The Cost of Corrosion in the New Zealand Electricity Industry

Background

The World Corrosion Organisation (WCO) places the worldwide annual cost of corrosion at US$1.8 trillion per annum, some 3% of the world's GDP[1].

The estimated cost of corrosion in the United States electrical power industry in 1998 was US$15.4 billion[2], representing about 7.9% of the cost of electricity to their consumers.

About 20% or US$3 billion of the corrosion costs were considered avoidable. Whilst the issue of corrosion is generally understood within New Zealand industry it is often disregarded or acknowledged to be an inherent problem with metals generally. If the avoidable cost of corrosion is established throughout the electricity industry it would help the participants to better manage their assets and benefit from longer term cost savings.

Previous Cost of Corrosion Studies

Corrosion costs money. The cost to New Zealand is thought to be in the order of 2.5% of GDP or about $2.8 billion – annually. Unfortunately, there are no government statistics to back up this number; we only have some convoluted extrapolation of aged international data to support the assumption.

Over the last 60 years, a number of studies have been initiated by industrial nations concerned with the cost of corrosion. The costs, expressed as a percentage of the Gross National Product (GNP) range from 1.5 to 5.2%.

There were several different methodologies used to calculate the direct costs and a number of wide ranging estimates of the avoidable cost, anything from 10 to 40%. The common theme was that the indirect costs of corrosion were not only very difficult to estimate but were significantly greater than the direct costs.

Table 1 Summary of Previous Studies[3]

Country	Total Annual Corrosion Cost	% GNP	Report Year
USA	$5.5 billion	2.10	1949
India	$ 320 million	-	1960
Finland	$ 54 million	-	1965
W Germany	$6 billion	3.00	1967
UK	£1.365 billion∗	3.50	1970
Japan	$9.2 billion	1.80	1974
USA	$70 billion	4.20	1975
Australia	$2 billion	1.50	1982
Kuwait	$1 billion	5.20	1987
USA	$276 billion	3.1	2001

∗ *Not reported in $US*

The most recent study, "Corrosion Costs and Preventive Strategies in the United States" by CC Technologies Laboratories, Inc. to the Federal Highway Administration (FHWA), summarised that the total direct cost of corrosion in the US in the study year 1998 was $276 billion and that the indirect costs were at least equal to the direct costs, implying that the cost to US society was in the order of $500 billion or 6% of GDP.

This study used two distinct methodologies to determine costs, the first analysed corrosion control materials, methods and services. This included obtaining the consumption of protective coatings, cathodic protection systems, corrosion resistant materials, inhibitors as well as corrosion R&D, education and training.

The second method analysed costs by industry sector, under five main headings as follows:-

1. Utilities

- Gas distribution
- Water and Sewer systems
- Electrical utilities
- Telecommunications

2. Transportation

- Motor vehicles
- Ships
- Aircraft
- Railroad cars
- Hazardous material transport

3. Infrastructure

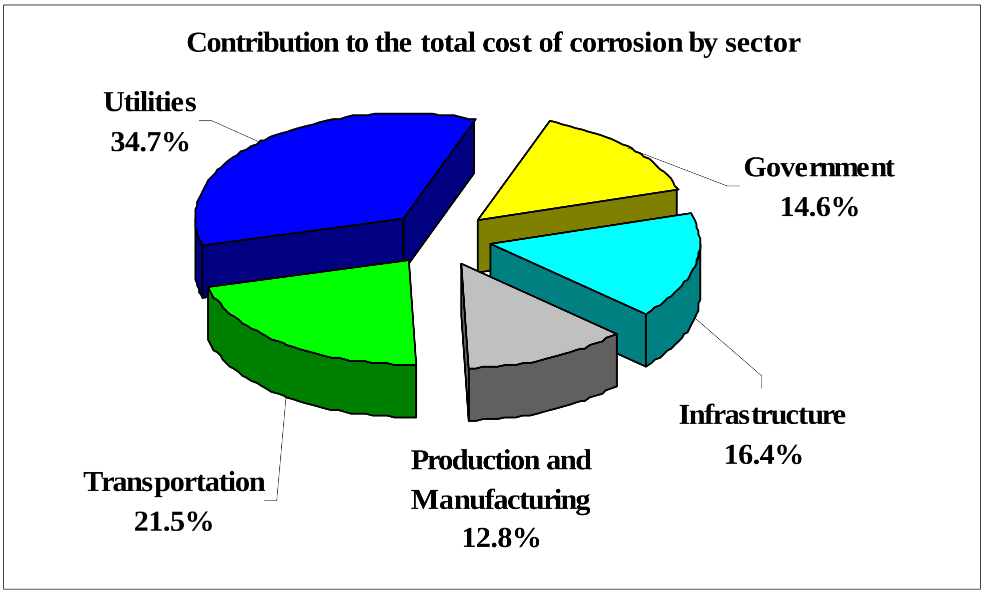
- Bridges
- Gas and Liquid Transmission lines
- Waterways and Ports
- Hazardous material storage
- Airports
- Railroads

