

**WASTE PACKAGE SPECIFICATION AND  
GUIDANCE DOCUMENTATION**

**WPS/630: Guidance on Environmental  
Conditions during Storage of Waste Packages**

**March 2008  
Number: 8766013**



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**WASTE PACKAGE SPECIFICATION AND GUIDANCE DOCUMENTATION  
GUIDANCE ON ENVIRONMENTAL CONDITIONS DURING STORAGE OF WASTE  
PACKAGES**

This document forms part of a suite of documents prepared and issued by the Radioactive Waste Management Directorate (RWMD) of the Nuclear Decommissioning Authority (NDA).

The Waste Package Specification and Guidance Documentation (WPSGD) provide specifications and guidance for waste packages, containing Intermediate Level Waste and certain Low Level Wastes, which meet the transport and disposability requirements of geological disposal in the UK. They are based on, and are compatible with, the Generic Waste Package Specification (GWPS).

The WPSGD are intended to provide a 'user-level' interpretation of the GWPS to assist Site License Companies (SLCs) in the early development of plans and strategies for the management of radioactive wastes. To aid in the interpretation of the criteria defined by the WPSGD, and in their application to proposals for the packaging of wastes, SLCs are advised to contact RWMD at an early stage.

The WPSGD will be subject to periodic enhancement and revision. SLCs are therefore advised to contact RWMD to confirm that they are in possession of the latest version of any documentation used.

**WPSGD DOCUMENT NUMBER WPS/630 - VERSION HISTORY**

<b>VERSION</b>	<b>DATE</b>	<b>COMMENTS</b>
WPS/630/01	September 2005	Aligns with GWPS (Nirex Report N/104) as published June 2005
WPS/630/02	March 2008	Responsibility for the WPSGD passed to the NDA RWMD. Aligns with Issue 2 of GWPS (Nirex Report N/104) as published March 2007.

This document has been compiled on the basis of information obtained by Nirex and latterly by the NDA. The document was verified in accordance with arrangements established by the NDA that meet the requirements of ISO 9001. The document has been fully verified and approved for publication by the NDA.



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## 1 INTRODUCTION

The Radioactive Waste Management Directorate (RWMD) of the Nuclear Decommissioning Authority (NDA) has been established with the remit to implement the geological disposal option for the UK's higher activity radioactive wastes. The NDA is currently working with Government and stakeholders through the *Managing Radioactive Waste Safely* (MRWS) consultation process to plan the development of a Geological Disposal Facility (GDF).

As the ultimate receiver of wastes, RWMD, acting as GDF implementer and future operator, has established waste packaging standards and defined package specifications to enable the industry to condition radioactive wastes in a form that will be compatible with future transport and disposal. In this respect RWMD is taking forward waste packaging standards and specifications which were originally developed by United Kingdom Nirex Ltd, which ceased trading on 1<sup>st</sup> April 2007 and whose work has been integrated into the NDA.

The primary document which defines the packaging standards and specifications for Intermediate Level Waste (ILW), and certain Low Level Wastes (LLW) not suitable for disposal in other LLW facilities is the Generic Waste Package Specification (GWPS) [1]. The GWPS is supported by the Waste Package Specification and Guidance Documentation (WPSGD) which comprises a suite of documentation primarily aimed at SLCs, its intention being to present the generic packaging standards and specifications at the user level. The WPSGD also includes explanatory material and guidance that users will find helpful when it comes to application of the specification to practical packaging projects. For further information on the extent and the role of the WPSGD, reference should be made to the *Introduction to the Waste Package Specification and Guidance Documentation, WPS/100*<sup>1</sup>.

Following their manufacture, waste packages are expected to be held in interim surface stores until a GDF is available. Following such storage, waste packages would be removed from stores and transported to the GDF, where they would be emplaced in underground vaults.

