VIBRATION DAMPERS – AN EVOLUTION IN AUSTRALIA

ABSTRACT

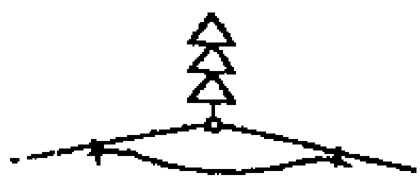
Because of its open terrain, Australia is more prone to aeolian vibration fatigue of overhead conductors, than most countries.

Since the early 1930's, we have experienced fatigue failures of conductors in suspension clamps and so there is a long history of this phenomenon and its treatment. This paper deals with the evolution of vibration dampers used in Australia from the early 1930's to the present time, which covers a period of over 60 years.

The first vibration dampers ever used were invented in Australia by Ernest Bate of the State Electricity Commission of Victoria and the paper by Bate and Callow in 1934 is still referred to in technical literature around the world - Ref 1.

The original BATE dampers, also called BRETELLE dampers are still used in France and on fiord crossings in Norway.

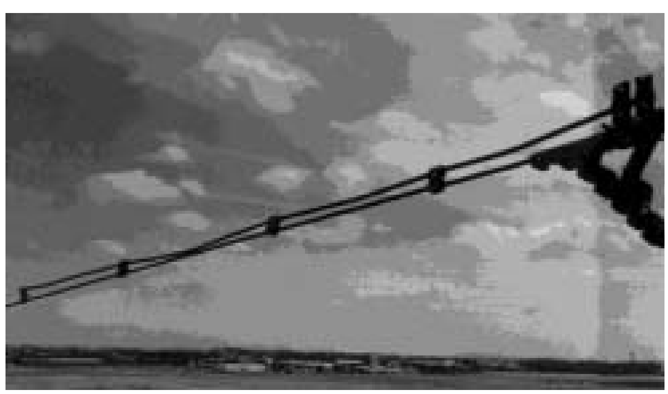
BATE dampers (BRETELLES) consist of a length of conductor similar to the main conductor in the span slung under a suspension string of insulators and attached by a type of parallel groove clamp to each adjacent span approx. 1-3 metres (depending on conductor size) out into the span (Figure 1). It looks and acts like the "JUMPER" or "BRIDGE" at a tension tower.



Bate

Figure 1

The Bate dampers took on many forms and in the 1930's and 40's a number of variations were tried including an inverted model where the extra conductor was mounted above the main conductor (Figure 2).



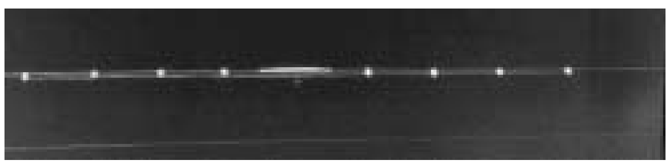
Inverted BATE Damper at Strain Clamp

Figure 2 and photo

Three and four loop dampers of one piece construction (Figure 3 and Figure 4) and even a Bate damper mounted around a mid span joint (Figure 5) where fatigue failures had occurred.

Modified BATE Damper | BATE Damper at Strain Clamp

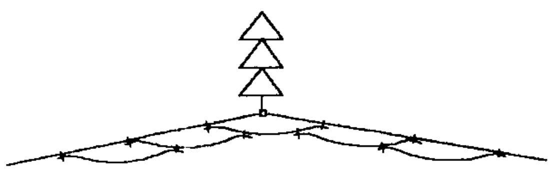
Figure 3 | Figure 4



BATE Damper around Mid Span Joint

Figure 5 and photo

For very long spans, such as in river and fiord crossings, extra lengths are added as in Figure 6.



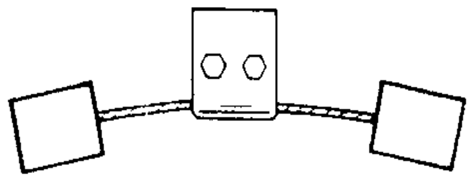
Festoon
Figure 6

These are known as FESTOONS and some long spans have been built with as many as ten festoons reaching out 50 metres into the span.

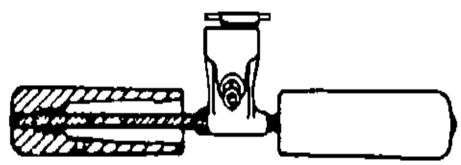
In Australia, where aeolian vibration is severe, the BATE dampers suffered fatigue failure to themselves and the conductor at the attachment clamps. At vibration frequencies where the damper was inactive the clamps became a reflection point and bending stresses were imposed at those points.