4. Production and Manufacturing

- Oil and gas Exploration and production
- Mining
- Petroleum refining
- Chemical, petrochemical & Pharmaceutical
- Pulp and paper
- Agricultural
- Food processing
- Electronics

5. Government

- Defence
- Nuclear waste storage



Report Findings & Comparisons

The annual cost of corrosion within the electrical utilities sector according to the FHWA report was calculated at $6.9 billion with the largest portion of $4.2 billion attributed to nuclear power generation. An industry specific study carried out alongside the FHWA by the Electric Power Research Institute (EPRI) estimated the total cost of corrosion to consumers was $15.4 billion. It should be noted that this larger number includes overheads, profit and tax considerations.

For the purposes of the comparative exercise between the US and the NZ model, the lower FHWA direct costs are used; any notional overheads can be attributed with further analysis.

The main form of electricity generation in the US is fossil fuel (coal/oil/gas) followed by nuclear, then hydro. By comparison, New Zealand's main generation is hydro, followed by fossil fuel types and then geothermal and wind power.

Table 2 Electricity Generation by Type[4]

Generation type	US	New Zealand	Australia
Fossil	71.4%	31.6%	90.8%
Hydro	5.6%	57.8%	8.3%
Nuclear	20.7%		
Other (wind – geothermal)	2.3%	10.6%	0.9%

Whilst nuclear power generation accounts for 20% of total production, it accounts for 60% of the total corrosion cost. In order to make any comparison, we need to isolate both the amount generated and the corresponding corrosion cost.

If we assume that the (direct) cost of corrosion is proportional to the electricity production, non nuclear production in the US was 3.22 trillion kWh per year. If the cost of corrosion – excluding nuclear costs is $ 2.7 billion (6.9 – 4.2) then the cost of corrosion per unit of power generated is: -

$$\frac{\$\ 2.7 \times 10^{9}}{3.22 \times 10^{12}\ \text{kWh}} = 0.83 \times 10^{-3}\ \$/\text{kWh}.$$

Based on NZ production figures of 42 billion kWh the cost of corrosion would be $35.3 million or NZ$ 44.7 million.
If we were to use the EPRI figure of $15.4 billion and extrapolate against the NZ production model, the corrosion cost to consumers would be in the order of NZ$200 million.
It is feasible that the cost of corrosion in the electrical generation, transmission and distribution is somewhere between NZ$45 and 200 million each year.
If we assume that the total cost of corrosion to the Nation is in the order of 2.5% of GDP and the current GDP figure is around NZ$113 billion[5], the cost of corrosion is around NZ$2.8 billion.
The FHWA study indicated that the total cost of corrosion on analysed sectors was $137.9 billion, of which the electrical utilities represented 5% ($6.9 billion).
The presumed costs of between NZ$45-200 million represents between 2% and 7% of the total NZ cost of NZ$2.8 billion. If we were to use the US figure of 5% of the analysed sector cost on our NZ$2.8 billion, then we are looking at an annual cost of corrosion in the electrical utility sector of NZ$140 million per year.

Generation

Apart from the obvious difference in size between the US and the NZ electrical utility sectors, it is worth noting some of the factors that will alter the relative corrosion cost figures.
New Zealand has a higher proportion of hydro generation, considered to have relatively low corrosion costs in comparison to thermal plants.
We do not have nuclear power plants; these structures attract large corrosion cost dollars. Alternative power sources such as geothermal and wind power make up around 10% of NZ power production, in the USA this number is 2.3% (although this is over twice the whole of NZ electricity production). Wind generation equipment, whilst relatively new here will have its own corrosion issues in due course and our geothermal production facilities are subject to aggressive conditions requiring a range of corrosion mitigation techniques.

