CORROSION CONTROL OF AGRICULTURAL EQUIPMENT AND BUILDINGS

CONTENTS

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1 INTRODUCTION

Agriculture and horticulture together represent one of the largest sectors of British industry. These industries are capital intensive, with investments per acre varying widely, depending upon the particular activity. High investments are found where structures are involved and particularly in the case of glasshouses, where re-equipment schemes such as thermal screening, auto-ventilation, controlled feeding etc, can be very costly

2 CORROSIVE ENVIRONMENTS

The wide variety of structures, machinery and fittings employed for farming purposes makes it difficult to define precisely and concisely where corrosion can be most damaging. The situation is further complicated by the different types of environment (rural, urban, coastal), the local 'microclimate', the type of farming activity, the seasonal use of certain equipment and machinery and the methods employed for storage.

2.1 GENERAL CONSIDERATIONS

The extent of corrosion of a metal depends on its local environment; behaviour in the atmosphere, in permanently wet conditions, and in soil, is different, and metals and protective treatments must be chosen accordingly.

When buildings and structures are being designed, the corrosiveness of the atmosphere must be assessed. areas within 8 km of a coast are considered to be one category of exposure higher than those inland , as are tall structures and those sites on exposed hillsides. Exposure is also more severe downwind of industrial areas.

Damage by corrosion is not always uniform in nature but may be localised to small areas. causing premature failure or damage but can be prevented by good design and best practice in the use of equipment.

2.2 CORROSION BY AGRICULTURAL CHEMICALS

Many commercial chemicals are used in farming, including fertilisers, grain and silage preservatives, chemicals for pest, disease and weed control, and proprietary acid solutions for cleaning dairy equipment. Farm wastes and slurries can also be significantly corrosive. The chemicals most frequently damaging to farming structures and machinery, as revealed in the recent study, include acid preservatives and additives, certain fertilisers and manures or slurries. The following paragraphs give details of particularly aggressive chemicals and provide information that can lead to improved reliability and performance of metals and other materials.

2.2.1 Fertilisers

Some fertilisers are more corrosive than others, especially if they decompose or react to produce aggressive substances such as ammonia or hydrogen sulphide, if chloride ions are present (including potassium or ammonium chloride), or if acidic conditions prevail. For example, dihydrogen ammonium phosphate or ammonium nitrate can lead to increased corrosion via hydrolysis to acids (i.e. a fall in pH).

The relative ratios of the essential plant nutrients can influence the corrosiveness of compound liquid fertilisers, there being some evidence that the greatest effects occur with fertiliser solutions containing about 15% nitrogen, especially when half the free nitrogen is derived from urea and half from ammonium nitrate. Some typical reactions for liquid fertilisers, are given in Table 1.

Table 1 Corrosive reactions of liquid fertilisers

Liquid fertilisers	Chemicals	Reactions with steel
Nitrogenous solutions	Ammonium nitrate, urea	Slow reaction with steel; can be more rapid at welds and bolt holes, etc.
Phosphate solutions	Ammonium phosphate	Tends to be less reactive; forms a protective phosphate coat which can protect metal from subsequent attack by nitrogenous solutions, unless acid conditions prevail.

If fertilisers are kept dry, then no corrosion occurs, but being hygroscopic they can pick up moisture and hence may become corrosive. The hygroscopic point – the relative humidity (RH) at and above which moisture is absorbed – varies from one compound to another and the lower its value the more corrosive the fertiliser is likely to be. Ammonium nitrate starts to absorb moisture at 60% RH, while certain phosphates absorb moisture only above 90% RH. Moisture initially causes caking of the fertiliser, which can increase its abrasive properties.

Galvanising of steel is generally beneficial in resisting corrosion, as can be noted from the results of laboratory tests, where metal was immersed in shallow pools of solution for 500 hours at ambient temperatures (see table 2)

Table 2 Steel corrosion rates in fertilisers determined in laboratory tests at ambient temperatures

Fertiliser	Equivalent thickness loss after first year (μm)	
	Mild steel	Galvanised steel
Ammonium nitrate:		
saturated solution	1,250	250
63% solution	380	280
Ammonium nitrate and chalk:		
saturated solution	815	330
67% solution	1,070	340
Compound fertiliser (0,24,24):		

saturated solution	200	60
‘Controls’ in clean potable water	60	20

Carbon steel is often used to contain fertilisers because it is cheap, but adequate surface cleaning, preparation and coating are necessary. Type 304 stainless steel has shown overall benefit for liquid fertiliser service over three-year service tests. Penetration figures for tanks exposed for 2.25 years to commercial liquid fertilisers are given in Table 3.