The period of time that waste packages will spend in interim surface storage is not fixed but it is assumed that it could extend for up to 150 years. Whatever the actual storage period it is important that waste packages retain their integrity and, following removal from storage, are suitable for transport through the public domain and for ongoing waste management. An important factor in maintaining the integrity of waste packages is the control of the environment in which they are stored. This document provides guidance to store designers and operators regarding the environmental conditions that should be maintained during the interim storage of waste packages.

## 2 BACKGROUND

The purpose of this document is to provide guidance to store designers and operators regarding the factors which should be considered in respect of the environmental conditions that should be maintained in the facilities where waste packages are stored, be they interim surface stores or GDF vaults, to allow waste packages to meet the necessary

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<sup>1</sup> Specific references to individual documents within the WPSGD are made in this document in *italic script*, followed by the relevant WPS number.

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integrity requirements. It has been prepared by RWMD following review of regulatory [2] and international guidance [3] on the subject.

The document is primarily concerned with the needs of interim surface stores but it is also relevant to the specification of environmental conditions during all of the subsequent stages of their long-term waste management. The document is intended to form an input into the development of strategies for the storage of waste packages manufactured using stainless steel containers, which meet the needs of the particular storage circumstances.

The major threat to the integrity of waste packages is corrosion of the waste container. The corrosion performance of waste containers can be optimised by a consideration of three key areas:

- design and fabrication;
- selection of material;
- control of storage environment.

In response to the first two areas, the preferred solution is to manufacture waste containers from austenitic stainless steel to grade 316L (European Steel Number EN 1.4404 [4]) or its equivalent (see Section 3.1). A study has shown that the corrosion performance and mechanical properties of this material, if good practise is followed during container manufacture, can be regarded as optimum for the manufacture of containers for the packaging of ILW and LLW. [5, 6]

However the optimum corrosion performance of any material can only be realised by control of the environment in which the material is kept. It is in this area that this document aims to provide guidance and advice.

### **3 DEFINITIONS**

Integrity is defined as the ability of a waste package to maintain the containment of its contents, as well as the surety of its handling features.

In the context of this document the specific requirement is for waste packages to maintain their integrity in order to facilitate safe and efficient handling during all subsequent stages of their long-term management, which may include continued surface storage at an alternate location, transport to and emplacement in a GDF, and to ensure their long-term disposability [7].

The following are given as examples of indicators that may provide evidence for the maintenance of package integrity:

- key waste package performance criteria, as defined by the GWPS, continue to be achieved;
- key waste package performance criteria for continued storage, as presented in the store safety case, continue to be achieved;
- the waste package meets the requirements for transport through the public domain;
- the waste package is mechanically sound and may be handled [8] using normal procedures;
- the engineered closures (e.g. the container lid seal and bolting arrangements) are functional and that the release of gas from the waste package is only through the filtered vent.

These requirements are not exhaustive or independent, but are listed as important factors influencing integrity.

## **4 THE INFLUENCE OF ENVIRONMENT ON WASTE PACKAGE INTEGRITY**

In this section the stainless steels that are commonly used for the fabrication of waste containers are described and the various mechanisms for its deterioration are outlined. The key environmental parameters affecting the corrosion of stainless steel are also described.

### **4.1 Materials**

As noted previously, the most commonly used material for waste containers is austenitic stainless steel by virtue of its good corrosion resistance. An overview of how the use of stainless steel for waste containers offers satisfactory corrosion resistance during storage, transport, and handling, and is compatible with potential disposal in a cementitious environment, is presented in [5].

Stainless steels are iron alloys with a minimum chromium content of 10.5% [9]. The presence of chromium leads to the formation of a chromium-rich oxide on the surface, which provides a high degree of corrosion protection against a wide range of environments, hence the description 'stainless'. In general terms, the higher the chromium, molybdenum, nitrogen, and nickel content, the more corrosion resistant the material. The most commonly used stainless steels for waste containers are the standard austenitic grades, namely 304, 304L, 316 and 316L alloys (in the European material numbering system [4] these are denoted 1.4301, 1.4307, 1.4401 and 1.4404 respectively). The molybdenum addition in the 316 grade provides superior resistance to localised corrosion. The designation L refers to the low carbon version of each alloy, which is required to ensure the corrosion resistance of welded structures.