Transmission & Distribution

In terms of electricity consumption, NZ and the USA have similar per capita rates at 9,800 and 12,300kWh/year respectively. Comparisons of the cost of corrosion of transmission and distribution assets are not easily made, although New Zealand’s environment is much more aggressive (corrosive) than the US and we have a higher coast/area ratio. It would be expected that our network assets would corrode at much higher rates. Similarly with transmission lines, proportionally few pylons would be close to the corrosive influences of the coast in the US, whereas at least 50% of NZ transmission towers are either within 25km of the coast or in geothermal areas.

Indirect Costs of Corrosion

Cost of corrosion studies do not look too deeply at the consequential, collateral or social costs involved, as there are too many variables. Although the FHWA report suggests that “the indirect or social costs are at least equal to the direct costs”, therefore doubling the cost to society.
International studies have suggested that by employing sound corrosion mitigation strategies the “avoidable” costs of up to 20% could be saved. To put that in perspective, using NZ$2.8 billion, 20% would be a saving of NZ$560 million – annually, surely enough of an incentive?

To give some idea of the indirect or collateral costs, consider the notorious shackle at Otahuhu, where programmed replacement, including labour and material costs would have been about $200. There were numbers brandished about at the time purporting that the blackout had cost Auckland business's "tens of millions" of dollars. Economists worked up numbers based on Auckland's contribution of 16% to the economy – worth around $113billion, for one day to be over $49 million. Unfortunately the electricity sector is extremely sensitive to unplanned outages and whilst failures from corrosion are uncommon, the impact can be catastrophic.

Environmental Costs

Worldwide studies have focused on the economic and safety elements of corrosion, but the environmental impact of corrosion is only starting to be realised.

We know that corrosion has been the cause of numerous environmental disasters which could have been avoided if appropriate corrosion control management were utilised. But now we are talking about the fundamental impact that corrosion control can have on the environment.

"Global Warming", "Sustainability", "CO_2 Emissions", "Carbon Footprints", "Ozone Layer" and "Greenhouse Gases" have all become part of the "Greenspeak" lexicon. It should be recognised that corrosion engineering is "green" engineering, they endeavour to preserve assets from degradation by various methods of corrosion control and in doing so, preserve natural resources and the impact the processing of these resources has on the environment.

For example, we prepare and paint steel so it will last longer in its processed state, but does the environmental impact of making a paint coating and applying it, outweigh the impact of making the replacement steel? We use natural resources in both cases, we need energy to process the materials, be it steel or the paint. We use energy to transport the material to its eventual location, again be it steel or paint. By far the lower environmental impact will be a programme of steel protection.

Whilst we cannot stand in the way of global progress and the need to process our natural resources, we can off-set some of the impact by better stewardship of those assets we already have. If at the same time we can save money, then we have both environmentalists and accountants taking note.

Conclusions

The electricity generation, transmission and distribution Industry embraces a wide range of engineering disciplines. Each discipline attracts specific corrosion issues; some disciplines have corrosion control strategies in place. Others are exploring solutions and some blithely ignore the problem.

It is worth paraphrasing the recommendations from the FHWA report that repeatedly points to education as being the key to increased awareness of corrosion costs and the potential savings. This includes changing the perception that nothing can be done about corrosion and that there are resources available but they need to be nurtured.

The report also suggested that Information sharing was seen as an important element in the fight against corrosion, there are a number of ways this can be implemented, either through industry groups or through technical societies.

References

[1]Hays G.F (2007) "*Now are the time*". Paper submission. WCO website. www.corrosion.org/

[2] *Priorities for Corrosion Research and Development for the Electric Power Industry*, EPRI, Palo Alto, CA: 2002. 1007274.

[3] *Corrosion Cost and Preventive Strategies in the United States*, Report by CC Technologies Laboratories, Inc., to Federal Highway Administration (FHWA) Office of Infrastructure Research and Development, Report # FHWA-RD-01-156 – Appendix A – Review of Previous Studies.

[4] Source: CIA. The World Fact Book. www.cia.gov/library/publications/the-world-factbook/

[5] Source: CIA. The World Fact Book. www.cia.gov/library/publications/the-world-factbook/rankorder/2001rank.html