Antarctic Observations: On metal corrosion at three historic huts on Ross Island

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Abstract

A range of commercial and standard corrosion inhibitors and coating systems were applied on-site or off-site onto a variety of metal artefacts and coupons and exposed to ambient conditions in three historic huts: Discovery Hut, Cape Evans and Cape Royds on Ross Island in Antarctica. Qualitative observations regarding the efficacy of these treatments has been made over a seven year period of exposure trials and these observations are compared with environmental data collected in the huts during that same period. The aim of this research was to significantly improve our qualitative understanding of the local corrosion phenomena and to answer the question "Is it feasible in the Antarctic summer period, to develop a tailored and effective on-site metals conservation program for artefacts in these historic huts?"

Keywords: Antarctica, corrosion, corrosion inhibitors, protection, coating, on-site treatment, observations,

1. Introduction

The Antarctic Heritage Trust (AHT) is based in Christchurch, New Zealand and was formed in 1987 to "preserve and protect the physical and historic heritage of human endeavour in Antarctica". Antarctic heritage primarily revolves around the heroic era of Antarctic exploration which includes "documented feats of scientific achievement, exploration and endurance" (Antarctic Heritage Trust ,2004) .

Under the auspices of the AHT a field event supported by Antarctica New Zealand titled K282 was sent seasonally to Ross Island in Antarctica to carry out conservation work primarily on the historic huts and their associated artefact assemblages.

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The huts were built by Borchgrevink, Shackleton and Scott's two expeditions.

The huts in order of erection are:

- Cape Adare in Northern Victoria Land (British Southern Cross Expedition 1898 -1900 led by Carsten Borchgrevink)
- Discovery Hut at Hut Point (Figure 1) (National Antarctic Expedition 1901 – 1904, led by Commander RF Scott)
- Nimrod Hut at Cape Royds (Figure 2)(British Antarctic (Nimrod) Expedition 1907 – 1909 led by Ernest Shackleton)
- Terra Nova Hut at Cape Evans (Figure 3) (British Antarctic Expedition 1910 – 1913 led by Captain R F Scott) (Antarctic Heritage Trust ,2004) .

Figure 1: View of Discovery Hut at Hut Point, National Antarctic Expedition 1901 – 1904, led by Commander RF Scott.

Figure 2: View of Nimrod Hut at Cape Royds British Antarctic (Nimrod) Expedition 1907 – 1909 led by Ernest Shackleton

Cape Adare is logistically the most problematic to reach and only periodically is visited by members of AHT.

Figure 3: View of Terra Nova Hut at Cape Evans, British Antarctic Expedition 1910 – 1913 led by Captain R F Scott.

Since the huts “rediscovery” in 1946 during the U.S. Navy launched *Operation Highjump* led by Rear Admiral Richard E. Byrd, loss of artefacts around the historic sites has accelerated due to a combination of environmental and human factors.

Each site has three basic components: the hut structure, artefacts inside, artefacts and small structures outside. This paper will address qualitative experimentation undertaken to better ascertain a conservation approach for the internal artefact assemblages. Preventive conservation is vitally required in all circumstances where the artefacts remain in situ; consequently the various merits of on-site versus off-site interventive conservation were assessed.

The Huts are all wooden structures located near the Ross Sea. Each hut is unique in its orientation, susceptibility to prevailing conditions and range of internal microclimates. A general approach to the huts by the NZ Antarctic Society began in 1960-1961 season at Cape Royds and Cape Evans. This was followed in 1963-1964 at Hut Point. Each hut was excavated to remove built up ice. Following the ice removal, hut structures were stabilised and weatherproofed resulting in the drying out of the internal environment.

In 1997 research was initiated to assess the potential of developing a tailored conservation approach for the internal artefact assemblage that could be effectively delivered during the summer period. Metal artefacts of particular significance for AHT were the range of historical food stuff cans that still have contents and labels (Figure 4). Sampling of internal metal objects was conducted to develop a baseline appreciation of the corrosion phenomena at each site and to determine the range and extent of chloride ions within the internal artefact assemblage. This program was conducted over six field seasons in the last seven year period.

Figure 4: An internal wall of packing cases filled with cans and bottles at Cape Evans.

1.1 Bumped, bounced or boomeranged

One important element to comprehend in regards to fieldwork in Antarctica is the simple logistical difficulties faced in getting to and from Antarctica and to and from the site. Antarctica New Zealand is able to coordinate flights to Antarctica with the US or Royal New Zealand Air Force. If you are fortunate to fly to Antarctica rather than sail for several weeks, the trip is still made problematic by the fact that you can be bumped, bounced or boomeranged. Travel to the ice is heavily weather dependant and also based on event priorities and status of travellers at times. Bumped means that your flight is cancelled for what ever reason and you may leave the next day. Bounced is when you have been in line for two to three hours, have handed in all your luggage, are dressed in full survival gear during summer and then told you are not flying that day and to go back to your accommodation. Boomeranged is where you have even managed to fly some or practically the whole 8-9 hours of the trip to Ross Island and then are forced to return to your point of departure to try again the next day.

Once on the ice where your event is reliant on helicopter access to get to sites, you are once again subject to the full array of possibilities and weather dependency. If you are very early in the season you can travel to the historic huts of Cape Evans and Royds by tracked vehicle. Hut Point is practically always accessible from Scott Base by car or foot.