Waste containers are fabricated by welding and the lids of waste packages are commonly sealed by use of a bolted lid and a polymeric seal, although welded fabrications are also possible. Waste packages are often vented and, when this is the case, the vent is filtered often using a sintered stainless steel filter.

### **4.2 Atmospheric Corrosion Mechanisms**

Atmospheric corrosion results from reaction between a metal surface and the atmosphere to which it is exposed. Ambient temperature atmospheric corrosion occurs if a thin surface layer of moisture is present. Atmospheric corrosion is the most likely type of corrosion to affect waste containers in interim surface stores.

The high chromium content of stainless steels results in the spontaneous formation of a thin, adherent chromium-rich oxide film on exposure to air or water. The film protects the underlying metal against further reaction with the environment and is termed 'passive'. If damaged by abrasion, the film will quickly reform.

The passive film on stainless steels restricts general or uniform corrosion over the whole surface and the corrosion resistance in normal atmospheric conditions is therefore high. However, in some circumstances the passive film on stainless steel can break down in small areas, leading to localised corrosion. On a free surface, localised corrosion takes the form of small depressions or pits in the surface (pitting corrosion), or it can occur at crevices between mated surfaces (crevice corrosion). In the presence of tensile stresses in the material, either residual or applied, the localised corrosion can take the form of cracks (stress corrosion cracking).

A common initiator of localised corrosion is the presence of aqueous chloride ions, which are able to disrupt the passive film. The higher the concentration of chloride ions the greater the risk of localised corrosion. Localised corrosion can occur on surfaces immersed in water or during atmospheric exposure. A review of the atmospheric corrosion behaviour of stainless steel waste packages during storage [10] provides further detail about the rates of corrosion that have been observed for stainless steel in various applications and types of exposure. More detailed explanations of the mechanisms of localised corrosion of stainless steels are available in reference [11].

### **4.3 Environmental Factors Affecting Atmospheric Corrosion**

Brown and Masters [12] reviewed the factors that affect the corrosion of metals in the atmosphere. They categorised them as:

- weathering (e.g. temperature, moisture, air pollutants, solar radiation, wind, normal air constituents);
- biological (e.g. microbial activity);
- mechanical (e.g. stresses, leading to the possibility of environmentally assisted cracking);
- incompatibility (e.g. galvanic interactions between dissimilar materials);
- use (e.g. wear and abuse).

These factors should be considered by the waste packager in developing a waste packaging and storage strategy. Other factors that should be taken into account are the presence of deposits on the surface and crevices between contacting surfaces. Each factor should be considered in relation to the individual stores, taking account of the nature of the stores, the types of packages therein and the storage arrangements.

#### **4.3.1 Temperature**

Temperature may affect the corrosion rate in a number of ways. Temperature affects the relative humidity of the air, the dew point and the timescale over which liquid water is available, and directly controls the kinetics of all corrosion reactions. Temperature also affects the rate of degradation of polymeric seal materials.

The temperature of the surface of the waste packages will be determined by the ambient air temperature of the storage building, the thermal properties of the waste packages, the flow of air over the waste package surfaces and the heat output of the waste.

#### **4.3.2 Relative Humidity**

The relative humidity (RH) determines the amount of water that will be available on the surface of the packages to support corrosion. RH, at a given temperature, T, is defined as:

$$RH = \frac{\text{partial pressure of water vapour}}{\text{saturation pressure at T}} \times 100$$

When a sample of moist air is heated the RH decreases. However the total amount of water that the air can accommodate increases with increasing temperature. As air is cooled, for example by contact with a cooler surface, the RH near the surface increases, until eventually a value of 100% is reached. At this point the water vapour starts to condense. The temperature at which this occurs is known as the dew point temperature. The higher the RH, the smaller the reduction in temperature required to reach the dewpoint and cause condensation.

