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Preliminary Recommendations for Maintenance of Factory Coated Metal Siding and Roofing

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Sponsored by:
Air Force Engineering and Services Center
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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ABSTRACT

Recommendations and guidelines are presented for condition assessment and maintenance of the exterior surfaces of factory coated metal siding and roofing. The metal siding and roofing products commonly encountered on Air Force installations are addressed. The types of deterioration of metal buildings and appropriate methods of repair and maintenance procedures are related to the materials and construction practices used. The results of field observations of the condition of many types of coatings on metal siding and roofing in varying states of deterioration are reported.

A quantitative condition assessment procedure was developed for exterior surfaces of metal buildings and consists of two parts. First, the condition of the siding and roofing of the building is evaluated using inspection forms, visual standards, and descriptions of levels of deterioration. In the second part, recommended maintenance procedures are determined using the evaluation data and analytical procedures which were developed. Visual standards and detailed coating failure descriptions were developed in order to identify and categorize the condition of the metal siding and roofing of buildings. Preliminary repair and coating maintenance system recommendations were made for frequently encountered problem conditions observed during inspections of buildings with metal siding and roofing on Air Force bases. The preliminary recommendations include those for surface preparation and selection of maintenance coatings. The recommendations were based on the types of existing coatings and metal materials, their condition, and whether the selected maintenance coatings are compatible with the existing coatings and selected surface preparation procedures.

Keywords: coating; condition assessment; maintenance coatings; metal roofing; metal siding; roofing; siding; surface preparation; visual standards.

ACKNOWLEDGMENT

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1. INTRODUCTION

1.1 BACKGROUND

Since the early 1950's, the Air Force has built a large number of buildings with factory coated sheet metal siding and roofing. Although exact figures are not available, it is estimated by the Air Force Engineering and Services Center that the surface area of the metal siding and roofing on these types of buildings at Air Force Bases exceeds 400 million square feet. Annual maintenance cost for periodic corrosion control and aesthetic recoating of this amount of metal siding and roofing is estimated to exceed $40 million. Current Air Force directives and guidance do not directly address the problems associated with metal roofing and siding. As a result, Air Force bases are using various coating systems that often fail prematurely, inadequately protect the metal, or are not aesthetically pleasing. The advancing age of many of the metal buildings increases the severity of the problems encountered with these types of buildings. Because of the problems experienced with metal buildings, the Air Force requested that the National Bureau of Standards (NBS) develop guidelines for coating maintenance of metal siding and roofing. The Naval Civil Engineering Laboratory (NCEL) was requested to provide technical assistance and to prepare a manual for use by Air Force personnel in the field for the maintenance of metal buildings. This report and other information resulting from this investigation will be used as the basis for the manual.

Preliminary recommendations for coating maintenance of metal buildings given in this report are intended for use by base level personnel for identification and assessment of coating deficiencies, repair of metal siding and roofing, substrate preparation prior to recoating, and selection of maintenance coatings that will predictably protect the metal during the expected service life of the coating. These preliminary recommendations are based on information from the literature, coating manufacturers, metal building manufacturers, and the condition of metal siding and roofing observed in the field. It is planned that the preliminary recommendations will be revised and interim criteria developed for selection of maintenance coating systems upon completion of another phase of this study which deals with laboratory and field evaluations of coating systems.

1.2 OBJECTIVE AND SCOPE OF THE STUDY

The objective of this study is to assist the Air Force in developing criteria for recoating metal siding and roofing on buildings at Air Force bases. The research is divided into two phases. In Phase I, the objective is to develop general field guidance for condition assessment and maintenance of the exterior surfaces of metal siding and roofing. Laboratory and field tests will be conducted in Phase II to evaluate potential maintenance coatings and surface preparation techniques. This report describes the work completed in Phase I and includes preliminary recommendations and guidance for the maintenance of metal buildings. The preliminary recommendations address condition assessment of metal siding and roofing, repair procedures, substrate preparation, and coating selection. The preliminary recommendations and guidance are limited to exterior metal siding, roofing, necessary fasteners, and drainage systems used on industrial-type buildings.

The steps taken in carrying out Phase I included obtaining information from personnel at Air Force bases regarding the condition of the metal buldings at particular locations. Field surveys were conducted by NBS and NCEL personnel to observe the condition of many different types of coatings on metal siding and roofing in varying states of deterioration. Photographs were taken of various types of coating failures and of different degrees of each type of failure in order to develop a technical basis for preliminary visual standards. Information was obtained from the literature, coating manufacturers, metal building manufacturers, and building owners regarding condition assessment, substrate preparation, and maintenance coating selection.

Visual standards and detailed coating failure descriptions will assist inspectors in their attempts to identify and categorize the condition of the surfaces of metal buildings or their components. The results of Phase I described in this report will be used as the basis for a manual to be prepared by NCEL with the assistance of NBS. The manual is intended to provide field personnel with a relatively simple but complete procedure for quantatively defining the conditions of painted exterior metal surfaces and then using the determined condition to select the most economical and practical method of maintaining an acceptable level of coating appearance and protection of the metal.