2. Experimental methods

2.1 Temperature and relative humidity data

Temperature and relative humidity data for the three huts was acquired hourly for two years using HOBO® H8 Pro data loggers by National Science Foundation event number BO-038-0 and New Zealand event K021, as part of an ongoing study of the biological deterioration of the huts (Held et al 2003, Blanchette et al 2002, Blanchette et al 2004, Held et al 2004). The loggers were downloaded annually in 2001 and 2002 by team members. The number of data loggers used in Discovery Hut, Cape Evans and Cape Royds are 4,6,5 respectively. The data loggers were distributed throughout the huts internally at varying points and heights and also located outside (Held et al 2003. Held et al 2004).

2.2 Coupon experimentation

2.2.1 Coupon Dimensions and Attachment

Two types of coupons were used in experiments:

- Traditional bronze coupons cast at the Roman Art Foundry in Epping, Victoria with metallurgy of 85% Cu, 5.5% Pb, 4.2% Sn and 5.3% Zn. The cast size for bronze coupons was 80 mm x 80 mm x 6 mm.
- Mild steel coupons complying with BHP AS/NZS 3678 – 250 structural steel plate. The maximum composition data for BHP structural steel plate is; C: 0.22, Mn: 1.70, P: 0.04, Si: 0.35, S: 0.035, A: 1.00. The mild steel coupons were 8 mm x 7.5 mm x 5 mm.

Mild steel coupons exposed in 1996 were clean faced. All coupons exposed in 1999 and again in 2001 were prepared to 400 grit using a polyurethane lap. A hole (5 mm) was drilled near one edge in the middle of each coupon to facilitate their being suspended using synthetic thread.

2.2.2 Coupon preparation

A range of commercial and standard corrosion inhibitors and coating systems were brush applied on-site or off-site, in controlled environmental conditions onto a variety of metal artefacts and coupons. They were exposed to ambient conditions in three historic huts: Discovery Hut, Cape Evans and Cape Royds on Ross Island in Antarctica. The brush method of application was chosen as it is the most useable method in the field for working on artefacts. All coupons were degreased with acetone and air-dried before coatings were applied.

2.2.3 Coupon Exposure Dates

All mild steel coupons were exposed inside the hut at Cape Evans suspended under the bed frames in Dimitri and Anton’s bunk area. The copper coupons were placed in 2001 on the upper shelf between the Biology area and Nelson and Day’s bunk (Figure 5).