All materials have an affinity for adsorbing water vapour. The amount of water adsorbed by the surface of a given material depends on the temperature, the partial pressure of water vapour, the surface area and the hygroscopicity of the material involved. As the amount of adsorbed water vapour increases, the thickness of the surface layer of water increases. For a given temperature, this behaviour is described by the material's adsorption isotherm [10].

As the RH increases, a thin discontinuous film of moisture develops on the surface of the metal. Three moisture regimes can be defined [13], namely:

- the metal surface is moisture free;
- an invisible adsorbed moisture film is present;
- a moisture film is visible.

When the adsorbed film of water is sufficiently thick, chemical and electrochemical reactions involving the metal surface can occur. The critical thickness may only be a few monolayers (i.e. less than ten) and it is not necessary to have a complete coverage, as clusters of water molecules may be sufficient to enable corrosion to proceed. The presence of deliquescent salts (e.g. sodium or calcium chlorides) or corrosion products can lead to the development of water films on the surface at lower RH than would be required on a clean surface. It has been found that the presence of certain types of chloride at low RH can also promote stress corrosion cracking [14].

#### **4.3.3 Transport of Moisture**

In storage buildings, the availability of moisture to support atmospheric corrosion is often constrained by moisture transport [15]. Moisture in buildings may be transported by several mechanisms, including liquid flow, capillary suction, air movement and vapour diffusion. Each mechanism can act independently and should be taken into account during design and construction, and subsequent operations.

Transport of moisture by air movement is probably the most important mechanism in storage buildings. The various driving forces for air movement include the stack effect, meteorological conditions (e.g. wind) and mechanical systems. Wind may have a significant effect on air infiltration patterns in storage buildings, particularly those constructed in regions with strong prevailing winds. Strong winds tend to promote infiltration on the windward side of buildings and exfiltration on the leeward side. This could promote condensation being concentrated towards the windward side of buildings in summer and the leeward side in winter [16, 17].

The air flow pattern introduced by mechanical ventilation will affect the distribution of moisture and airborne contamination around a waste store. Ducted mechanical air systems may lead to negative pressures being generated within parts of the building and may promote infiltration of external air.

Although moisture may enter a building as a result of any of these processes, moisture may not necessarily be deposited. For this to occur, airflow speeds must be slow enough for the air to cool to the dew point temperature before it moves away from cold surfaces. Fast flowing air can warm the surfaces of the flow path to above the dew point temperature and condensation may not occur [16, 17]. Stagnation points, where airflow is very low or negligible, are the most likely places in a building for moisture to be deposited.

#### **4.3.4 Atmospheric Pollution**

Atmospheric pollution can be divided into two types, namely aerosols and gases. Aerosols are suspensions of fine liquid or solid particles in a gaseous medium and include such materials as salt spray and dust. The main pollutant gases include nitrogen

oxides, sulphur oxides, hydrogen sulphide and organic acid vapours. Pollutant aerosols and gases may enhance stainless steel corrosion rates.

**i) Aerosols**

Aerosols may be deposited on waste package surfaces. Chloride- and sulphate-containing particles are common in marine atmospheres, and in the UK are likely to be an important factor determining atmospheric corrosion rates in waste stores, both at coastal locations and inland. At low RH, the deposition of absorbent particles such as carbon on surfaces can increase the amount of water present on the surface [18]. For example, particles on the metal surface also provide sites for capillary condensation to occur. There may also be a galvanic enhancement of corrosion of stainless steel in contact with carbon-bearing particles (e.g. from diesel engines). Inert, non-adsorbent particles have little direct effect on the corrosion of stainless steel except that they will create tiny sites which may be conducive to the initiation of crevice corrosion.

Airborne particles are less abundant inside buildings, and the reduction in the concentration of coarse particles is greater than it is for fine particles. The atmosphere can also transport microbes, such as bacteria, algae and fungal spores, which could promote microbially influenced corrosion.

