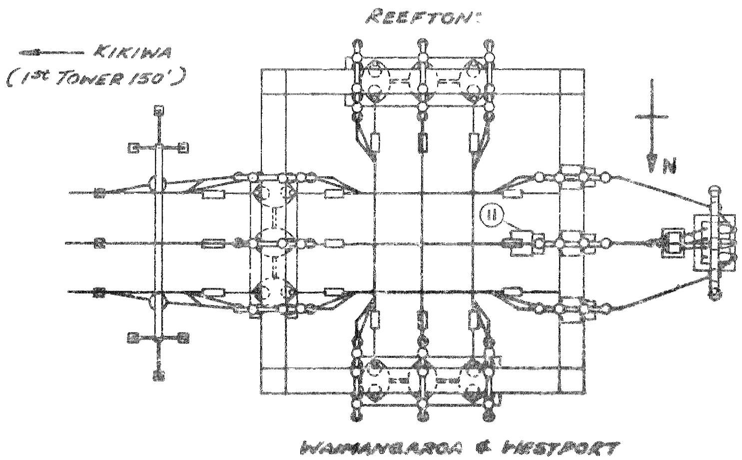
ELEVATION



SECTION 'A'-'A'



CONTROL ROOM PLAN
SCALE 1/8" = 1'-0"



SWITCHGEAR & STRUCTURE PLAN
SCALE 1/16" = 1'-0"

20

LEGEND

1 - LIGHTNING ARRESTORS.
2 - LINE TRAP.
3 - CAPACITORS.
4 - EARTHWIRE
5 - BY PASS AIR BREAK SWITCH.
6 - 100 k.V.A 66/11 kV TRANSFORMER.
7 - TRANSFORMER ISOLATOR.
8 - O.C.B. LINE SIDE ISOLATOR.
9 - O.C.B. (M.V. G.11).
10 - LATTICE STEEL STRUCTURE.
11 - VOLTAGE TRANSFORMER.
12 - 50 k.V.A. 11/0.4 kV TRANSFORMER.
13 - WOOD POLE LIFTING GANTRY AND JUMPER SUPPORT.
14 - D.C. PANEL
15 - CONTROL PANEL.
16 - RELAY PANEL.
17 - COMMUNICATION PANEL
18 - STATION BATTERY.
19 - COMMUNICATION BATTERY.
20 - OIL TANK.

(3) The damage caused by tight jumpers repeats experience at Napier in 1931. The "earthquake release clamps" devised at that time were found unsatisfactory because they gave trouble in storm conditions and became increasingly difficult to design for higher current ratings. It is a continuing challenge to engineering ingenuity to devise connections which are tidy and will not clash in the wind but which allow earthquake movement.

(4) Buchholz relays almost universally incorporate mercury switches which falsely trip circuit breakers during earthquakes. A type using reed relays for contacts is now available but for existing installations a contact making pendulum has been developed which will energise a time delayed relay to interrupt the tripping circuit for the duration of an earthquake and about a second thereafter. This is being fitted to a transformer bank on a trial basis.

(5) Permanent repairs to electrical equipment were hampered by the need to rehabilitate accommodation first. This suggests that houses and buildings for public utilities would better serve their purpose if by closer attention to detail they were designed to survive an earthquake of this size not necessarily without damage but "in working condition". In this connection it should be noted that the standard of earthquake resistance provided by the N.Z. Model Building Bylaws NZSS 1900: Chapter 8 is a minimum and as indicated in section 9.9 of the "Commentary on Chapter 8" (MP12:1965) the owner of a building should decide whether for economic or operational reasons he should specify and pay for a higher standard of construction.

(6) The violent shaking of wood-framed houses on low strength foundations and of the poorly braced depot building in spite of its solid foundations can be explained, by inspection of an earthquake response spectrum, as an example of the "fail unsafe" potential of rigid constructions which loose their rigidity by yielding at accelerations less than about .4g or .5g - a point which must be borne in mind when designing earthquake fastenings for heavy plant like transformers.

(7) Distribution Authorities have less choice in locating poles and substations and some damage must be expected. It is pleasing to note that no pole mounted transformers are reported thrown to the ground as they were in previous earthquakes.

(8) The more modern higher voltage equipment in use in other parts of N.Z. has yet to be earthquake tested but it is now known to be more susceptible and measures are in hand to improve its resistance.

(9) A study on this subject will be published shortly (Ref. 3) which shows the need for dynamic analysis of the earthquake response of electrical equipment and where this is not available, suggests a seismic design factor of .75g for general use but with special consideration as follows:

large transformers - reduce to .4g if installed so that natural period of vibration on its final foundations is less than 0.1 second;

equipment which fails in porcelain or other brittle components - increase to 1.5 g if nothing is known of its dynamic properties but if Equivalent Viscous Damping (Fraction of Critical) can be shown to be not less than .02, .05, .1, .2 or .4 then the Seismic Design factor must be at least 1.3g, .95g, .75g, .55g, or .4g respectively. Equipment with more than one mode of vibration requires an appropriate dynamic analysis.

References

(1) Effect of Earthquakes on Electric Supply Systems. I.R. Robinson and H.L. Benjamin; Proc. N.Z. Soc. C.E. V.XIX 1932 - 33.

(2) Earthquake Risk in New Zealand: J. Henderson. N.Z. Journal of Science and Technology, V.XXIV No.5B, 1943.

(3) Electrical Equipment and Earthquakes. H.C. Hitchcock N. Z. ENGINEERING 1969 V.24 No. 1