Table 3 Material performance in commercial liquid fertilisers after 2.25 years’ service tests

Material	Penetration (μm)
304 stainless steel	0.253
Carbon steel	282
5052 aluminium	132

The onset and progression of corrosion by fertiliser solutions can be controlled by better design of equipment and by improved maintenance and cleaning (see Section 3). Inhibitors are available for use with fertilisers during storage, transportation and application. Sulphur compounds, such as thiourea, ammonium thiocyanate and 2-mercapto benzothiazole, are suitable for mild steel exposed to ammonium nitrate/ammonia/water – in the absence of urea – whilst moderate success has been reported with polyphosphates (sodium polyphosphate, dibasic ammonium phosphate) for aqueous ammonium nitrate/ammonia/urea. Free ammonia can reduce inhibition by orthophosphate by protection of exposed metal.

2.2.2 Silage

Tower silos are prone to corrosion damage, primarily by the organic acids that are produced during the process of ensilage. The most acidic and corrosive environment is claimed to exist within silos containing whole crop maize silage, which ferments readily and rapidly to produce acids with typical concentrations in solution of 2% lactic acid and 0.5% acetic acid and with the pH as low as 3.6. Lactic acid is regarded as the stronger acid and, if oxygen is present also, then secondary fermentation can occur, giving silage which is predominantly butyric acid, thus yielding a higher pH value. Furthermore, temperatures inside silos can be as high as 30 °C, so corrosion rates inside tend to be higher than those on the external walls.

The use of certain organic acids as additives in silage-making has increased over the last 10 years. Such acids, added to grain prior to storage, inhibit the growth of moulds, bacteria and yeasts, which generally destroy the nutrient value of the grain when stored at high moisture content. Formic acid has a long history of use and, more recently other acids in the aliphatic carboxylic group, including propionic acid, have been employed.

In practice, the contact time for acids on machinery, e.g. on augers and balers, is low, so corrosion rates are usually less than 1 mm/year (on mild steel). During storage, acid-treated grain has little effect, the major precaution needed being to minimise the risk of concentration in local areas such as crevices, or where stagnant pools of liquid can collect. Propionic acid is highly corrosive, but little damage should occur if correct precautions are taken, such as the complete removal of the acid-treated grain from the silo after use, washing with water, and avoidance of contact of treated grain with unprotected machinery.

A particular problem with organic acid additives is their paint-stripping properties, but compositions modified, for example, by the addition of a cation to produce complex acid salts, are significantly less corrosive and less liable to strip paint.

Materials that have given good service for silos are aluminium (over 10 years's life), and vitreous enamelled steel which is particularly easy to clean and maintain. Plastic coatings are liable to surface damage, and crevice corrosion can occur if adhesion is lost. Galvanised steel may deteriorate in contact with silage juices and slurries, but is resistant to silage vapours. The order of preference for metals of construction for storage vessels is: aluminium (best), galvanised steel, mild steel.

Equipment used for unloading and conveying silage can be subjected to corrosive wear (see Section 3), 'Machinery and equipment') because it is not unusual for silage from the bottom of the silo to have a consistency akin to chipboard. The combination of abrasion and acid attack is also especially destructive to concrete because acids react with lime; covering of floors with plastic sheeting, or with an acid-resisting coating such as chlorinated rubber or epoxy paint, provides protection.

2.2.3 Slurries and manures

The intensification of animal husbandry has increased the problems of handling manure, and much equipment has been developed to cope with the large quantities involved. Enhanced corrosion in crevices and awkward corners can be avoided at the design stage by the use of round-section tankers and other equipment.

Slurry is a mixture of dung and urine, and farmyard manure (FYM) is slurry composted with litter, i.e. straw or wood shavings, etc. Both ferment to release moisture, ammonia and carbon dioxide. The corrosive constituents in slurry and FYM are urea, uric acid, ammonia and ammonium salts, and naturally excreted chloride (common salt), and the mixture is corrosive towards steel structures and machinery that are poorly protected and maintained.

The results of laboratory tests are given in Table 4. The figures can be compared with those in Table 2.

Table 4 Steel corrosion rates in various FYM in laboratory tests at ambient temperature.