**ii) Contaminant gases**

This category of contaminants includes carbon dioxide, ozone, sulphur dioxide, nitrogen oxides, hydrogen sulphide, hydrogen and organic acid vapours, all of which may have an effect on the corrosion of waste packages. The exact composition of atmospheric pollutants in a waste store will depend on a number of variables, such as the concentration of pollutants in the external atmosphere, which will be site-specific, and the operating procedures that are adopted within the waste store. Hydrogen sulphide is likely to be oxidised to sulphur dioxide fairly rapidly.

**4.3.5 Microbial Activity**

Microbially influenced corrosion (MIC) [19] results from the ability of micro organisms to change the nature of the local environment, such that it promotes corrosion of the underlying metal. MIC can proceed by a range of mechanisms, and should be considered as a group of corrosion processes rather than a single one. For MIC to occur, there have to be sources of viable micro organisms, a source of suitable nutrients and water. The micro organisms involved can be bacteria, fungi or algae. Possible nutrients include carbon dioxide, nitrogen oxides, and organic materials. Operational lighting or natural light could provide an energy source for photosynthesising algae.

**4.4 Radiation Fields**

Containers will be exposed internally and externally to  $\gamma$ -radiation emanating from all the packages in a store. The main effect of radiation upon the environment is to produce nitric acid from atmospheric nitrogen, oxygen and water. The nitric acid will dissolve in moisture films on the surface of the containers. The rate of formation of nitric acid will depend on the radiation flux emanating from the waste package and hence on the exact nature of the radioactive waste. Higher concentrations of nitric acid would be produced on the surfaces of higher activity unshielded<sup>2</sup> waste packages. Stainless steel does not corrode to any significant extent in nitric acid, but the simultaneous presence of chloride can cause corrosion at elevated temperatures.

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<sup>2</sup> Waste packages with no integral shielding, these include the standard 500 litre Drum and 3 cubic metre Boxes and 3 cubic metre Drum waste packages.

## 5 CONTROL OF ENVIRONMENTAL CONDITIONS IN PACKAGES WASTE STORES

### 5.1 Control of Environment to Avoid Localised Corrosion

Some experimental studies of the localised corrosion of grade 304L stainless steel have found that pitting and atmospheric stress corrosion cracking are influenced by the surface concentration and form of chloride and by the RH. In the light of this, for grade 304L tight control has been applied to the permitted chloride level in some instances. The data reported in reference [20] suggests that at 25°C ambient temperature and a RH of 50-70%, there is a risk of pitting corrosion or rust staining above a surface chloride concentration of  $10\mu\text{gcm}^{-2}$ . Whilst the depth of attack is likely to be minimal [21, 22], in view of the potentially long storage timescales it would be advisable to follow the normal practice of designing so that localised attack can never initiate [23].

For 316L stainless steel corrosion resistance is known to be greater but there is little data to provide a quantitative indication as to how these factors will affect its performance. RWMD is therefore continuing to undertake research to examine the susceptibility of grade 316L to chloride enhanced corrosion such as pitting, atmospheric stress corrosion cracking and crevice corrosion. In view of the importance of chloride levels and in the absence of firm quantitative data on tolerable levels on surfaces, waste packagers should apply best practice to minimise chloride deposition on waste containers. Measurements on the levels and chemical form of chloride should form part of a monitoring programme within waste package stores, to support cases for the continued adequacy of the waste package, or to allow intervention or remedial measures to be taken if the onset of corrosion is predicted or detected. Some examples of the levels of chloride contamination that may arise in buildings are given in the following paragraph. Waste packagers should consider what is relevant in their locality.

The concentration of airborne chloride depends on the location of the store. The concentration is high at coastal locations, due to the presence of sea spray, and falls rapidly on moving away from the coast. For example, the chloride deposition rate at a coastal location (Windscale) has been measured as  $15$  to  $75\mu\text{gNaClcm}^{-2}\text{day}^{-1}$  [24]. Recent measurements of surface chloride concentrations on a waste container inside a store at an inland semi-rural location (Culham, Oxfordshire) have yielded surface chloride concentrations of up to  $5\mu\text{gNaClcm}^{-2}$  [25] in the space of a year. Store designers should consider the design of store buildings, filtration and ventilation systems and the effect these may have on internal chloride levels.