The objective of Phase II is to improve the preliminary guidelines by providing the needed technical support data through laboratory and field tests. Laboratory and field test methods will be selected and candidate maintenance coating systems along with application methods will be tested and evaluated. Surface preparation techniques will also be evaluated taking into consideration the type and condition of the substrate. To the extent feasible, factorial design experiments will be carried out with the parameters being initial surface condition, surface preparation techniques, coating materials, and application methods.

By using the results of the laboratory tests, the initial results of the field tests, and the information in this report, interim criteria will be prepared. These criteria will include procedures for assessing exterior surface conditions of existing metal buildings and selecting appropriate surface preparation procedures, coating systems, and application methods for a range of condition categories. It is recommended that the performance of the coatings in the field tests be assessed for a period of at least 3 years before preparation of final maintenance criteria.

1.3 SCOPE OF THIS REPORT

This report is not intended for use in procuring or recommending materials or design information for new metal buildings. The report does, however, address the types of metal siding and roofing commonly encountered on Air Force installations, since both the type of deterioration and appropriate methods of repair are directly related to the types of materials and construction practices used. This report is also intended to describe design features that may attribute to accelerated coating and metal deterioration. Thus, special attention should be given during inspection for early signs of deterioration and in maintenance activities where modifications can reduce further deterioration.

Basically, the guidelines and recommendations are intended to provide a procedure to obtain, on a prescribed schedule a rating of the condition of existing metal building exterior surfaces. This rating is to be used both as a data base for later reference and for determining present necessary maintenance actions. The rating data are to be filed and analyzed according to prescribed procedures to determine necessary maintenance actions, establish their priority, and to determine in detail how this is best achieved. The recommended actions may include no action, simple cleaning of the painted exterior, spot or limited recoating, repair or replacement of a limited number of metal siding or roofing panels, and total recoating. The tightening of loose fasteners and replacement of missing fasteners is addresssed, since in some cases, deterioration of fasteners is much greater than deterioration of siding or roofing. In all areas to be considered, the guidelines and recommendations are intended to be as simple and concise as possible, while providing the necessary information for effective coating maintenance of metal buildings.

1.4 BENEFITS OF A SYSTEMATIC MAINTENANCE PROGRAM

A systematic maintenance program approach will not only benefit the Air Force, but also other owners of metal buildings. It provides a record of existing conditions that can be used to determine which metal buildings require maintenance actions, the nature of the appropriate actions, and how to achieve them technically and economically. This simplifies the work of the base engineer by assisting in technical decisions on maintenance of metal buildings. It also assists in establishing priorities for maintenance actions, and in providing lead time for timely and economical maintenance. Effectively implemented, it can provide for attractive working and living areas on bases, extend the service life of metal buildings, and economically maintain operationally ready facilities.

2. METAL SIDING AND ROOFING MATERIALS COMMONLY ENCOUNTERED ON AIR FORCE BASES

There are many metal siding and roofing products presently in use at Air Force bases. Buildings fabricated with metal panels may have metal siding or cladding, they may have metal roofing, or they may have both. Those with both metal siding and roofing are generally referred to as metal building systems. A metal building system, as defined by the Metal Building Manufacturers Association, "consists of a group of coordinated components, including structural members, exterior covering panels, fastening devices and accessories which have been designed for specific loads, which will work together compatibly and which have been engineered so that they may be mass produced and assembled in various combinations with various collateral materials, to provide an enclosed or partially enclosed structure" [1].*

Two types of metal siding may be found on buildings at Air Force bases. One is used on industrial-type buildings and the other is used on residences. Industrial-type metal siding has vertical ribs or corrugations and seams in contrast to residential siding which usually has horizontal seams and configurations. This report deals only with metal siding and roofing used on industrial-type buildings including hangars, warehouses, dormitories, and recreational facilities such as gymnasiums and bowling alleys.

The metal siding and roofing panels used in buildings are generally roll-formed from either steel or aluminum and are covered with some form of factory-applied organic coating sytem. Most of the siding and roofing panels in use at Air Force bases are hot-dipped galvanized (zinc coated) steel with an organic coating. The panels are usually cold-rolled from high-strength low-alloy sheet steel. The organic coatings on the panels fall into three categories: liquid-process coatings, dry-film laminates, and protected metal [2]. Liquid-process coatings consist of one or more films of synthetic resin coating materials applied as a liquid to the substrate and then heat cured. A dry-film laminate is a dry film coating material bonded to the metal substrate with an adhesive. Protected metal is referred to as a galvanized steel substrate coated with a relatively thick coating of an asphaltic material, with or without an inert mineral filler addition, which itself may be covered with a thin decorative coating.

