

**BEFORE THE BOARD OF INQUIRY**

**IN THE MATTER** of the Resource Management Act  
1991

**AND**

**IN THE MATTER** of applications for resource consent  
and notices of requirement by  
Transpower New Zealand Limited for  
the North Island Grid Upgrade Project

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**STATEMENT OF EVIDENCE OF ROBERT GEORGE LAKE IN REBUTTAL (1) ON  
BEHALF OF TRANSPOWER NEW ZEALAND LIMITED  
(Transmission line engineering, design, structures and foundations)**

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SIMPSON GRIERSON  
D J S LAING / J G A WINCHESTER  
TELEPHONE: +64-4-499 4599  
FACSIMILE: +64-4-472 6986  
DX SX11174: PO BOX 2402  
SOLICITORS  
WELLINGTON

J S KÓS QC  
STOUT STREET CHAMBERS  
TELEPHONE: +64-4-472 9026  
FACSIMILE: +64-4-472 9027  
PO BOX 117  
WELLINGTON

## Introduction

1. **MY** name is Robert George Lake. I wish to present rebuttal evidence in relation to the statements of evidence of:
  - (a) Mr Paul Robinson;
  - (b) Mr Doug Parker on behalf of Hunua and Paparimu Valley Residents' Association Incorporated; and,
  - (c) Mr Lance and Mrs Donna Levesque.
  
2. I address the evidence of each submitter below.

### **Dr Paul Robinson (Submission number 0643)**

3. **REFERENCE** is made by Dr Robinson in his paragraph 11 (and by Mr Levesque on his page 5) to the proximity of the existing lines to the proposed line, and the potential for multiple line impact from a significant event. The centreline of the proposed line will be a minimum of about 60m from the centreline of any existing line to ensure all electrical impacts are within required limits, but this spacing also provides a reasonable separation to minimise event impacts on multiple lines.
  
4. **THERE** are no regulations that cover this separation other than to provide a safe installation. Because the individual lines effectively cross different terrain, the towers are generally not in line with each other, and would prevent the extreme situation of one tower failing and affecting a tower or even the conductors on an adjacent line.
  
5. **WITH** reference to paragraph 16 of Dr Robinson's evidence, under any wind event, the conductors on adjacent lines would generally be blown in the same direction and to a similar lateral extent, depending upon the span lengths, such that the conductors from one line would not affect the conductors on another line. The details of adjacent lines and their behaviour are considered when defining minimum spacing of lines and associated tower positions and when reviewing clearances. For all design events, at no point along the proposed line would the

conductors of the proposed line be separated less than the required electrical spacing distances.

6. **AS** indicated in my first statement of evidence at paragraph 110, failure of the proposed tower types would generally only affect a small area of land immediately adjacent to the failed tower, and they tend to fail such that the tower top collapses onto itself rather than to where they could affect adjacent lines. It is therefore highly unlikely that the effect of an extreme event causing the unexpected failure of a tower would have an impact on the adjacent OTA-WKM lines.
7. **THE** failure of the 3 sequential HVDC towers on the Benmore to Haywards line in 2004 was caused by an extreme wind event that NIWA calculated had a return period of greater than 600 years and possibly as high as 1300 years. The wind was also associated with the 'lee zone' affect that only occurs a limited distance from high mountain ranges. The proposed line is not within an identified lee zone.

**Mr Doug Parker on behalf of Hunua and Papparimu Valley Residents' Association Incorporated (Submission number 0748)**

8. **MR** Parker raises a number of issues regarding the design of the line configuration relating to the spacing of the phases and circuits and the resulting height of the conductors off the ground and overall tower height. Mr Khot has replied in relation to the electrical considerations and calculations that produced the tower design being proposed, and I will add to that understanding in relation to the effect on the tower loading of the various spacings and alternative insulation options that are part of a review for compact design.
9. **IN** Appendix 2, paragraph 11 of Mr Parker's evidence, various comments are made about compact design covering both electrical and structural considerations. In particular, in the third dot point, the issue of loads in the crossarm region of the tower was raised for the use of V string insulators.
10. **BY** definition, V string insulators are a pair of insulators supporting a single bundle of conductors (phase) which have an included angle of about 90 degrees. The arrangement spreads the normal loads out to two points on the crossarm, compared to one point for a single vertical insulator, but under high wind loads,

where one arm of the V string is near going into compression, the total load is still effectively taken at just one point on the tower.