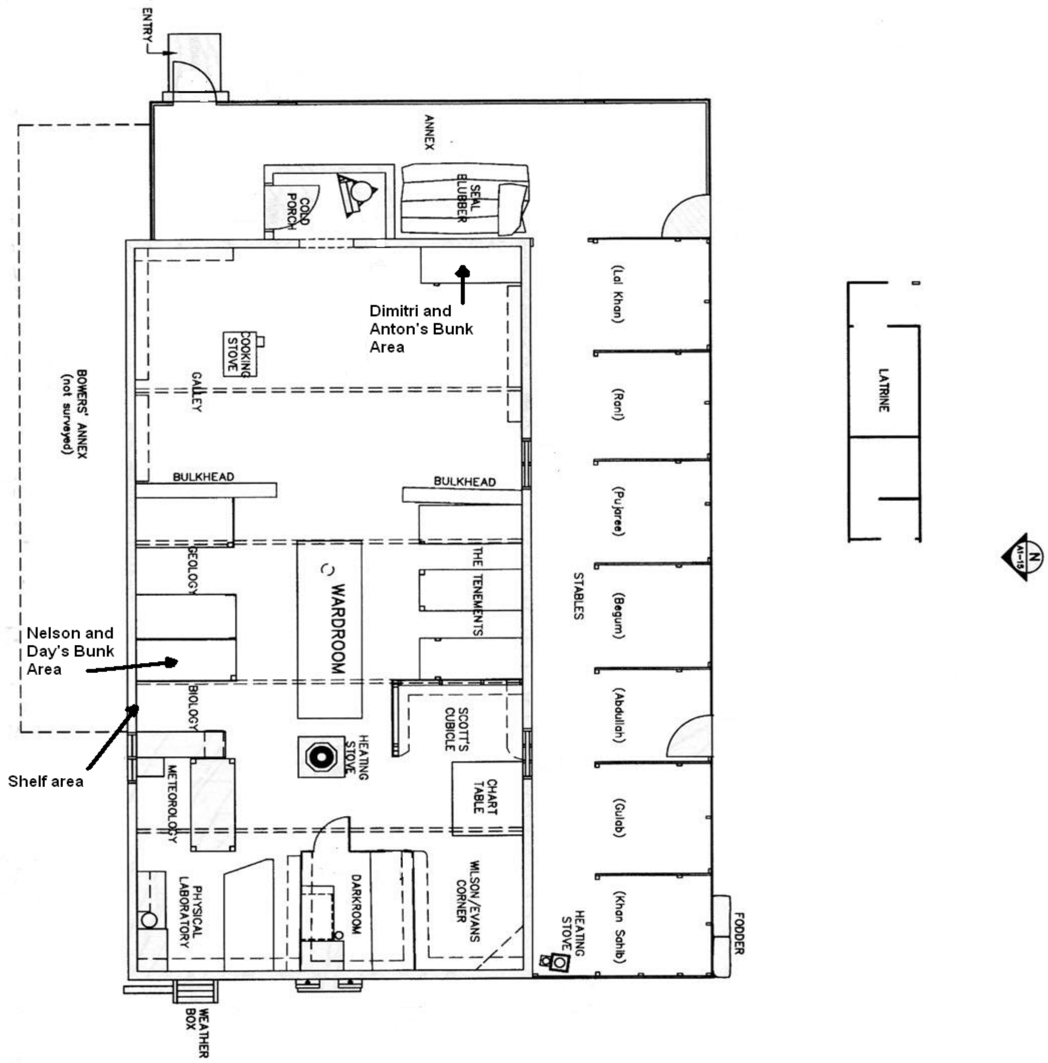

Figure 5: Location of coupons exposed inside the hut at Cape Evans suspended under the bed frames in Dimitri and Anton's bunk area and on the shelf between the biology area and Nelson and Day's bunk area. Interior plan from JASMAX Architects, 65 Upper Queen St, Box 6648, Auckland, New Zealand.

Three exposure trials were undertaken. The first trial was for approximately a three year exposure period (November 1996 –December 1999). Mild steel coupons were coated with Galmet Ironize, Dinitrol AV8, Rusticide, microcrystalline wax, Ferro Guard F.S. Grease and or combinations of the above (Maxwell, 1998).

The second trial was for approximately a one year period (December 1999 - January 2001). Coupons were mild steel, coated with Rust Stabiliser M.D.P., Preservation Wax 400, Dinitrol 4010, Tectyl 506 and ARI(Maxwell, 1999). .

The third coating trial was also for approximately a one year period (January 2001 – January 2002). Copper and mild steel coupons were coated with ARI or Besq 195 a microcrystalline wax (Viduka 2001,. Viduka 2002)

2.3 Artefacts off-site treatment

Ten iron alloy objects from the laboratory at Cape Evans located in the South East Wall area of the Hut were removed and conserved off-site by Lynn Campbell and Karel Peters, conservators then based in New Zealand working for the Trust. The objects were all treated with 10% citric acid, an inhibitor being 1% potassium chromate, or corrosion converter 3% tannic acid and a wax coating. Objects were relocated in 1987 to their previous locations inside the hut at Cape Evans and exposed to internal ambient conditions.

In 1997 nine objects were removed for off-site treatment as they represented the range of metal and metal alloys present inside the hut at Cape Royds. Their surface conditions varied from poor to very poor. This terminology related to the state of corrosion. Poor was a corroded surface with a mixture of stable and unstable corrosion salts, and very poor being a surface consisting of all active corrosion and mechanical damage/losses to the object. The objects consisted of:

Object	**Material**	**Conservation Treatment**
1. Enamel pie dish – small	Iron base alloy	Galmet (conversion coating/lacquer)
2. Enamel pie dish – large	Iron base alloy	Galmet (conversion coating/lacquer)
3. Shelf bracket – small	Iron base alloy	Rusticide plus Ferroguard FS
4. Shelf bracket – large	Iron base alloy	Rusticide plus Dinatrol 4010
5. Iron bolt	Iron base alloy	Rusticide plus Tectyl 506
6. Tube valve	Zinc/copper base alloy	2 coats of Ferroguard FS
7. Zinc pulley casing	Zinc base alloy	2 coats of Ferroguard FS
8. Copper tube	Copper	3% Benzotriazole (BTA) plus microcrystalline wax
9. Oil tin	Tinned, iron alloy, brass & leather	3% Phosphoric acid plus 2 coats Ferroguard FS

Table 1: Objects, material and conservation treatment applied. (Data on coating and inhibitors available in materials and supplies section.)

All objects were initially treated to remove free corrosion salts as follows:

1. Loose corrosion products were removed by lightly brushing with a soft paint brush
2. Objects (except no. 9) were then washed for 24 hours in a bath of water and 2.5% non ionic detergent (Lissapol)
3. After removal from the bath and drying with ethanol, the objects were left for 48 hours exposed to the air indoors in a non air conditioned environment. This timing allowed for redevelopment of any corrosion products

After the initial washing and cleaning processes the objects were treated using a range of standard conservation and commercial products (Table 1). The aim of applying a variety of treatments was:

1. to establish suitable treatments for stabilisation of corroded metal
2. Analyse corrosion salts to determine the extent or pattern of the corrosion salts present and suitability of treatments for field testing
3. Investigate the feasibility of applying those treatments at Scott Base or in the field

Objects were all returned to their previous locations within the hut at Cape Royds during the 1998-9 season (Maxwell, 1999).

2.4 Artefacts - on-site treatment experimentation

2.4.1 Metals

The methodology to treat objects on-site was constrained by two factors;

- Environmental conservation and workplace regulations that restrict the types of materials that can be taken to Antarctica,

- the ambient conditions during the summer months that further limited product choice.

In 1998-1999, on-site treatments were performed on a series of artefacts that included cans with labels and contents, bed frames and the stove at Cape Royds. The artefacts were coated by brush application using either halogen lights to heat the metal surface before application, or directly onto the surface. A coating or coatings were applied until a smooth even coat was observed (Maxwell, 1999).

The coating product used on-site now trades as ACTIVE RUST INHIBITOR GP3000 (ARI) but in 1998 was still in its early developmental phases. ARI was trialled because it complied with the existing Antarctic constraints and whilst problematic to apply in the ambient conditions, it is suitable to be transported by air, is removable with caustic solution and offered several advantages over other then commercially available products.