Efforts to improve the clamps have been made over the years but although this has alleviated the problem somewhat, the real problem is that the damping device does not respond to most of the frequencies experienced over the range of wind speeds causing vibration. With the addition of multiple festoons of varying lengths this limitation was somewhat alleviated.

In 1926, the stockbridge damper was invented (Figure 7) and when Monroe and Templin patented their improvements to it to respond to two frequency ranges it was introduced in Australia by Alconac Pty Ltd in 1950 and replaced the BATE damper almost completely (Figure 8).

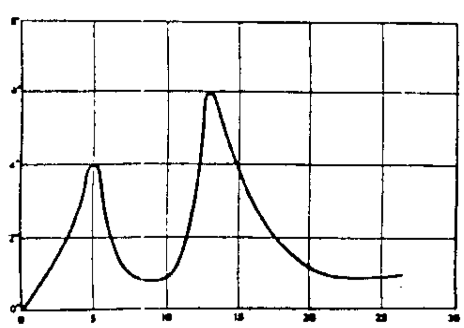


Original Stockbridge Damper
Figure 7



Monroe & Templin Stockbridge Damper
Figure 8 and photo

The Monroe and Templin improvement on G H Stockbridge's design provided 2 degrees of freedom and usually responded to frequencies peaking at about 7Hz and 12Hz (Figure 9) for transmission size conductors up to 1 inch in diameter.



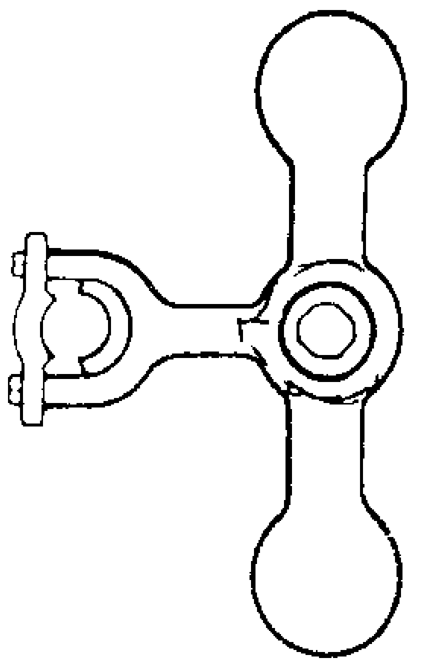
Typical frequency response curve of Monroe and Templin Stockbridge Vibration Damper

Figure 9

Unfortunately wind speeds causing vibration did not oblige by corresponding to these resonances so conductor fatigue failures at the damper clamps again caused problems.

Because it was known (or thought) that conductor tension was the main cause of aeolian vibration, it became the practice for stockbridge dampers to be applied only at tension towers on most transmission lines in Australia from 1950 through to 1975 - Ref 2. This practice led to many fatigue failures of conductors at suspension points, until it was realised that the static bending stresses at suspension clamps, when added to the dynamic bending reversal caused by vibration was the main cause of vibration induced failures. At tension towers the conductors were hinged in line with the sag of the span, so there were no bending stresses, either static or dynamic at those places. Indeed the conductor jumper at tension towers served as an effective "Bate" damper anyway.

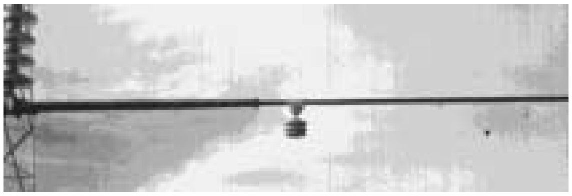
A small number of "TEBO" Dumbbell torsional dampers were installed on the Homebush-Tallawarra 132kV line in 1952. These were invented by H. TEBO of Ontario Hydro and used in large numbers in Canada for many years. Whilst they were subsequently abandoned because of inefficiency at most frequencies and a tendency to freeze up they are still in service in NSW on the original line (Figure 10) and on some lines in Western Australia.