To minimise surface contamination with chloride prior to use, new waste containers should be protected during transport to the processing plant, for example by wrapping in protective plastic sheeting; where wrapping is not practical containers should be washed before storage.

It should also be recognised that there would be a risk of crevice corrosion if the levels of chloride in crevices is allowed to become more concentrated by, for example, repeated condensation cycles. In this situation it is not possible to define an acceptable chloride concentration in the vicinity of the crevice.

### 5.2 Moisture and Temperature Control

It is important to guard against exposure of waste packages to liquid water, since localised corrosion of stainless steel is more likely if a water film is present, particularly if the water were to penetrate into crevices. Liquid water might enter the store as a result of roof leaks or external flooding, or might form as a result of condensation as previously mentioned.

Although increases in temperature generally lead to an increase in corrosion rate, for a given storage environment the most important consideration is the relationship between temperature and RH.

### **5.2.1 Control of Moisture**

Strategies for moisture control in buildings fall into two general categories:

- minimising moisture entry into the building envelope, and;
- removing moisture from the building envelope.

Selection of moisture control options depends on an understanding of basic moisture transport mechanisms and the effect of climatic variations.

Source control is an important issue. The potential of cementitious materials in newly constructed building walls and in the conditioned wastefrom to contribute significant moisture should be considered. One of the single largest sources of moisture in buildings, regardless of the climate zone or the season, is the migration of moisture from the surrounding soil into the foundations, and subsequently into the building interior [15]. An IAEA Technical Committee Meeting report [3] has stated:

*'If buildings are planned to be used for storage of radioactive waste they should be situated above the groundwater level, and certainly not in a flood plain. In cases where a subsurface storage facility is designed, this facility should be constructed with appropriate systems to protect against in-leakage of groundwater'.*

The floor of the building should be sealed, or underlain by an impermeable membrane.

Dense packing of waste packages may promote condensation in the interior of drum stacks where the air may be stagnant and the effects of heated or forced ventilation may not be felt. Detailed monitoring of temperature and RH within a store could allow the store operator to guard against the development of unfavourable environmental conditions.

Dehumidification of the air may be used to reduce indoor humidity levels. This is best performed on inlet of air to the store; if performed after inlet the condensed water may contain tritium (if released from waste packages) and may have to be disposed via special routes.

### **5.2.2 Control of Temperature**

Condensation typically occurs when moist air comes into contact with a surface that has a temperature lower than the dew point of that air. The chief remedies to surface condensation are as follows:

- increase surface temperatures, by heating or insulation, although increased temperatures may promote faster degradation of some wastefroms;
- reduce water vapour pressure by minimising interior vapour sources, by diluting moist indoor air with drier air, or through use of dehumidifiers (see Section 4.1.1).

The strategy chosen will vary depending upon the local climate and the type of store building. To prevent condensation from occurring, interior surfaces should be sufficiently thermally insulated to ensure that the package surface temperature always exceeds the dew point temperature.

Various design tools [15] may be used to predict the likelihood of condensation on building interior surfaces. Simple estimates of the ventilation and heating requirements to prevent condensation from occurring on the interior surfaces of buildings may be obtained relatively easily for different building designs. More specific thermal analyses



could be applied to specific waste packages having a range of thermal insulation properties.

In specific types of store there may be a need to restrict the ambient temperature to minimise the corrosion rate of waste metals. For example, the corrosion rate of recently packaged Magnox increases with temperature and it would be appropriate to ensure that the temperature is minimised, consistent with the waste package surface temperature remaining above the dewpoint.

### **5.3 Air Filtration**

Precipitation of particles from the air is likely to occur when air passes through buildings and ventilation shafts. The rate at which particles precipitate will depend on their size, with larger particles precipitating more readily than fine particles. At storage facilities with mechanical ventilation systems, engineered air intake systems should be filtered to prevent ingress of saline and other potentially harmful particles, which may become deposited on the surface of waste packages.