The ARI coating is a water-based emulsion of non-toxic polymers incorporating corrosion inhibitors of low odour. On application the product produces a hydrophobic film that is not easily displaced or penetrated by water and does not alter the surface appearance significantly. According to Gerald Cairns, senior chemist at Cairns Corporation, when ARI GP 3000 is "applied to oxidised metal surfaces, especially rusty steel surfaces, it partially dissolves the upper oxide layers and carries this down into the interstices in the underlying rust then penetrates to the parent metal surface where it reacts to form a tight bond. The oxide layer tends to flatten out under this influence. Thus the whole oxide layer becomes a hydrophobic protective coating without altering the surface appearance significantly. The amounts of oxides present determine how much needs to be applied either by way of dilution rate or multiple coats" (Cairns 2000).

2.4.2 Paper experimentation

A series of panels of acid-free paper were coated with a range of concentrations of ARI and water: pure ARI, 1:1, 1:2, 1:3 and left in the dark in Shackleton's room to be seasonally assessed for colour change against a blank (Figure 6) (Viduka 2002).

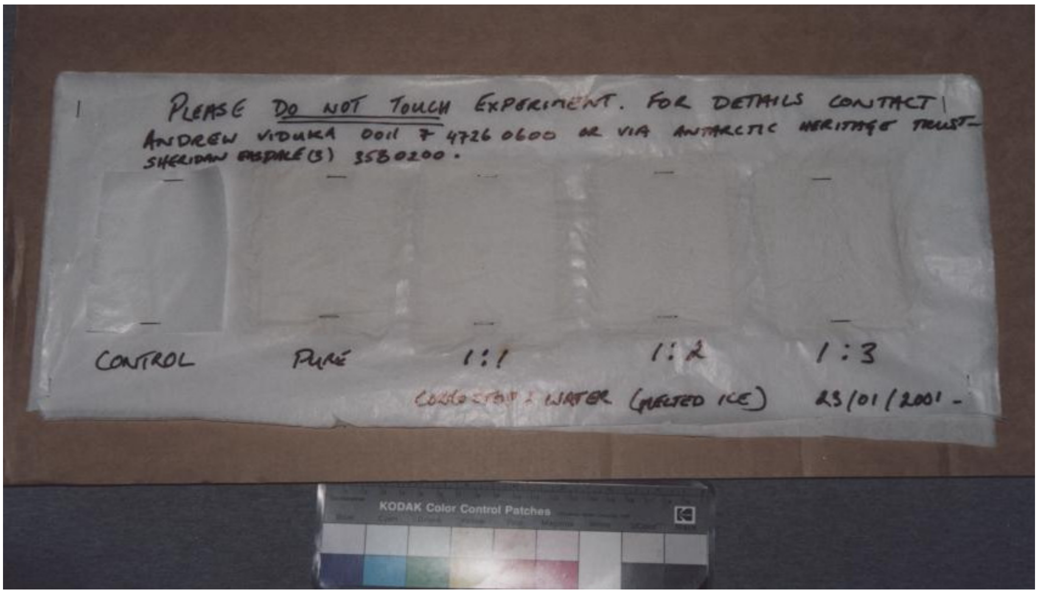

Figure 6: Simple experiment to monitor the effects of ARI on paper.

3. Results and Discussion

3.1 The Corrosive Environment

Observations made over the years by the authors have borne out several now well documented facts (Held 2003, Maxwell 1998, Viduka 2001) Each site is not uniformly corrosive and prevailing conditions and site layout can be used to comprehend the topography of deterioration. The primary driving mechanisms for the deterioration of the outside and inside artefact assemblages are different. Outside artefacts are exposed to a combination of:

- high wind's [that can collect scoria dust and physically scour the surface (Figure 7)]
- high UV causing bleaching of organic materials
- significant concentrations of corrosive salts in the soil and in the snow and ice that on Ross Island can form thin crusts on the surface of the soil (Campbell and Claridge 1987)
- aerosol salt solutions from the Ross Sea
- the summer period when temperatures rise above freezing allowing snow to turn into melt water and increases rate and extent of fluctuating Relative Humidity

For inorganic objects the proximity to dissimilar metals, the location of snow banks, run off channels, melt water drip lines and exposure to prevailing weather conditions do cause accelerated rates of corrosion. The presence of free water condensing onto cold metal surfaces is enough to start cyclic corrosion (Figure 8) and is compounded by the presence of corrosive salts present in ice, snow and air.

Figure 7: Early wood has been removed by wind ablation on Discovery Hut leaving late wood in pronounced ridges. Note paint drip lines afforded longer protection leaving a last vestige of the original surface.

Figure 8: Active corrosion on can (Reserve Collection Scott Base)

The rate of chemical deterioration is constrained by the shortness of the summer period after which objects located outside are in the majority of instances, covered by snow or ice. Analysis of iron corrosion products from objects inside and outside the huts has identified Goethite as a common corrosion product (Tilbrooke, 1998.). This mineral salt is formed in low temperatures and low humidity indicating that corrosion, whilst at a slower rate, still does commonly occur outside the summer period (Viduka 2002, Deer 1966).