TEBO Dumbbell Torsional Damper

Figure 10

Some ELGRA dampers from Sweden were installed on the first 330kV lines emanating from the Snowy River. These consisted of a number of weights resting on elastomer pads around a central rod suspended vertically. They were subsequently discarded from service in Sweden and elsewhere because of excessive wear at the connecting rod joint (Figure 11).



Elgra

Figure 11

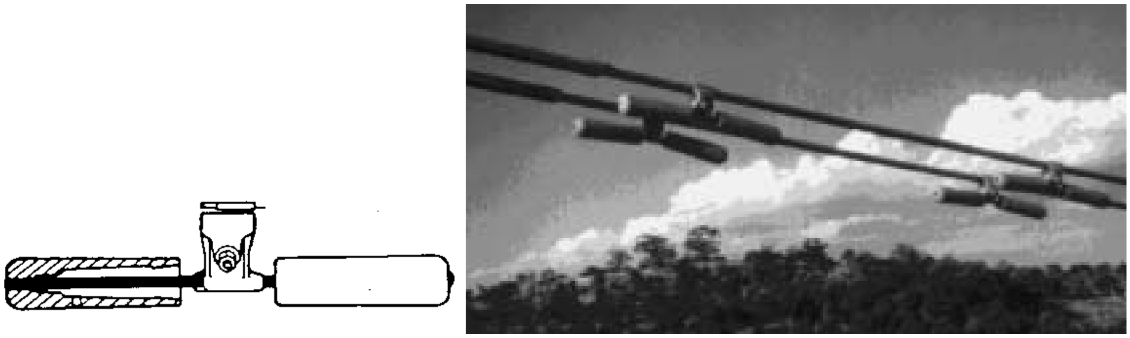
After 1962, first "Zenith" and then "Ontario Hydro" recorders were introduced and installed on lines in Victoria and South Australia.

An attempt to provide damping at higher frequencies which were being recorded on many lines across flat open country in South Australia was made by Dulmison who developed the ES-1 Stockbridge. This was, in effect, a standard stockbridge damper with an elastomer sandwich between the 7 strand messenger cable and the weights - an attempt to use viscous damping at the higher frequencies. At this time it was the practise to make "Stockbridge" dampers (actually Monroe and Templin dampers) with 7 strand messenger cable similar to that used in earth wire or guy wire. This was of 90 ton (1400 mPa) grade and heavily galvanised.

As the messenger strand weathered or became polluted by dust and other contaminants entering its open strand lay, it was thought that its performance as a coulomb damper would be affected. Following English and European practice of the time the messenger strand was heavily greased and then covered by a protective sleeve of flexible conduit with the intention of making it weatherproof and long lasting.

The vulcanised neoprene covering provided in the ES-1 design served this same purpose so that the performance of the damper was expected to be consistent throughout its service life.

Unfortunately, the damping properties were responsive to frequencies far above the range caused by aeolian vibration and they proved to be less effective in the critical frequency range. Most of the ES-1 dampers suffered from the weights falling off the end of the neoprene covered messenger cable (Figure 12).

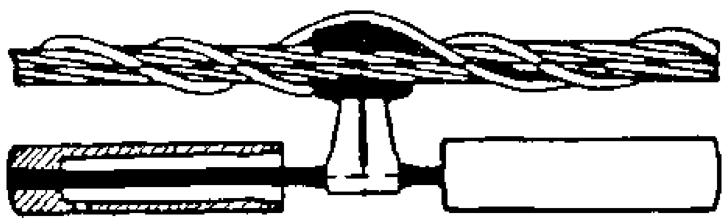


Elastomer Sandwich (ES-1)
Figure 12

Because of these failures the weight pull-off test was introduced into the Australian Standard 1154/1.

At the same time, because of conductor fatigue failures at the stockbridge damper attachment points, another attempt was made to improve the clamping mechanism, which was in effect, addressing the symptom and not the cause.

The attachment clamp was lined with a heavy coating of elastomer and clamped on to the conductor using helical rods. This "improvement" was called the ES-2 (Figure 13).



Elastomer Sandwich (ES-2)
Figure 13

Whilst the ES-2 solved the problem of fatigue damage to the conductor at the damper attachment point the effect of the elastomer sandwich was to inhibit the transfer of energy from the vibrating conductor to the messenger cable at the appropriate frequencies and to exhibit viscous damping properties at frequencies beyond the range experienced.

The ES-2 did not absorb enough energy at the frequencies recorded and although the damper caused no fatigue to the conductor at the attachment point it did not dampen the vibration at the most damaging frequencies.