11. **IT** is correct to say that a crossarm designed specifically for a single vertical insulator arrangement would not necessarily be able to accommodate the loads from a V string arrangement, especially if the inner arm of the V string support is mid way along the crossarm. Therefore to go from one type to another could involve some additional members, and consideration of the appropriate loading distribution through the members, but is unlikely to involve any significant additional loads on the foundations for conductors at the same level.

**Figure 8 Photo of Typical V String Insulator Arrangement (Bottom Phases)**

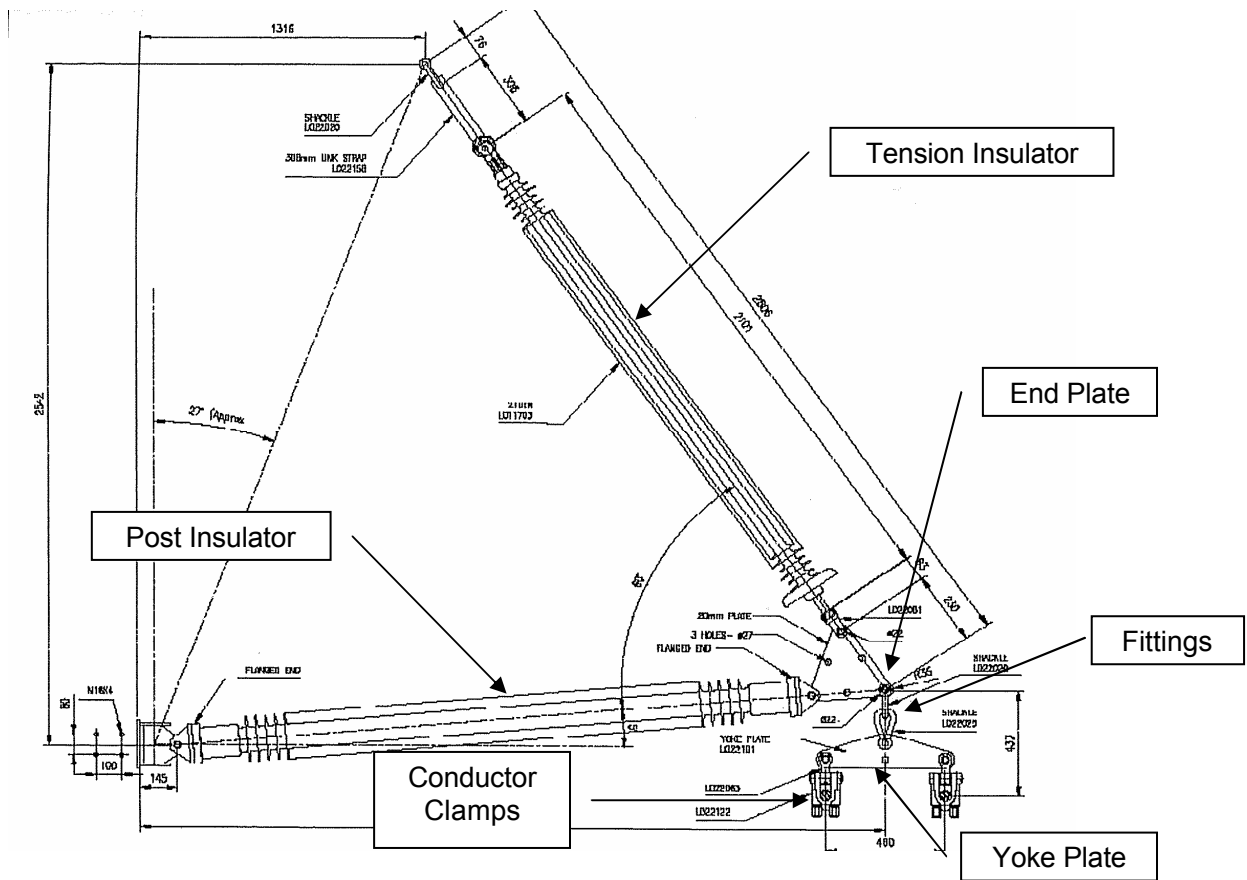


12. **CROSSARM** lengths for V string arrangements are generally the same or longer than for single vertical insulators because of the included angle, even for a more compact design. As such the loads are effectively applied to the tower at a greater distance from its centreline, which can impact the overall tower loads. The first method of reducing such an effect would be to increase the slope of the top chord member of the crossarm, but as indicated in my first statement of evidence in paragraph 46, any increase in the top chord slope can significantly affect the

required vertical spacing of the phases which has the flow on effect to tower height.