Manure	Equivalent metal thickness loss after 1 year (μm)	
	Mild steel	Galvanised steel
Poultry	167	160
Pig	130	75
Cattle	199	95
'Controls' in clean, potable water	60	20

According to these tests, galvanised steel has little benefit for some manures, notably that derived from poultry and cattle. However, service conditions do not apparently cause undue concern for manufacturers, who generally advocate galvanised steel or concrete for livestock floors. Results for piglets where copper compounds are incorporated in the feed, result in galvanised metal thickness losses nearer to 0.1 mm/year – probably a result of local deposit/galvanic corrosion effects.

Corrosion associated with wastes in contact with steel and concrete is given in table 5.

Table 5 Corrosive reactions of wastes

Wastes	Chemicals	Reactions with steel and concrete
Silage effluent*	Lactic acid Acetic acid Butyric acid	Such acids in sufficient concentration will react with lime in cement; concrete subject to such acids should be designed to a medium workability mix .
Milk wastes	Lactic acid	Any steel surfaces need suitable protection.
Slurry*	Varies from neutral to slightly acid	Special precautions are not normally needed.

* Note: If silage effluent and slurry are mixed together, dangerous concentrations of hydrogen sulphide gas can be formed.

2.2.4 Herbicides and pesticides

During the last decade there has been intensive development of chemicals used for crop protection, and corrosion by herbicides and pesticides can be significant under certain conditions, especially if harmful species concentrate in local areas. Copper-bearing fluids such as Bordeaux mixture – made from copper sulphate, water and lime – can, for example, be aggressive to aluminium or to zinc (as on galvanised steel), a feature associated with incompatible metals. Glasshouse structures has shown that 'zinc drip' can become significant if such fluids are used. This attack is particularly harmful on new structures with fresh galvanising.

Intense waterline attack has been reported in steel drums containing 50% aqueous TCA (sodium trichloroacetate) weedkiller within nine months. Heavy attack was noted for aluminium, galvanised steel, various brasses and copper, but tinned steel and molybdenum-containing stainless steel) Type 316) were resistant. Nitrophenolic compounds, of general formula 2,4-dinitro, 6-alkyl phenol, commonly used as weed-killers, have corroded steels and irons used in spraying equipment, whether in aqueous or oleaginous dispersion. Inhibitors such as 0.7% sodium dichromate (for TCA) and 1.5% furfural (for 2,4-dinitro) have been useful; surface coverage by oil has also inhibited waterline attack.

Certain insecticides, such as chlorodane, are particularly corrosive and acidic (pH = 2) and aqueous solutions of sodium arsenite and DDT in salt water have been found to be aggressive to common metals like carbon steel, galvanised steel, copper and aluminium. Of the more common materials, stainless steel is reported to be the most resistant for use with herbicides and pesticides and aluminium is satisfactory in all but aqueous sodium arsenite. Insecticides dissolved in kerosene or fuel oil are not aggressive.

2.2.5 Dairy farming

Stainless steels are widely used for dairy equipment, so generally corrosion in this area is relatively uncommon. Specific problems arise with cleaning and sterilisation of associated buildings and machinery, there being particular need to protect mild steel supporting structures from milk wastes; lactic acid, for example, can remove 1.25 mm of steel in one year. Chlorine-containing agents (sodium hypochlorite, etc) are potentially corrosive to all constructions metals encountered in the dairy industry, and efforts should be taken to minimise any local build-up of chloride ions which can destroy or weaken naturally forming protective films on the metal surface. Under certain conditions)tensile stress, temperatures above about 70 ^{o}C) some stainless steels may crack by stress corrosion when in contact with chloride ions.

The use of phosphoric acid as a chemical for removing scale or milk stone requires careful attention, it is not advised for use with aluminium utensils and tinned surfaces should not be over-treated.

3 RISK AREAS AND CORROSION CONTROL

The response of farmers and horticulturists in a recent survey has revealed that damage by corrosion to buildings and structures is comparable with damage to machinery and equipment.

The information so collected shows that high-risk areas include galvanised structures and sheeting, certain animal houses – notably piggeries – and units that handle fertilisers and slurries, where the influence of chemicals (see Section 2, ‘Corrosion by agricultural chemicals’), often in association with wear, can be significant.

3.2 STRUCTURES AND BUILDINGS

Galvanised structures corrode when the protective zinc coating has been corroded away by acid or salty environments (or by strong alkali). In rural environments, galvanised sheet may well last more than 30 years, but life in a severely polluted area may be only five to ten years.