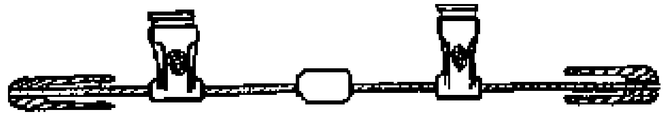
Many conductor fatigue failures from varying types of vibration dampers were experienced at the attachment points of the vibration dampers which were reported to CIGRE in 1971 - Ref 3.

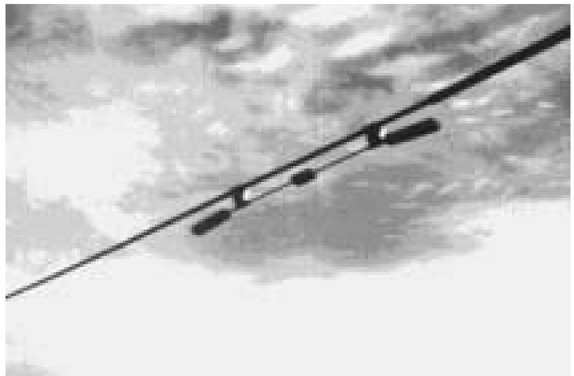
It was realised that the energy from a vibrating conductor had to be transferred directly into the messenger cable so that it could be absorbed by hysteresis and interstrand friction and then dissipated into the air in the form of heat.

The solution it was thought, was to have a conventional stockbridge type damper but with more than 2 degrees of freedom and a more energy absorbing type of messenger cable.

Because of unsolvable problems with vibration in Saskatchewan in Canada, a consultancy programme was commenced in Finland, where a disused railway tunnel allowed full span experiments to be conducted without the influence of ambient wind and temperature variations. - Ref 4.

In 1970 Lauri Haro of Imatran Voima and Tapani Seppa devised a "stockbridge" damper with three weights, suspended from two clamps attaching it to the conductor. The weights were of varying dimensions and at different moment arms on the messenger cable. Each of the two main weights had two degrees of freedom as in a normal stockbridge damper - but at different and overlapping frequencies. The weight on the short arm responded to frequencies higher than that on the longer arm (Figure 14).

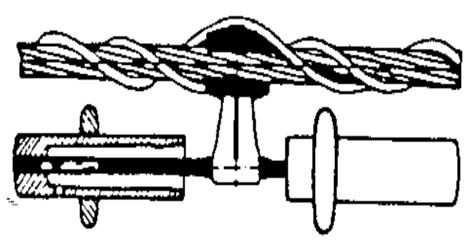


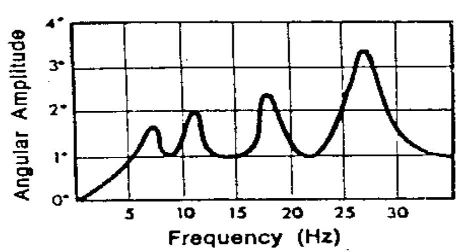


Haro Damper
Figure 14 and Photo

The Haro damper, although expensive, virtually solved the vibration problems at Saskatchewan Power. Its one disadvantage was that it was over a metre in length and was difficult to transport and install - many became bent and damaged in transit. Dulmison obtained the license to manufacture Haro dampers and sold many thousands to the Canadian utilities but very few in Australia.

Dulmison produced the VARISPOND damper in 1975 which employed two equal weights with moveable doughnut shaped attachments which could be positioned at different stations on the main weight. This changed the centre of gravity of each weight so that one side of the damper could be tuned to a higher frequency than the other. The theory was that any damper could be "tuned" to the required ranges of frequencies depending on vibration frequencies actually being recorded on the line. It was found from experience that certain fixed settings of the moveable donuts performed best so that frequency response, whilst broadened, was no longer variable (Figures 15 ,16).

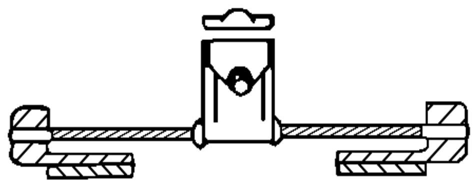




Varispond Damper
Figure 15 Figure 16

A stockbridge type damper with 3 degrees of freedom was invented by Dulmison in 1976. This employed the two conventional modes of the stockbridge (bending of the messenger cable in the vertical plane) but added a torsional mode by offsetting the weight from the vertical plane.