The thickness or weight of the galvanized coating on the steel panels may be varied, as well as the thickness of the sheet itself. This depends on the requirements and the specifications used to procure the panels when the building was constructed. Requirements for metal buildings depend on the intended use of the building and the environment to which they will be exposed.

Table 1 summarizes information about the metal siding and roofing materials commonly encountered on Air Force bases. Also included in the table are maintenance coatings which are used periodically to recoat the siding and roofing for aesthetic reasons and to protect the steel from corrosion.

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* Figures in brackets indicate references listed in Chapter 8.

Table 1. Metal Siding and Roofing Materials Commonly Encountered

Categories or Properties of Materials	Types of Materials
Sheet Metal Types	steel, aluminum
Sheet Steel Types	carbon, high strength low alloy, alloy
Steel Sheet Rolling Processes	hot rolled, cold rolled
Metal Coatings on Sheet Steel	none, galvanized (zinc), aluminum, zinc/aluminum
Metal Siding and Roofing Configurations	corrugated, V-crimp, V-beam, ribbed, standing seam
Metal Surface Treatments	primer, phosphate, chromate
Organic Factory Coatings	none, thermosetting acrylics, solution vinyls, silicone modified (alkyds, polyesters, and acrylics), plastics and organosols (vinyls), fluocarbons, poly-(vinyl fluoride), poly(vinylidene fluoride), heavy build elastomeric, fluorocarbon film laminate, acrylic film laminate, poly(vinyl chloride) laminate, bitumen, bitumen with asbestos fibers, bitumen with asbestos fabrics, bitumen with top coat (polyester)
Surface Characteristics of Metal Panels	smooth, texured
Fasteners for Sheet Steel	steel, blued/acid treated steel, metal coated, galvanized, plastic cap over steel
Maintenance Coatings	Zn/ZnO alkyd (TT-P-641)*, latex, elastomeric, alkyd, epoxy, urethane, bitumen, aluminum-pigmented bitumen, bitumen with fibers, and aluminum-pigmented bitumen with fibers

* Federal Specification

Additional information about metallic and organic coatings for metal siding and roofing and methods for fastening coil coated steels is reported in reference [3]. Sketches of configurations of typical metal siding and roofing panels commonly encountered are shown in figure 1. It is noted that the size and spacing of the configurations and the thickness and length of the panels may vary from one building to another depending on the building design with regard to appearance, construction details, and anticipated loads. Standing seams are often encountered in roofing applications but are in general not found in siding applications. The other configurations of metal panels shown in figure 1 are usually encountered in siding and also are often included in roofing applications.

There are many possible combinations of metallic coatings, panel configurations, organic factory applied coatings, and maintenance coatings that may be used to produce and to maintain metal siding and roofing panels (table 1). The newer types of siding and roofing are coil coated or roll coated with thin organic coatings about 1 mil or 0.001 in. (0.025 mm) thick. Most of the older metal buildings and some newer ones are of the protected metal type. These buildings have panels of steel, usually galvanized, coated with a relatively thick, about 25 mils or 0.025 in. (0.625 mm) bituminous material with mineral fillers, and in some cases, covered with a thin decorative coating. In addition, some of the older thick factory applied bituminous coatings (usually asphalt) may contain asbestos fibers or asbestos fabric.

Over a period of time, the factory applied organic coatings deteriorate due to weathering. Therefore, periodically, the panels need to be recoated. There are many types of maintenance coatings listed in table 1.