3.1.2 Inside Objects

Analysis of corrosion product samples collected by Maxwell in 1997 - 1998, 1998 -1999 seasons was analysed using semi-micro qualitative wet chemical methods to determine the anions and cations present and to allow an estimate of their concentration levels in the sample (Viduka 2002).The analysis was conducted by David Tilbrooke of Museum Environment and Conservation Services based in South Australia. Results from the analysis indicated that inside artefacts were found to be generally free of chlorides ions. These objects were observably in better condition than similar objects located outside. Some inside artefacts have higher concentrations of chloride ions than others, but this may indicate previous collection management practices rather than differentiated exposure inside a hut. David Harrowfield (a leading Antarctic historian) confirms that artefacts have been recovered and brought back into the huts subsequent to the huts excavation from the ice (Harrowfield 2000.).

For objects located inside the huts, the instigating mechanisms of corrosion are:

- Actual amount of water vapour present at low temperatures and associated with high RH (Figures 9, 10,11,12). (Viduka 2002)
- Presence of free water condensing onto cold metal surfaces
- Proximity of the object to the floor or external walls
- Lack of air circulation around objects
- Proximity of dissimilar objects to each other

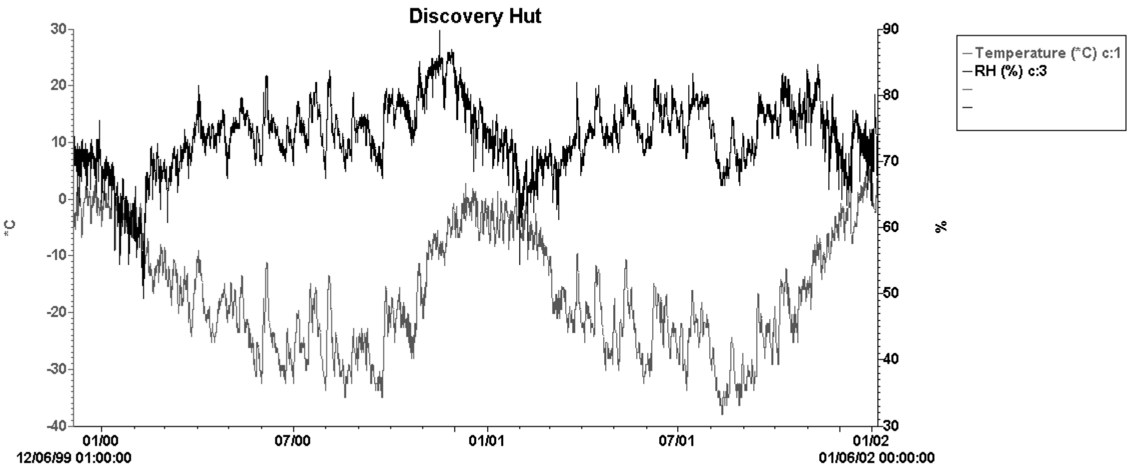

Figure 9: Graph of relative humidity and temperature in *Discovery* hut over a 2 year period (Held *et al* 2003).

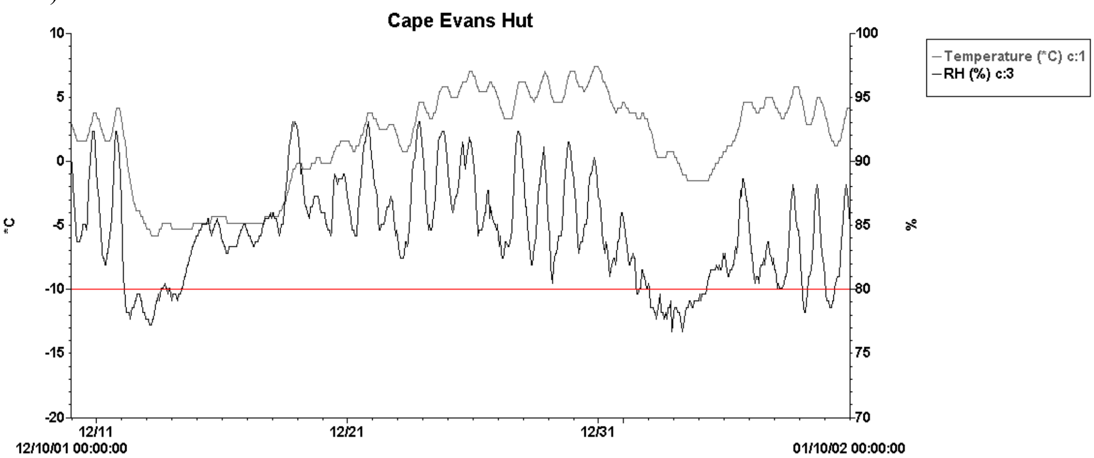

Figure 10: Graph showing relative humidity and temperature in Cape Evans hut over a one month period indicating high relative humidity and temperatures above 0ºC. The horizontal line indicates 80% relative humidity (Held *et al* 2003).