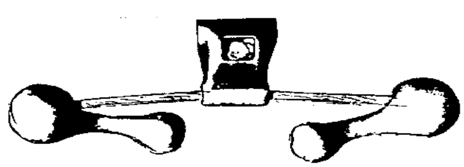
The original proposal was to provide a weight shape which could be made cheaply so that internal cores and the manufacturing problems with galvanising the inside of the cylindrical shaped weights could be eliminated. Experiments were conducted with the top half of cylindrical weights cut off and welded to the bottom section so that the centre of gravity of the weights would remain the same (Figure 17).

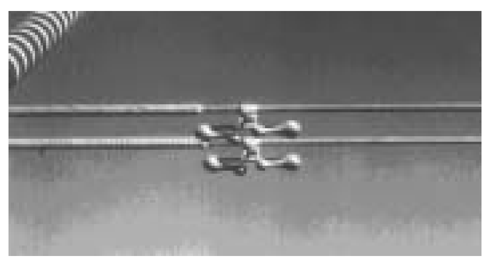


Dogbone Damper Prototype
Figure 17

If the weights were then rotated 90 degrees so that all mass was on one side, it would impart a torsional movement to the messenger at the same time as the two vertical modes of bending.

With experimentation the weight shape was refined until what we now know as the DOGBONE was developed (Figure 18).

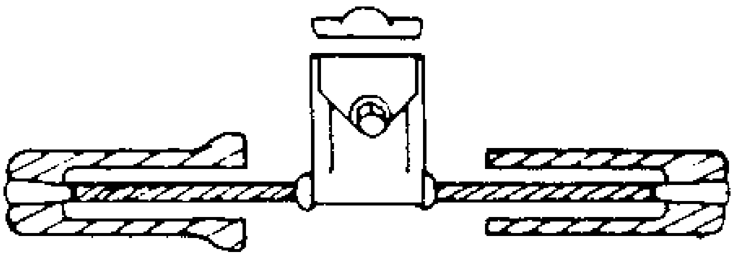




Dogbone Damper
Figure 18 and photo

Whilst the DOGBONE damper did not have the same coverage of frequencies as the HARO damper nor the VARISPOND damper it was very simple and inexpensive to manufacture and became very popular in most parts of the globe.

About the same time as the DOGBONE damper was developed in Australia, the University of Milano driven by Drs Diana and Falco and Dr Claren of SALVI developed a HARO type damper on simpler lines. They used two weights instead of the complicated three weights of the HARO damper and opened up the cylindrical weights into an open clothes peg design, thus making them cheaper to produce (Figure 19).



Salvi 4R Damper
Figure 19

At the same time, they recognised the importance of the messenger cable which had to dissipate all the wind energy imparted to the conductor at all the frequencies experienced. They developed a 19 strand cable instead of the earlier 7 strand dampers and wound it tightly in short pitches around a central king wire. To be effective the strands were made of preformed wires and then post-formed so that they were tightly embedded against each other.

The earlier problems of clamping stresses at damper attachment points was finally overcome, not by developing a better clamp (for there had never really been anything wrong with the attachment method) but by satisfactorily controlling and damping the conductor vibration at all frequencies. With the amplitude of vibration reduced to very low levels there are virtually no dynamic stresses either at the suspension clamp or the damper clamp. SALVI'S 4R damper utilised a flat sided hexagonal clamp so that a large range of conductor sizes can be accommodated (Figure 20).

Salvi hexagonal clamp
Figure 20

Other European and American manufacturers adopted the HARO/SALVI principle.

From computer programmes and experiments the frequency responses were designed, for the first time, to cover the full spectrum experienced from aeolian vibration.

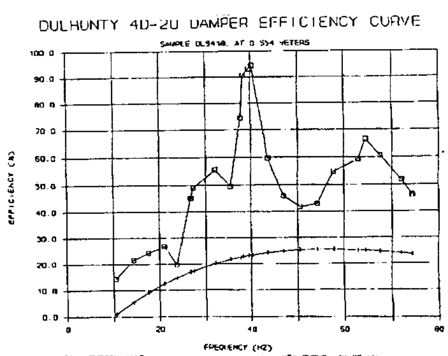
Although widely used all over the world and made by Italian, German, Austrian, French and American manufacturers, this multi-resonant damper was not used in Australia to any extent until 1994 when Dulhunty Industries started to produce the 4D series. It is now used in considerable numbers in every state of Australia (Figure 21 - Photo).