Galvanised steel does not satisfactorily withstand aggressive soils (e.g. peats or marshes containing sulphate and chloride) or acid conditions that may occur at ground level in some buildings, nor can it withstand the severe condensation that is not uncommon in some farm buildings. When buildings are sited in marine or other highly corrosive atmospheres, painting is recommended. Contact the Galvanisers Association for further advice.

In this context, calcium orthoplumbate alkyd primers plus matching alkyd top-coats, acrylic resin dispersions and paints based on combinations of tung oil and alkyd phenolic resins have been found to be particularly easy to apply to suitable prepared galvanised surfaces.

Piggeries and poultry houses experience very severe corrosion attack, probably as a consequence of intense slurry action where the internal atmosphere can contain ammonia in high concentration. Designs to reduce condensation effects beneath roof surfaces include the use of double layers of roof sheeting with an air-space, improved ventilation using air-space, improved ventilation using air inlets in walls and outlets high in the roof, or the use of materials less prone to corrosion, with or without protective coatings (providing the latter is ‘safe’, i.e. non-toxic, in areas that house animals).

Careful consideration is recommended for fixings and fasteners for all structures, whether they are metallic or not. Corrosion in crevices can be a problem, and corrosive reactions are possible if aluminium or zinc (on galvanised steel) come into direct contact with timber, particularly if it is treated with preservatives containing copper, mercury or fluorides in *damp* conditions. Table 6 outlines various corrosion possibilities for timber preservatives.

Table 6 The effect of preservative treatments for timber

Preservative type	Comments on corrosion
Creosote, coal tar,	Little corrosive action except to lead. NOT FOR GLASSHOUSES – detrimental to growing crops.
Water-borne preservatives, copper-chrome-arsenic	Can be corrosive to iron, zinc and aluminium, especially after fresh treatment; preferable to age timber for seven days prior to fastener fixing.
PCP in heavy oil, pentachlorophenol,	Negligible unless alkali is present to covnert PCP to soluble chloride ions.
Organic solvent preservatives	
Copper naphthenate,	Soluble copper a problem on zinc, aluminium and iron.
PCP as above Tributytin oxideZinc naphthenate pentachloride	)) No corrosion problems.))

Damage to metals in contact with timber can be reduced if the area of contact is isolated with a suitable tape or bituminous layer, or if the metal fitting is first dipped in lanolin or tallow. Some timbers are naturally durable and can be used for most situations, including contact with the ground or with other damp materials; jarrah and teak can last for 50 years whilst other timbers, e.g. sweet chestnut, pine or cedar can be used for up to 20 years. The majority of timber used for glasshouses is European red wood, suitably impregnated with preservative, to minimise the risk of decay. If timbers are not so treated they should be painted, but neither creosote nor emulsion paint should be used because they are detrimental to growing crops.

In poorly ventilated enclosures, acid vapours emitted by timber as part of the natural seasoning process can corrode metals nearby but not actually in contact. Some woods, notably oak and sweet chestnut, are very active in this way.

Farm fencing on average lasts for about 14 years but lifetimes are reduced in those sectors of farming which involve active chemicals (e.g. pig and poultry). Overall, galvanised steel outlasts wood and mild steel for fences and gates, although more attack has been noticed on zinc used in cereal farms where there is a high usage of lime and chemical sprays.

Gutters are also subject to premature failure, probably as a consequence of poor maintenance, or due to poor locations during erection. Recommendations that are available for glasshouses encourage sloping guttering to minimise the formation of silt deposits and also to avoid the accumulation of pools of stagnant liquid, which, for greenhouses, could be dilute hydrofluoric acid derived from glass-cleaning operations, such solutions would rapidly attack galvanised steel guttering.

3.3 MACHINERY AND EQUIPMENT

The machines most vulnerable to corrosion are those that handle chemicals, particularly artificial fertilisers and slurries (see Section 2, 'Corrosion by agricultural chemicals'). Of paramount importance are the care and maintenance of machinery during and after use and particularly during out-of-season storage. Corrosion can result in a variety of defects, seizure of moving parts, distortion of metering equipment, blocked outlets, etc, which can seriously affect the function of the machine (e.g. cause uneven distribution of fertiliser).

Most corrosion damage occurs in poorly drained areas that remain damp and dirty, e.g. in overlapped joints, on spot-welds and in crevices generally, and on moving parts, e.g. hinges, bed-chains, feed mechanisms, vanes, and cutters.