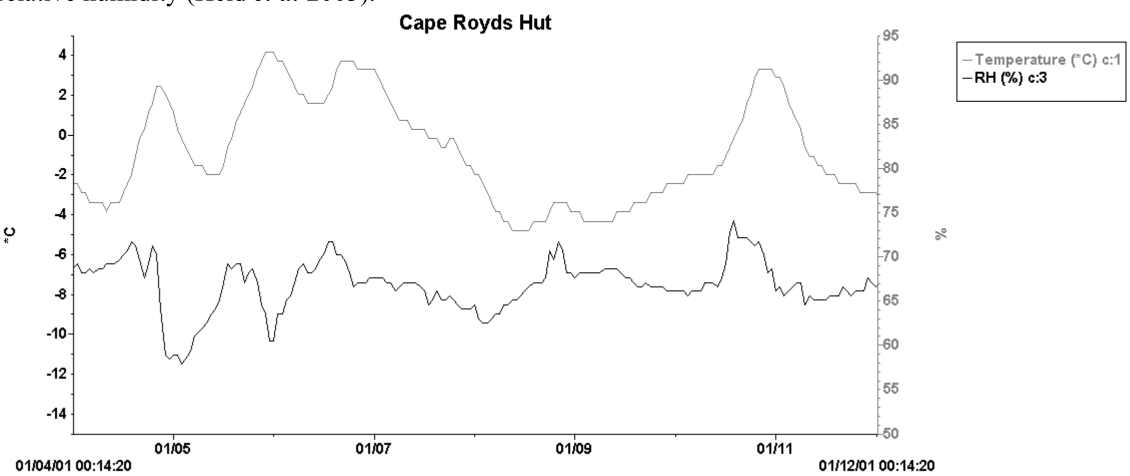

Figure 11: Graph of relative humidity and temperature in Cape Royds hut. The vertical line indicates a day in which 66 visitors entered the hut (Held *et al* 2003).

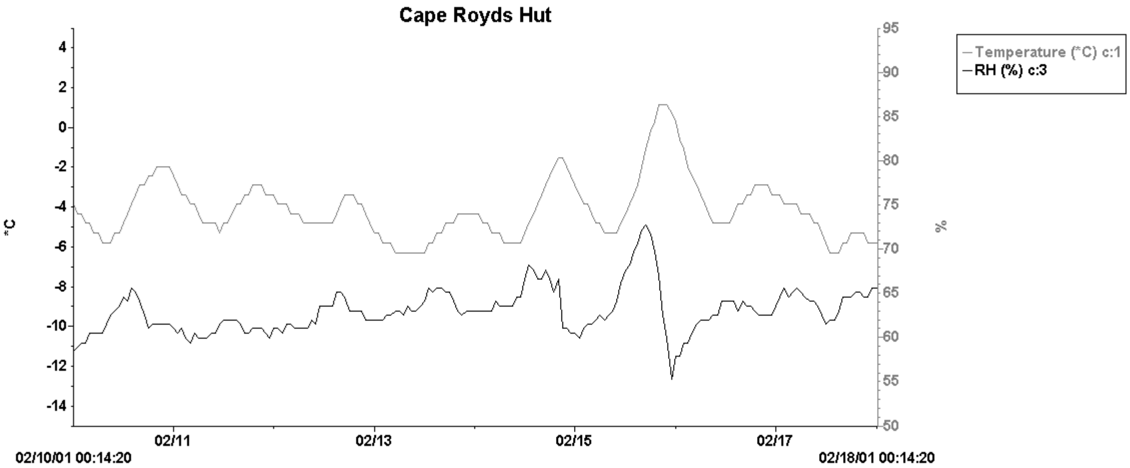

Figure 12: Graph of relative humidity and temperature in Cape Royds hut. The vertical line indicates one day in which 45 visitors entered the hut (Held *et al* 2003).

Corrosion on objects inside the huts is typically cyclic pitting corrosion developing to sheet like corrosion. Inside the huts biological deterioration is present in the form of soft rot of timbers, surface moulds on wood, leather, foodstuffs and other artefacts indicative of the availability of water in the closed system. Held writes, “Fungal growth is most common on wood near or on the floor and often in areas with limited air circulation” (Held *et al* 2003) . Equally, metal corrosion is most extensive in similar physical locations as there is more available water and greater temperature extremes.

Environmental data acquired from the huts reveal that in summer, temperatures rise above freezing, and relative humidity (elevated for most of the year) is often over 80%. Data from Discovery Hut shows the relationship of RH and temperature over time. RH is quite elevated though temperature only rises above freezing for short periods in summer (Figure 9). Data collected at Cape Evans over one month from December-January 2002 shows RH at 85% up to a maximum of 93%, average temperature for the period is 1.4^{0}C and reaches a maximum of 7^{0}C. These conditions are conducive to forming corrosion cells and mould growth within the hut (Figure 10) (Held 2003).

3.2 Coupon experimentation

3.2.1 November 1996 - December 1999 coupon trial

Coupons were coated with: Galmet Ironize, Dinitrol AV8, Rusticide, microcrystalline wax, Ferro Guard F.S. Grease and or combinations of the above. Results of the exposure trials were that only those coupons coated with lacquers did not fail and start corroding. All wax coatings used in the study broke down.
The results from the study indicated:

- the extreme internal corrosive environment an object faces when located on the floor or near an outside wall
- that preventive conservation should be prioritised in those areas that are subject to extreme damp and cold.
- that water access to the metal surface must be totally stopped to inhibit corrosion within the inside environment
- that the difference in micro-environments within a hut is extreme.

The last observation is borne out by comparative observation with Karel Peter’s stripped and wax coated objects located high up on a shelf in the South East wall area. Eight of the original ten objects treated in 1987 were still stable and showed no sign of re-corrosion in 2004 [15].

3.2.2 December 1999 – January 2001 coupon trial

The coupons were coated with: Rust Stabiliser MDB, Preservation Wax 400, Dinitrol 4010, Tectyl 500 and ARI developmental formula and exposed internally for one year after which there was no visible signs of recorrosion. The coupons coated with Tectyl 500 were still sticky to the touch. The length of exposure was insufficient to make observations regarding the long term performance or suitability of these products.