Dulhunty 4D Vibration Damper
Fig 21 photo

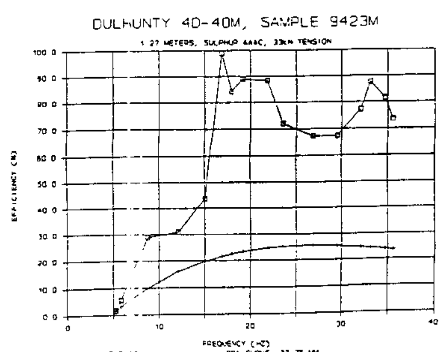
With the ever-increasing use of AAAC1120 alloy conductors in Australia replacing conventional ACSR on transmission lines the need for a highly efficient energy absorbing damper with a wide range of frequency response has become vital. Not only is this conductor more prone to vibration because its mass per unit length is so much lower, but because its self damping properties have been shown to be considerably less than equivalent ACSR.

Independent investigation and testing of the Dulhunty 4D series dampers on AAAC1120 alloy by the Georgia Power Research Laboratories in Atlanta has demonstrated the remarkably wide range of frequency response and high level of efficiency of this latest family of vibration dampers (Figures 22 and 23).

Typical Dulhunty 4D Damper Efficiency (ISWR) Curves



4D-20 Damper on "KRYPTON" AAAC
(16.25dia)
Figure 22



4D-40M Damper on "SULPHUR" AAAC
(33.75dia)
Figure 23

Impact (High Frequency) Dampers

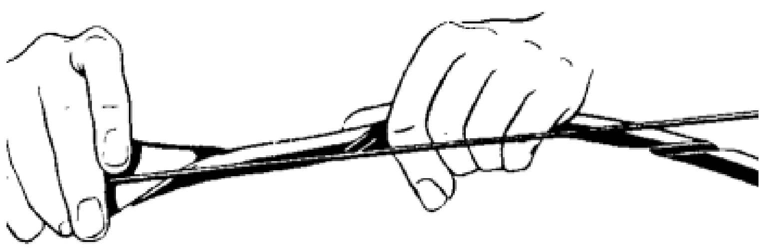
Impact dampers were found to be successful when vibration frequencies were very high - say over 100hz to 300hz.

Such frequencies occur on small diameter wires and cause short loop lengths. The impact damper is made long enough to cover many vibration loops and rests loosely on the conductor. Vibration is dissipated by slapping or impacting against the conductor, reducing the amplitudes within its length.

For smaller conductors, say below 5/8" in diameter (16mm), it was the practice in Australia to use impact dampers in the form of a helically slit tube.

This was particularly successful and popular with the Australian Post Office (now Telecom) for their overhead trunk lines in the 1950's to 1975.

Similar impact dampers were used on the earth wires of overhead power lines where a design emanating from Canada, called the SLAPAC damper was also used (Figure 24).



Spiral Impact Damper - Tube Type
Figure 24

In the last 20 years the preformed spiral damper SVD, has taken over this role doing an equally good job but at a much lower price (Figure 25).

Spiral Vibration Damper
Figure 25

BIOGRAPHY

Mr P W Dulhunty was the founder and Managing Director of the Dulmison Group of Companies for some 40 years. During this time he was involved in many vibration studies in many parts of the world and developed many of the solutions to these problems with some of the vibration dampers mentioned in the paper.

Mr Dulhunty is a senior member of IEEE and is an Honorary Life Member of CIGRE and has been involved with the overhead lines committee for some 35 years. He is now the Managing Director of Dulhunty Industries Pty Ltd of Australia and New Zealand and of Dulhunty Engineering in China.

References

Ref 1E Bate and J Callow, "The Quantitative Determination of the Energy Involved in the Vibration of a Cylinder in Air Stream", 1934, Vol. 6 1405 Journal of Institute of Engineers, Australia

Ref 2 Electricity Commission of NSW Specification No. 196

Ref 3 CIGRE Paper ISC22-71 WG04 - May 1971 "Some Recent Field Experiences with Vibration Dampers" by P W Dulhunty

Ref 4 Squaw Rapids to Saskatoon 230kV Line by K A Birch - June 1968