13. **AS** indicated in my earlier description, it is always a compromise and optimisation process to come up with the best and most efficient shape of a tower, to both minimise the loads and resulting member sizes, but also to provide the necessary electrical clearances and line behaviour.
  
14. **ANOTHER** consideration for V string arrangements is that they are generally acceptable for straight lines, but for turn-off angles, alternative arrangements need to be designed. In some cases, the use of insulators that can accommodate some compression loads (e.g. post insulators or composite long-rod insulators), are necessary to resist the loads and maintain the conductor position in the required position. V string arrangements require strict limits on the wind span versus the weight span to ensure that the insulators can not go into compression, which would in turn have an influence on where towers can be located along the line. There are also issues with limited live line access to V string supported conductors that are not consistent with the design philosophy of the proposed line.
  
15. **IN** Appendix 2, paragraph 11 of Mr Parker's evidence, fifth dot point, reference is made to an Akimbo insulator arrangement, as presented in his Figure 5. This arrangement has been used on several Transpower lines where existing towers were involved, to raise the conductor as part of line uprating works. An example is the Henderson-Otahuhu A line (HEN-OTA A). Akimbos have the advantage of effectively replacing the crossarm, but as for the V string arrangement discussed above, the loading is limited due to the need for compression capacity of the insulators, and therefore restrictions in to which spans they can be applied.

**Figure 9 Typical Akimbo Insulator Arrangement**



16. **IN** the Akimbo arrangement, the lower almost horizontal insulator has to accommodate basically all the horizontal load due to conductor tensions in turn-off situations, and the applied wind load. For the common two part arrangement, they have very little longitudinal restraint to accommodate unbalanced loads. The axis of rotation at the structure end is rotated from the vertical to provide some restoring force – as the assembly rotates the conductor has to be lifted up.
17. **SINGLE** vertical insulators can readily accommodate longitudinal unbalanced loads, as they are free to swing into the adjacent span. As such Akimbos are inherently unstable in the longitudinal direction, and for long spans they tend to swing into the span with generally limited restoring forces involved.
18. **TO** assist this, some utilities (e.g. Powerlink (Queensland)) use two lower chord insulators spread at the structure end, or possibly a second top chord insulator. These add to the insulator maintenance requirements, the initial cost is higher, and the compression capable insulators are significantly more expensive than normal suspension insulators. However these modified arrangements are still limited as

to where they can be used, and still only in generally straight line sections, with alternative arrangements applied at the turn-off angles.

19. **FOR** the HEN-OTA A 220kV line, a significant amount of work went into analysing the proposed loading situations to ensure they would be stable under all expected wind events. For the HEN-OTA A line, the Akimbos are only located in spans adjacent to strain towers, such that the amount of longitudinal movement (slack in the conductor) is automatically limited. It is understood that Powerlink are not proposing to use Akimbo insulators on any new lines because of their inherent Akimbo stability issues.
20. **WITH** reference to Appendix 2, paragraph 11, dot point 5 of Mr Parker's evidence, regarding the loading associated with Akimbo insulators, this arrangement produces basically the same loading as for single vertical insulator arrangements. Although physically for the single vertical arrangement, the load is applied at the conductor level, which is in turn transferred up to the crossarm and then into the tower superstructure, for conductors at exactly the same height for both an Akimbo and a conventional vertical insulator, the horizontal loads can still only be applied at the conductor level. Therefore as far as the overall tower is concerned, the load is basically identical, with the only difference in loading being due to the slightly increased height resulting from the swing of the insulator lifting the conductor attachment point, and therefore the level at which the load is applied. For normal design situations, Transpower tends to take the phase loads and apply them at the actual crossarm level, and ignore the small changes in geometry of the situation.
21. **WITH** reference to Appendix 2, paragraph 11, dot point 6 of his evidence, the impact of decreasing the righting moment for the single vertical insulator arrangement when under wind, is also small as the conductor position never goes past the centre of the tower, and the weight load involved is also relatively small compared to the horizontal wind load. The conservative nature of applying the actual conductor loads at the level of the crossarm allows for this small variation in the loading.
22. **THE** impact on the easement width for using the single vertical insulator as noted in Appendix 2, paragraph 11, dot point 7, is also small. Because the conductor within a given span length swings the same amount, irrespective of how it is attached to the tower, the only difference in resulting easement width between an