3.2.3 January 2001 – January 2002 coupon trial

The third coupon based experiment focussed on the potentially most environmentally friendly commercial product ARI and was expanded to include copper coupons for comparative purposes. Previous Electrochemical Impedance Spectroscopy (EIS) studies conducted in Australia on the ageing properties and corrosion resistance of protective wax coatings on metal surfaces, found TWA2095 a microcrystalline wax, offered the best long term corrosion resistance of a group of commercial preparations including BeSq 195, Cor-Trol 400, Cor-Trol 450, Dinitrol AV100, Dinitrol AV25 and Dinitrol 4010 (Otieno-Alego et al 2000, Otieno-Alego et al 1998) When TWA 2095 became difficult to acquire in Australia, BeSq195, another micro-crystalline wax, was identified as the best commercial replacement. Even though waxes were found ineffective in the first trial, the rationale for Besq 195's inclusion in this trial was the belief that this wax might survive and offer a performance baseline against the 2000 ARI formula, giving meaningful comparative results when studied post exposure using EIS.

Observations made during application (Viduka 2001) noted that the ARI coating formula did not apply evenly, and that spots of flash rusting occurred almost immediately on some objects. Subsequent to the field season this issue was investigated further and the Cairns Corporation identified a phase separation problem in the 2000 ARI formula. The stoichiometry of the formula was subsequently changed to remedy this, immediately invalidating the exposure trials.

During the 2001-2002 field season the coupons were visually assessed on-site and the ARI formula was found to have universally not inhibited corrosion. The coupons exhibited streaky corrosion lines associated with phase separation, while the BeSq 195 gave uniform protection. Besq 195 was not subsequently studied using EIS due to logistic and equipment difficulties at the time.

3.3 Artefacts off-site treatment

Of the nineteen artefacts that had been removed and treated off-site using various standard conservation or commercial treatments, by 2004 only two of these objects had started to show active corrosion and these two were from the earlier 1987 treatment batch. The 1987 treatments were essentially a strip, inhibit and wax coat process. The only variable between the two objects that are corroding is that a different solution was used, one had tannic acid conversion and the other potassium chromate inhibition, and both were waxed coated.

Since conservation is not a one off process and the object's environment is not conducive to long term storage, the recorrosion of some artefacts is not surprising. But why have the other objects survived so well? Certainly the artefacts that have been treated have not been located in any of the more aggressive internal micro-environments, and this fact combined with effective conservation treatments may explain the continuing stability of the remaining seventeen artefacts.

3.4 Artefacts on-site treatment experimentation

3.4.1 Metals

Prior to departure for the 2001-2002 field season the Cairns Corporation supplied a new batch of ARI to be used in the field. Since no coupons were prepared for that year, three cast iron bed frames at Cape Evans and two food cans with contents at Cape Royds were approved to be included in the artefact experiment trials. The beds were Atkinson's, Oates' and Cherry-Garrard's and the two cans contained boiled mutton and had labels in situ. The beds and cans were coated with a 2:1 solution of ARI:water. Bickersteth and Clendon who went to the ice with K440 in 2004, report that the condition of these bed frames appears stable with no observable active corrosion. The two cans of boiled mutton were tacky to the touch, glossy on the outside, but matt near the seams. Active corrosion was evident, particularly on one can (Clendon and Bickersteth 2004).

3.4.2 Observations of GP300 Active Rust Inhibitor (ARI)

All the promise of ARI has not been fully realised within the studies so far conducted. Ongoing product development coupled with regular formula changes has resulted in much effort for little useable return. Practical experience with ARI has taught that the product can require a variable number of coating applications depending on the degree of surface corrosion and the formula of the solution. The changing formula during the development phase meant that some product batches separated in the container and this contributed to uneven and flawed coatings that for a period not only allowed recorrosion but potentially accelerated the phenomena. Subsequent re-application was required to obtain good coating distribution.

Unfortunately all the questions initially posed for this product have not been answered, since each new formula has fundamentally changed the characteristics of the product. The effectiveness of ARI can only be ascertained once the product's development is completed and this is not yet foreseeable.

3.4.3 Paper

Since one of the rationales for trialling ARI was its potential suitability to consolidate both a corroded can body as well as a can's label *in situ*, the effects of ARI on paper alone were trialled at Cape Royds in 2001 with a range of concentrations applied to acid free paper. This paper experiment was observed as recently as February 2004 and at that time, no deterioration, yellowing or staining of the paper swatches coated with ARI had occurred (Clendon and Bickersteth 2004).

3.5 Observations of object treatment off-site versus on-site

Off-site conservation and replacement has been an effective model for the treatment of a very small number of selected artefacts. Difficulties in packing and transport from the ice were circumvented by a careful choice of artefacts. Observations conducted annually since 1997 have shown that Karel Peter's 1987 objects returned to Cape Evans and Peter Maxwell's 1998 objects returned to Cape Royds, post off-site treatment, have remained predominantly stable with only two artefacts recorroding. This statement is subject to one very important caveat: none of these returned objects were relocated in a high risk microenvironment.

In situ interventive experimentation which included treatment applications on corroding artefacts has had mixed results. Prior to 1997 commercial products were applied to artefacts if a treatment was considered required. The most significant example of this was a polyurethane coating applied to the stove at Cape Royds.