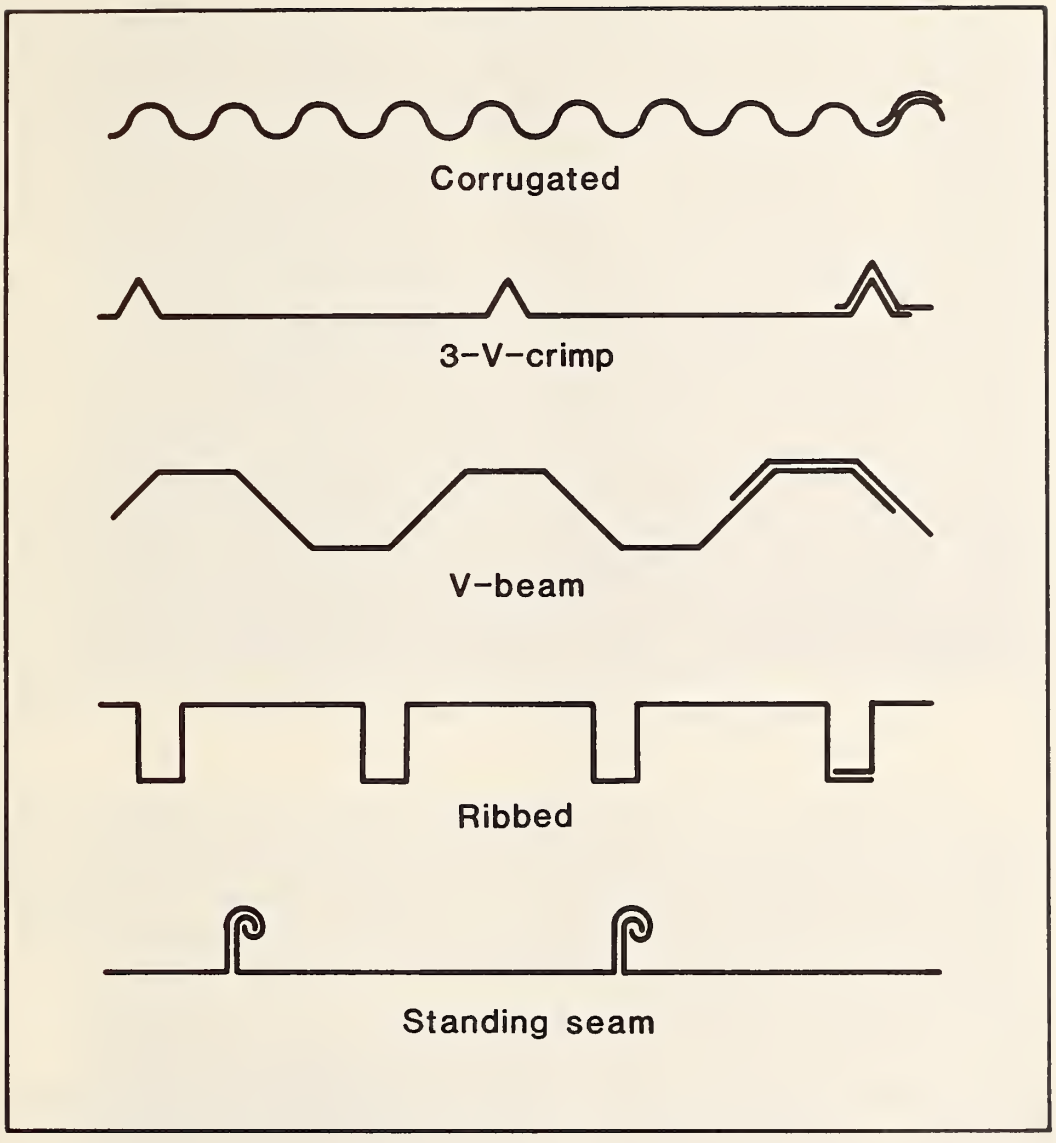

Figure 1. Configurations of typical metal siding and roofing (not to scale)

3. CONDITION OF METAL SIDING AND ROOFING OBSERVED IN THE FIELD

A field study was conducted to obtain information about the condition of metal siding and roofing at twelve Air Force bases in various geographic locations in the United States. The intent of the field study, in addition to assessing the condition of various steel siding and roofing products, was to identify problems with factory coated panels which had been exposed to weathering over different periods of time, and to assess the performance of the various types of factory applied and maintenance coatings. Observations during the field study also included the condition of fasteners and drainage systems, the extent and locations of corrosion of metal siding and roofing panels, and the effectiveness of different types of maintenance coatings. Many of the civil engineering staff at the bases visited, provided information about their experience regarding performance of factory applied coatings and maintenance coatings used on galvanized and non-galvanized sheet steel exterior panels.

The inspection of buildings on Air Force bases indicated that most of the metal siding and roofing was steel and that the condition of the metal siding and roofing tended to fall into one of several classifications. The condition of the siding and roofing resulting from in-service exposure varied depending on the extent of deterioration, damage, or loss of coating protection. The different classifications of the conditions of the metal siding and roofing which were observed are described and illustrated with photographs in this section of the report. This information will assist Air Force personnel in the inspection of the condition of metal siding and roofing and acquaint them with conditions they are likely to see.

The problem conditions identified with the metal siding and roofing were divided into two major classifications. One classification addressed problems with metal panels and building systems which needed repair before recoating, and the other addressed problems related to the integrity of the coating protection. The two major classifications are further divided into several subclassifications which are discussed in sections 3.1 and 3.2.

3.1 CONDITIONS REQUIRING REPAIR BEFORE RECOATING

Although the overall condition of metal panels, fasteners, and drainage systems of most buildings observed during the study was generally considered to be good, some problems were observed that require repair before coating. A discussion of these problems with illustrations follows:

a. Loss of Metal

Metal loss due to corrosion was observed mostly at the following locations: at the bottom edges of the panels near the ground, just under the eaves, or at laps and seams (figures 2, 3, and 4). On one roof, corrosion of the metal was not visible from the top, however, severe loss of metal at most laps could be seen from the inside of the building.