### **5.4 Care of Stainless Steel**

The corrosion performance of stainless steels is strongly dependent of the condition of the surface of the material and RWMD have produced guidance as to how the surface finish of stainless steel can be controlled to ensure optimum corrosion resistance [26].

Prior to use, stainless steel containers should be kept dry and, where possible, surfaces should be protected from contamination by dirt and dust; even embedded particles of an inert nature can cause corrosion by creating a crevice with the stainless steel surface. Hand contact should be avoided, e.g. by use of gloves, to avoid transfer of chloride.

If cleaning is necessary, it is generally recommended to use a detergent solution and to rinse with water [27]; if it is necessary to use solvents, they must be non-chlorinated solvents.

Ferrous particles from tools or handling equipment can become embedded in the surface of stainless steel at pressure points and suffer from corrosion. The presence of corroding ferrous material can initiate corrosion of the underlying stainless steel. It is important to avoid contaminating stainless steel with embedded iron, or to remove it after manufacture by appropriate chemical or mechanical cleaning procedures which are capable of removing embedded iron [28]. Recommendations for acid cleaning of stainless steel are included in an ASTM standard [29], which states that a citric acid-sodium nitrate treatment is the least hazardous for removal of free iron and other metallic contamination and light surface contamination. Cleaning agents should be removed by rinsing with water.

### **5.5 Contaminant Gases**

The following gases have been implicated in the atmospheric corrosion of metals [10]:

- sulphur dioxide and hydrogen sulphide;
- nitrogen oxides;
- organic acid vapours (e.g. formic acid, acetic acid from wood, plastics, adhesives).

It is unlikely that these gases will be present in significant quantities in an engineered waste store, but steps should be taken to eliminate them if, for example, they were being generated by a particular type of waste. There are no clear threshold data available on which to base acceptable targets for airborne concentrations of these gases. If these are found, further interaction with RWMD is advised to enable any implications to be assessed.

### **5.6 Microbial Activity**

To reduce the risk of MIC, surface contamination by water and nutrients, such as organic materials, should be minimised by appropriate operational procedures. Microbial activity is unlikely if the waste package surface remains dry and clean. By keeping waste packages in the dark the possibility of algal growth will be eliminated. The use of inlet filters will reduce the ingress of organic particles.

### **5.7 Evolving and Transient Conditions**

The environmental conditions are likely to evolve during the life cycle of a store. For example, as the store fills there may be an increase in the ambient temperature, due to heat produced by the waste packages. The dynamics of ventilation will also change as the volume occupied by waste packages increase. These factors should be addressed in design and during operation of packaged waste stores.

Waste packages are also likely to be exposed to transient storage conditions, for example when newly manufactured packages enter the store, or when packages are removed from the store. On these occasions, there may be a rapid and temporary change in the ambient temperature and RH, or an excursion in the concentration of airborne chloride or microbes. If extended operations are undertaken within the store, the increased light levels could have an influence on algal growth. Consideration should be given as to how these transients might affect the corrosion behaviour of stored waste packages.

Individual waste packages will experience changes in environmental conditions when they are moved from the processing plant to a store or transported out of storage. These will probably be the times when waste packages are most at risk of exposure to aggressive conditions, such as condensation, mechanical abrasion, deposition of contaminants (including liquid water), and higher exterior concentrations of chloride. Appropriate measures should be considered to protect against the effects of these transient conditions.