Since significant issues regarding the transport and use of commercial products in Antarctica exist, ARI was trialled as an alternative product during its developmental phases. The subsequent difficulties with ARI have been previously outlined and no baseline for comparative purposes was ever established. Best applications of ARI were achieved when halogen lamps were shone onto the metal surface, warming the environment and object surface. The re-treatment done at the rear of the Cape Royds stove in 2000 best exemplifies the effectiveness of this method. Applications of any water borne products generally are applied above 10 ^{o}C for maximum performance.

On the whole, *in situ* conservation is seriously constrained by the simple logistics of working in Antarctic conditions and complying with Antarctic environmental requirements. It would be bold to put forward a view that an effective interventive conservation program encompassing all artefacts could be conducted within the existing framework of camping on the ice.

4. Conclusions

In regards to the conservation of outside objects, the current conditions and technology is such that no viable metal conservation treatment program can be conducted. Some preventive conservation work may be suitable for a portion of this collection. The universal presence of chloride ions both as an aerosol or as salts in the earth and ice, combined with the effects of wind ablation and moisture availability are usually beyond any control.

Observations inside the huts, supported by the environmental data collected by Held *et al* 2003, stress the importance of recognizing the effects of variation in environmental conditions between the huts and within each hut when trying to preserve or prioritise the preventive or interventive conservation needs of interior artefacts. Artefacts located near the floor or outside walls have significantly increased rates of deterioration associated with greater moisture availability.

During summer the RH is high and the temperature is above freezing. The potential and rate of corrosion activity is consequently much higher, and a focus on reducing the RH within the huts during these periods should result in a significant reduction in general corrosion rates and a universally more beneficial environment for the interior artefact assemblage. It does appear from data acquired by Held *et al* 2003 that visitor numbers to the huts have no significant impact on RH inside the huts.

The major process of deterioration for metals inside the huts has been observed to be one of cyclic corrosion, developing from pitting to sheet like corrosion. Obviously the presence of chloride ions will further accelerate this process on a case by case basis. Results from sampling and analysis show that the presence of chloride ions is far from universal within the inside artefact assemblages.

A full range of conservation practices is not recommended for all objects. Some objects inside the hut have not been exposed to the outside environment or damp areas inside the hut and are not assessed as either significant or iconic. Objects which were located outside the hut prior to 1960, and that have been brought inside because of their significance, have a range of conditions.

The challenge put forward by the AHT is to preserve the large number of food cans in the collection, where conditions vary from pristine to very poor. Treating objects off-site has been mainly successful, however, the treatment of this wide range of objects is a costly and slow exercise. In the authors' view it is currently only possible to treat metal objects effectively off-site in a controlled environment, on-site activities should be restricted to preventive conservation only. For the long term conservation of the collection *in situ* the challenge is to stabilise the interior of the huts, and minimise the effects of relative humidity in summer.

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Materials and suppliers

Galmet Ionize A rust converter and sealer consisting of resin vinyl/vinylidene Chloride acrylic copolymer. ITW Polymers & Fluids. 100 Hassall Street, Wetherill Park, NSW, 2164 Australia.Tel: (02) 9757 8800 Fax: (02) 9757 3855

Dinitrol AV8 sulfonate corrosion inhibiting compound in an aliphatic hydrocarbon base Gibson Chemical Industries. 138 Kingston Road, Underwood QLD 4119.Tel: (07) 3208 9333 Fax: (07) 3808 4865.

Dinitrol 4010 A high temperature polyester modified wax dispersed with inhibitors Gibson Chemical Industries. 138 Kingston Road, Underwood QLD 4119.Tel: (07) 3208 9333 Fax: (07) 3808 4865

Ferroguard Full Spectrum A solution of vinyl copolymers and organic corrosion inhibitors in an isopropanol base Senson Technology Pty Ltd Unit 1/69 Division Street, Welshpool, Western Australia, 6106.Tel: 61-8-9358 3388 Fax: 61-8-9358 3390

Valvoline "Tectyl 506" A wax emulsion with inhibitors present. Automotive outlets, e.g. Bumper to Bumper, AutoBarn, Thompsons

Active Rust Inhibitor GP3000 (ARI) A water based polymer inhibiting product which has excellent properties to maintain an "as found" appearance. Cairns Corporation Pty Ltd, 221 Brisbane Street, Ipswich, QLD 4306. Tel: (07) 5426 7285 Fax: (07) 5426 7589

Rusticide A tannic/oxalic acid product used for converting active rust to a stable surface. Finish is matt black, but requires overcoating to give maximum performance. A water based product. Flo-Kleen Products, 216 Balcatta Road, Balcatta, WA 6021. Tel: (08) 9345 3122

Rust Stabiliser M.D.P. A moisture displacing pretreatment containing rust stabilizing pigments, synthetic waxes, mineral oils and white spirit solvent. Corroless Automotive Pty Ltd 27 Birubi Street, Cooparoo, Qld 4151. Tel: (07) 3394 3299

Preservation Wax 400 (Now trading as Corroless 400B reinforced wax). A solvent based wax and corrosion inhibitor composition with inert pigment. Corroless Automotive Pty Ltd 27 Birubi Street, Cooparoo, Qld 4151. Tel: (07) 3394 3299

Besq 195 a microcrystalline wax. Dussek Campbell Pty. Ltd., Vic, 3026.

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