Akimbo and a single vertical insulator, is the horizontal component of the insulator swing.

23. **A** single vertical insulator that is 4.4m long, even if it could be swung round under wind load to be perfectly horizontal, could not affect the easement width by more than its length. In reality, the corresponding insulator swing is only of the order of 30 degrees meaning a horizontal distance of only about 2.5m due to insulator movement and overall less than 10% of the proposed minimum easement width. This is another compromise situation, where on one hand we are trying to maximise the easement width to ensure tree clearances can be accommodated, but wanting to minimise the easement width impact for land use.
24. **MR** Khot has described the limited advantage in overall tower height by using Akimbos. Other disadvantages with these insulators are the maintenance aspects, in that they provide no way of direct access to the conductors, while conventional crossarms allow personnel to be positioned directly above the conductors. In addition, if live line maintenance was possible, safe working practices would require the longitudinal movement to be independently restrained. Akimbo insulators would only be proposed in special situations where the use of normal crossarms and single vertical insulator arrangements were not possible.
25. **ON** page 10 of his evidence, Mr Parker refers to the proposed lattice towers as being “unchanged since the first half of the 20<sup>th</sup> century” or in Appendix 2 as “traditional large 19<sup>th</sup> century angle-iron structures”. Although there have been subtle changes in tower geometries, and certainly improvements in the way these towers are analysed, the basic concept has stood the test of time, and I believe is still the most common form of new transmission structure being erected. The use of this basic design for the new 1000kV towers in China is a recent example.
26. **THE** steel lattice towers are very efficient for load distribution, and because of their large number of relatively small members, are easy to construct. A significant amount of research is proceeding even today (CIGRE) to improve the understanding of the behaviour of loads in these towers, and to maximise the utilisation of any inherent strength involved. While some countries may be using steel poles or architecturally designed structures for some of their lines, they are generally for unique locations or short sections of line or for specific construction reasons, but with the preference always being to use lattice steel towers for higher voltage transmission structures.

27. **SIMILARLY** on page 17 of his evidence, Mr Parker refers to the proposed towers being the “largest towers, in both height and bulk, to be constructed in this country”. While the 70m maximum height is greater than for the 220kV tower families in the country, the proposed maximum height provides a similar height range to 400kV towers used in other countries. With regard to the ‘bulk’, the likely tower leg members are similar in size to those already used in many other towers around the country, as these are limited in size to what is available from the manufacturer.
28. **THE** width of the tower is adjusted (to reduce the applied load) to ensure these members are appropriate. The ‘bulk’ comes from the number of bracing members included to distribute the load and to support the leg members, and in particular the size and shape of the connecting gusset plates. In fact, there are many Japanese designed towers within New Zealand that are considered to have a bulky arrangement of members and plates. Mr Lister discusses the visual aspects of this consequence in more detail.

**Mr Lance and Mrs Donna Levesque (Submission number 0914)**

29. **ON** page 14 of their evidence, Mr and Mrs Levesque comment on the likelihood of a large magnitude earthquake in the area causing concerns over security of supply. As indicated in my evidence in paragraph 70, the proposed line route does not cross any active faults, and although some sites may experience the effects of seismically induced liquefaction of the soils, these locations will be accommodated appropriately to ensure that the tower foundations are designed to accommodate the effect.
30. **OTHER** seismic effects that can be significant for rigid multi storey buildings are not significant for normal transmission lines appropriately located and aligned, where the suspended conductors tend to dampen out the vibration effects. As indicated in paragraph 5 above, it is unlikely that an extreme event failure of one of the proposed towers would affect the adjacent OTA-WKM lines, and therefore not have an impact on the overall security of supply.

**Robert George Lake**

**2 April 2008**