## 6 REFERENCES

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- 1 Nirex, *Generic Waste Package Specification*, Nirex Report N/104 Issue 2, 2007.
- 2 W Seddon, *Engineering Considerations Associated with Plants Used for the Storage of Intermediate-level Waste - a Regulator's View*, Nuclear Energy 40(1), 59-64, 2001.
- 3 IAEA, *Interim Storage of Radioactive Waste Packages*, IAEA Technical Report Series No 390, 1998.
- 4 British Stainless Steel Association, *Guide to Stainless Steel Specifications*, 2003.
- 5 Nirex, *Corrosion Resistance of Stainless Steel Radioactive Waste Containers*, Nirex Report N/110, 2004.
- 6 The Welding Institute, *Best Practice Guide – Welded Joint Design and Manufacture for Stainless Steel Containers*, TWI Report No. 13451/1/02, 2002.
- 7 HSE/EA/SEPA, *Conditioning of Intermediate Level Radioactive Waste on Nuclear Licensed Sites: Guidance to Industry*, 2005.
- 8 HSE, *Safe use of Lifting Equipment: Lifting Operations and Lifting Equipment Regulations 1998 - Approved Code of Practice and Guidance*, HSC 1998.
- 9 J E Truman, *Stainless Steels*, in 'Corrosion' L L Shreir, R A Jarman and G T Burstein (eds.), Chapter 3.3, Butterworth Heinemann, 1994.
- 10 Nirex, *Atmospheric Corrosion of Stainless Steel Waste Containers during Storage*, T/REP/326679/E/04, 2000.
- 11 A J Sedriks, *Corrosion of Stainless Steels*, second edition, John Wiley, 1996.
- 12 P W Brown and L W Masters, *Factors Affecting the Corrosion of Metals in the Atmosphere*, pg. 31 in 'Atmospheric Corrosion', W H Ailor (ed.), John Wiley, 1982.
- 13 N D Tomashov, *Theory of Corrosion and Protection of Metals*, MacMillan, New York, 1966.
- 14 S Shoji and N Ohnaka, *Effects of Relative Humidity and Chloride Type on Stainless Steel Room Temperature Atmospheric Stress Corrosion Cracking*, Corrosion Engineering 38, 111-119, 1989.
- 15 H R Trechsel (ed), *Moisture Control in Buildings*, Chapter 10, ASTM MNL 18, 1994.
- 16 J Lstiburek and J Carbody, *Moisture Control Handbook – Principles and Practices for Residential and Small Commercial Buildings*. Van Nostrand Reinhold, New York, 1993.
- 17 N Hutcheon and G O Handegord, *Building Science for a Cold Climate*, Construction Technology Centre, Atlantic, 1983.
- 18 D Fyfe, *The Atmosphere*, in 'Corrosion' L L Shreir, R A Jarman and G T Burstein (eds.), Chapter 2.2, Butterworth Heinemann, 1994.
- 19 G Kobrin (ed.), *A Practical Manual on Microbiologically Influenced Corrosion*, NACE, Houston, 1993.
- 20 M F Taylor, *The Significance of Salt Contamination on Steel Surfaces, Its Measurement and Removal*, Eurocorr'94, 1994.

- 21 NiDI, *Advantages for Architects Who Design for Beauty, Permanence, Utility and Prestige with Nickel Containing Stainless Steel; An Architects Guide on Corrosion Resistance*, NiDI publication 12009, 1990.
- 22 N G Needham, P F Freeman, J Wilkinson and J Chapman, *The Atmospheric Corrosion Resistance of Stainless Steels*, Stainless Steels'87, York, 1987.
- 23 *Design and structural integrity - Corrosion*, The Welding Institute, August 2000.
- 24 H R Ambler, *Atmospheric Salinity and Metal Corrosion at Various Places in Great Britain*, J. Applied Chemistry 10, 213, 1960.
- 25 N R Smart et al, *4m ILW Box Condition Monitoring Programme - Results of First Two Years*, AEAT/R/PS-0048, February 2001.
- 26 Nirex, *Waste Container Design Requirements and Methods for Control of Surface Finish*, Nirex Report N/087, 2003.
- 27 NiDI, *Stainless steel in architecture, building and construction: guidelines for maintenance and cleaning*, NiDI Reference Book Series No. 11 014, 1994.
- 28 NiDI, *Design Guidelines for the Selection and Use of Stainless Steel*, NiDI Document 9014.
- 29 *Standard Practice for Cleaning, Descaling and Passivation of Stainless Steel Parts, Equipment and Systems*, ASTM Standard A 380 -- 99.