Figure 2. Illustration of loss of metal at bottom edges of panels

Figure 3. Illustration of loss of metal at top edges of panels under the eave

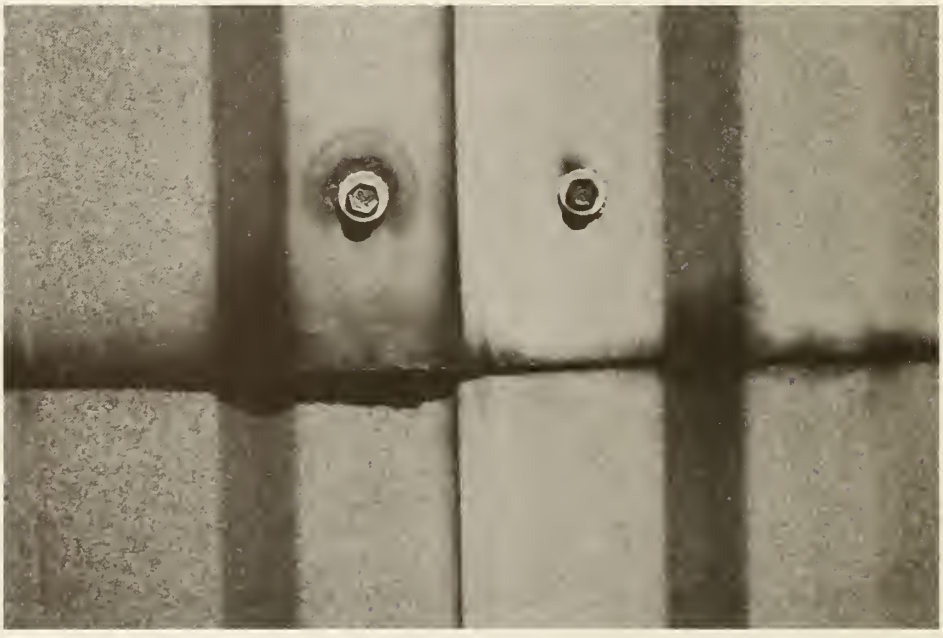

Figure 4. Illustration of corrosion of metal at laps

Figure 5. Bituminous mastic material used on roof to cover fasteners

b. Roof Leaks

In many instances, roof repairs were observed. One type of repair frequently observed, particularly on roofs with relatively little slope, was the use of bituminous mastic material to cover fasteners (figure 5). It was reported by base personnel that leaking often occurred at these fastener locations. Another type of repair was the use of thick bituminous coatings at the junction between two different types of roofing systems such as encountered with building modifications, additions, or repairs (figure 6).

c. Impact Damage

Dents or severe localized bending of sheet metal was often observed (figure 7). This damage was attributed primarily to vehicles bumping into the buildings.

d. Gutter or Drainage Problems

Many problems with gutters or other parts of drainage systems were observed. These problems included deterioration of valleys, gutters, and downspouts (figure 8), and corroded gutter hangers (figure 9).

e. Loose, Missing, or Corroded Fasteners

The extent of fastener corrosion ranged from slight to severe. In some cases where fasteners were badly corroded, the sheet steel adjacent to the fasteners was also corroded (figure 10). Some fasteners had pulled out of the panels (figure 11), and others were loose or missing. It appeared that in some instances the loose fasteners were never securely attached to the panels or support structures.

3.2 CONDITIONS RELATED TO COATING PROTECTION

The condition of the metal substrates of the panels and the protective organic coatings was observed to vary from good to severely deteriorated. This was expected since the ages of the metal buildings ranged from nearly new to more than 40 years old. The problems associated with coating protection are divided into two parts. One part deals with buildings which did not have maintenance coatings and the other pertains to buildings which had been repainted.

3.2.1 Metal Siding and Roofing without Maintenance Coatings

The condition of metal siding and roofing panels not having maintenance coatings depended to some extent on the type of panel. The types of panels fall into the following three groups: metal panels without organic coating, steel or galvanized steel panels with a bituminous protective coating (protected metal), and steel panels with a thin 1 to 2 mil or 0.001 to 0.002 in. (0.025 to 0.050 mm), organic coating.

Figure 6. Thick fibrated bituminous roof coatings

Figure 7. Impact damage of metal panels

Figure 8. Deterioration of drainage system

Figure 9. Corroded gutter hangers

Figure 10. Corroded fasteners with associated corrosion of the metal panels

Figure 11. Loose fasteners

a. Metal Panels without Organic Coating

Galvanized steel panels were the most commonly observed material in this group. Anodized aluminum was also observed in a few instances. Most of the galvanized steel panels which were observed had either white rusting or moderate red rusting (corrosion of the base steel). A typical example of red rusting of galvanized steel is shown in figure 12.