Corrosion can be much reduced by regular cleaning and good storage. Great benefit results from thorough hosing down with water after use, and in particular from the removal of mud poultices, followed when dry by a generous application of oil or grease or a temporary protective to moving, cutting, and other parts. A range of temporary protectives is available, from short-term inhibited oils and greases to long-term hard film systems and supplementary sealants as used on the undersides of vehicles.

The designer's choice of materials for the manufacture of agricultural equipment is governed by many factors, including resistance to the weather and to farm chemicals; strength, ease of manufacture, resistance to rough handling and cheapness are paramount. Corrosion-resistant metals are not necessarily uneconomic, nor are plastics too weak; nylon, polypropylene and ABS are all suitable for many agricultural environments. The importance of design detail cannot be overstressed, as examples, the sealing of overlapped joints with elastomeric sealant, and the provision of generous working clearances at hinges to allow easy greasing, could each contribute quite a lot to the life of a piece of equipment.

4. CHECKLIST FOR CONTROL

The following list has been compiled in an attempt to prompt awareness of potential hazards which might otherwise by overlooked. The examples, many of which are derived from available codes of practice, specifications and advisory booklets, are by no means exhaustive, but they are representative of potential problem areas/situations in this field.

Location (see Section 2, 'General considerations')

i Natural environments can induce different corrosion rates.
ii Beware of possible local pollution from heavy industry.
iii Salt-containing mists can affect materials near coasts and estuaries, especially on the western 'exposed' coast.
iv Assess the direction of prevailing winds with respect to ii and iii and the siting of structures or equipment.

Structures – external (see Section 3, 'Structures and buildings')

i Be aware of the immediate environment and any special circumstances, especially if harmful elements can accumulate or concentrate.
ii Give especial attention to fixings and fasteners; avoid crevices. Use seals/grommets where appropriate.
iii Ensure that eaves, gutters, rainwater pipes, gullies, etc, have adequate drainage to avoid stagnation and concentration effects, especially for cast iron, mild steel, galvanised steel and aluminium.
iv Be conscious that foundations and structures at ground/soil-level can be more susceptible to corrosion/degradation (through a microbial attack of metals in soils and acidic solutions from slurries or wastes – see Section 2, 'Corrosion by agricultural chemicals').

Structures – internal

i Designs that reduce condensation effects beneath roof surfaces are essential (see Section 3, 'Structures and buildings'). Improved ventilation is desirable.
ii The use of water-vapour barrier coatings can be beneficial.
iii Use materials less prone to corrosion or decay and use protective measures (good coatings).
iv Avoid direct metal contact with timbers (some woods and preservatives can attack aluminium, zinc, etc – see Section 3, 'Structures and buildings').
v Maintain accessibility to metal structures or fittings to facilitate ease of maintenance.

vi Ensure that electrical fittings have gaskets to minimise entry of moisture.

Machinery and equipment (see Section 3, ‘Machinery and equipment’)

i Adequate cleaning prior to storage is essential.
ii Storage conditions need to be considered and appropriate treatments applies where necessary (temporary protectives, etc – see Section 3, ‘Machinery and equipment’).
iii Use a *suitable* primer for metal coatings and sufficient top-coats, e.g. the use of two layers of chlorinates rubber in corrosive environments (see Section 3, ‘Structures and buildings’).

A galvanic series of metals

For any two metals in contact; the metal uppermost in the following list corrodes; the further apart the metals are in the table, usually the greater is the tendency towards corrosion.
Magnesium Zinc, cadmium Aluminium Steel, iron Stainless steel Lead, tin Low-copper brass Nickel Copper, high-copper brass
To prevent corrosion, the contact surfaces of both metals should be painted, or that of the metal lower in the list, never that of the higher metal alone, as in this case there would be extreme current density on a small area should any small holes occur in the paint layer.

iv Care is necessary when selecting materials where metal-to-metal contact is involved. v Be aware of local corrosion possibilities, especially associated with conjoint action of stresses, movement, temperature.
vi Contact with corrosive chemicals and wastes should be minimised (see Section 2, ‘Corrosion by agricultural chemicals’).
vii If equipment is subject to sterilisation (e.g. dairying plant) care should be taken to clean such equipment of detergent residues (especially chlorine-containing chemicals – see Section 2, ‘Corrosion by agricultural chemicals: Dairy farming’).