b. Metal Panels Protected with a Bituminous Coating

Bituminous coatings both with and without fibers and with and without factory applied topcoats were observed. All of the panels with bituminous coatings were more than 15 years old. These types of coating systems generally exhibited cracking. In cases where the bituminous coating was not topcoated, the cracks or breaks in the coating tended to extend to the metal substrate (figure 13). When the bituminous coating was topcoated, the cracks or breaks tended to be found only in the topcoat (figure 14). The topcoats were sometimes chalked and faded. The appearance of some buildings, without a topcoat, that were about 25 years old had an overall whitish cast. This was due to loss of the bituminous coating, and subsequent exposure of the white fibers in the reinforcing fabric which was in the coating (figure 15).

c. Metal Panels Protected with Thin Organic Coatings

Most of the buildings constructed with metal panels having thin organic coatings, about 1 mil or 0.001 in. (0.025 mm), that were observed were less than 10 years old. The metal panels of these buildings were in general in excellent condition. However, deterioration was noted in some cases at the factory formed bends (figure 16) and at the edges of the siding and roofing panels (figure 17). Red rusting was detected at these locations. The deterioration for these noted cases was in some instances severe enough that recoating was needed. In a few cases, pin point rusting over flat surfaces was observed. Pin point rusting is characterized by tiny holes in the coating with rust staining extending from the holes. Fading, chalking, and mildew were also observed. The fading and chalking tended to be found together and was observed on the older buildings, those more than 10 years old.

3.2.2 Metal Siding and Roofing Having Maintenance Coatings

Many combinations of siding and roofing products and maintenance coatings were observed. The combinations that were frequently observed and the problems most commonly associated with those particular combinations of materials involved are listed in table 2. Paint peeling from galvanized steel was the most extensive and frequently observed problem. Thus, it is listed first in the table. The remainder of the systems of maintenance coatings over metal siding and roofing listed in the table are not in any particular order with regard to the performance of metal siding and roofing.

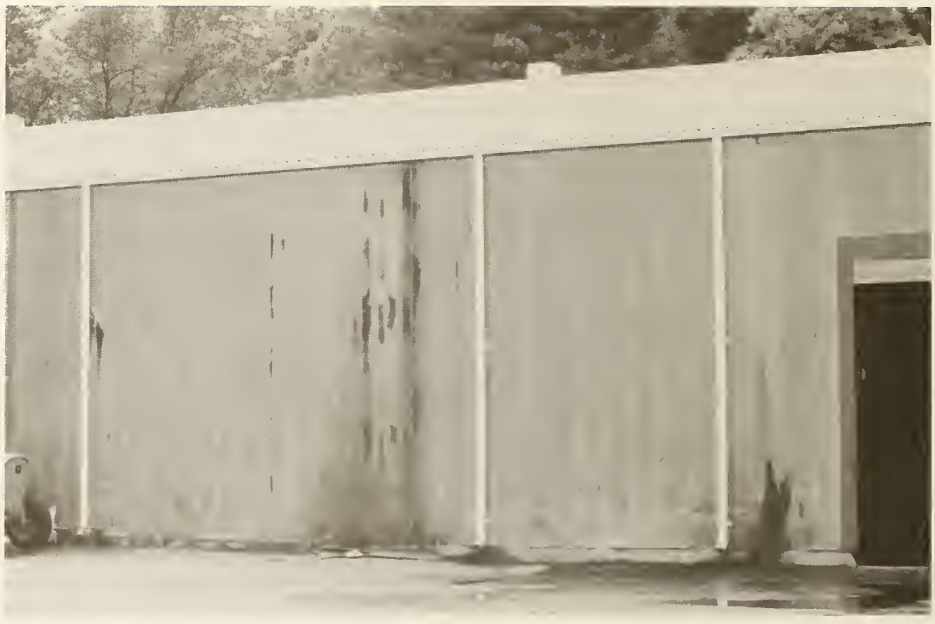

Figure 12. Corrosion of galvanized steel panels

Figure 13. Cracking of bituminous coating

Figure 14. Cracking of topcoated bituminous coating systems

Figure 15. Fibers of reinforcing fabric showing on surface of deteriorated bituminous coating

Figure 16. Corrosion along factory formed bends of steel panels protected by a thin organic coating

Figure 17. Corrosion of steel at the edges of panels protected by a thin organic coating

Table 2. Systems of Maintenance Coatings Over Metal Siding And Roofing and Observed Problems Associated with Each System

System of Maintenance Coating Over Metal Siding and Roofing	Observed Problems
Galvanized steel and non-bituminous maintenance coating	Peeling paint, poor adhesion, corrosion of substrate
Galvanized steel and bituminous maintenance coating	Bleeding and cracking of thick coating, corrosion of substrate
Galvanized steel and bituminous factory coating and organic maintenance coating	Peeling and cracking of coatings, corrosion of substrate
Galvanized steel and thin organic factory coating and organic maintenance coating	Peeling paint, corrosion of substrate

The types of maintenance coatings that were observed on galvanized steel included zinc pigmented alkyd primers (e.g., TT-P-641)* with an alkyd topcoat, red lead pigmented alkyd primers with either alkyd or acrylic topcoats, vinyl wash primer (e.g., MIL-P-15328)** with alkyd or other topcoats, and acrylic or bituminous coatings with and without aluminum pigment. The condition of the maintenance coatings varied. It was often noted that alkyd systems either experienced peeling (figure 18) or they could be easily removed with tape after making an X-cut in the coating with a knife.

Fibrated bituminous maintenance coating systems, some containing aluminum pigment, were observed on many galvanized steel roofs. Some of the problems with these roofs included red rust (figure 19), severe cracking (figure 20), bleeding of bituminous material which produced a nonuniform appearance, and heavy build-up of material, e.g., about 0.5 in. (12.7 mm). Two types of thick, 15 - 30 mils or 0.015-0.030 in.(0.375-0.750 mm) elastomeric systems, acrylic and urethane, had also been applied as maintenance coatings over some of the galvanized steel roofs. These systems had been applied about two years prior to the field study and were judged in good condition (figure 21). It can be seen in this figure that a portion of the coating has been cut to show the paint layers.

On one large metal building, a paint containing mineral spirits had been applied to a bituminous factory coating with a polyester type of topcoat. During inspection of this building it was observed that the bituminous coating had

* Federal specification.
** Military specification.

Figure 18. Peeling of alkyd coating from galvanized steel panels

Figure 19. Red rust showing through aluminum pigmented bituminous coating on steel roof panels

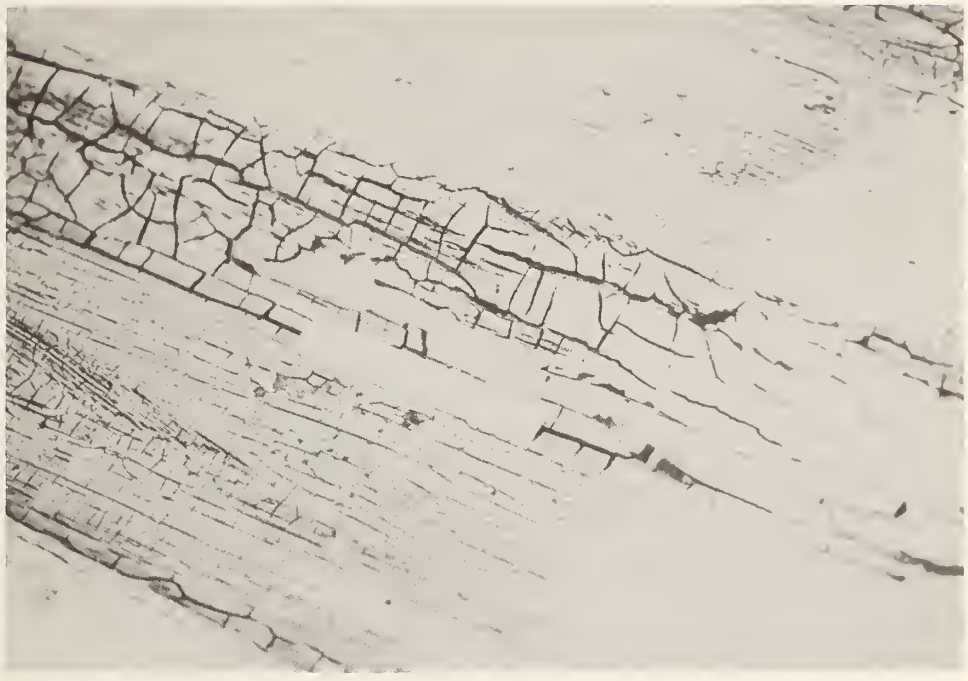

Figure 20. Severe cracking of bituminous roof coating

Figure 21. Elastomeric roof coating about two years old, a piece had been cut away to show the paint layers

peeled extensively from the metal siding (figure 22). The solvent in the maintenance coating had likely weakened the bond between the bituminous coating and the metal.

Latex paints (e.g., acrylics) were also observed as maintenance coatings over bituminous factory coatings. In these cases, the condition of the latex coatings was good two years after their application. Maintenance coatings had been applied to only a few of the observed metal buildings with thin organic factory coatings. In one case, a new building had been painted with an acrylic latex paint. After one year, the adhesion was very good and the overall condition was good. A potential problem with maintenance coatings over thin organic factory applied coatings is illustrated in figure 23. The maintenance coating on this building did not adhere to the thin organic factory coating and adhesion failure was observed at the interface between coating layers. Bituminous maintenance coatings were also observed to have been applied over roofs with thin organic factory coatings. Some of these maintenance coatings over thin organic factory coatings had performed satisfactorily while others had exhibited adhesion failure between coating layers during the short time they had been in service. There is the potential for similar problems to occur where bituminous maintenance coatings are used over galvanized steel.

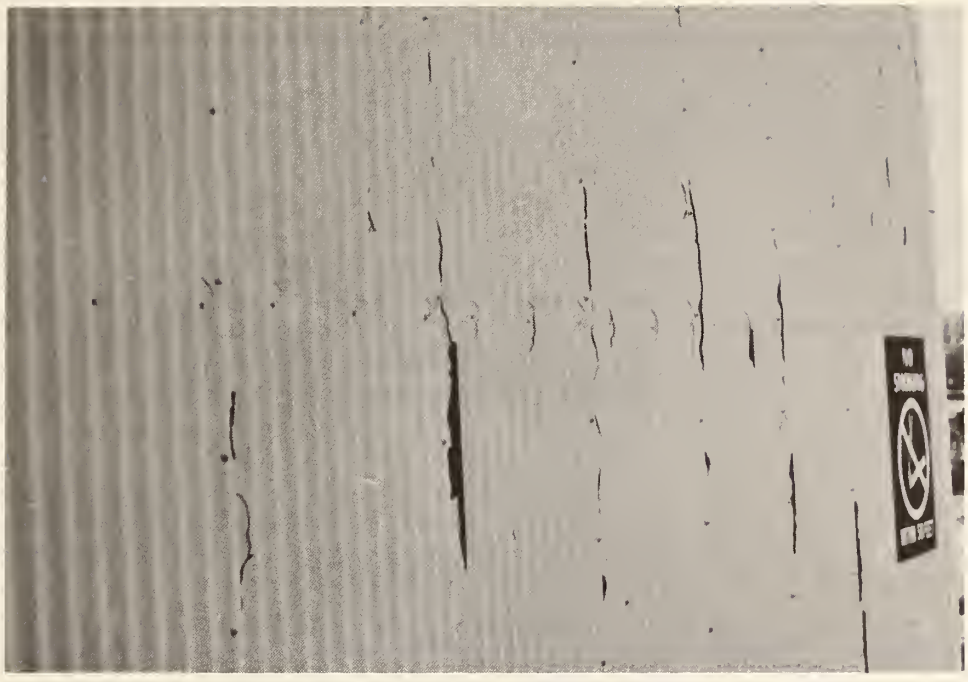

Figure 22. Peeling of bituminous factory coating system recoated with a mineral spirit solvent paint

Figure 23. Adhesion failure of maintenance coating to a thin organic factory coating

4. DESIGN, CONSTRUCTION, AND MAINTENANCE PRACTICES AFFECTING COATING DETERIORATION AND METAL CORROSION

There are many design, construction, and maintenance practices that can adversely affect the performance of coated metal siding and roofing. Poor practices may introduce conditions promoting deterioration of the coating, corrosion of the metal, or both. It is important in the maintenance of metal buildings to be aware of practices that may result in problems affecting the performance of siding and roofing. Problems resulting from poor practices should receive special attention during periodic maintenance inspections of buildings. This chapter is intended to aquaint maintenance personnel with some acceptable and poor practices in the design, construction, and maintenance of exterior metal siding, roofing, fasteners, and drainage systems. Problems resulting from poor practices can be identified and in many cases corrected or alleviated by modification, repair, or by appropriate maintenance practices.

Some of the problems associated with poor practices are discussed in sections 4.1 through 4.4 along with some acceptable practices for metal buildings. These practices deal with building location, building design, surface configuration and texture, and selection of materials. Table 3 summarizes many acceptable and poor practices discussed in this chapter.

4.1 BUILDING LOCATION

Although it is not usually possible to change the geographical location of a building, some sites on a particular military installation may have less aggressive environments than others. Locations close to coastal waters, particularly where there is appreciable salt spray, should be avoided as much as possible. Similarly, metal buildings should be located away from industrial areas or other areas emitting air pollutants. Industrial air pollution may cause early soiling of coated surfaces, as well as coating deterioration and metal corrosion. The direction of prevailing winds may also be important with regard to carrying salt spray, industrial air pollution, or sand particles. Windborne sand and dirt can cause coating erosion and soiling of coated metal siding and roofing.

4.2 BUILDING DESIGN

The design and layout of buildings, particularly industrial type buildings, can influence the durability of coated metal components. If the buildings have stacks, the stacks should be high and located so that contact of the emissions with the building and other structures is minimal. This applies to emissions of steam as well as smoke and particulates.

The roof design should provide a system with enough slope and capacity for complete drainage while requiring minimal maintenance. The drainage should be through gutters, conduits, and downspouts rather than down the side of the building. If the siding or roofing of a building remains wet for long periods of time it promotes coating deterioration, underfilm corrosion, and growth of mildew organisms. It is obvious that leaks in roofing or siding should be

repaired as soon as possible using recommended methods rather than adhesive cement or putty type products that provide incomplete or temporary repair.

If buildings are air-conditioned using window units, water from window air-conditioners should not be allowed to drain down the side of the building or to drip from upper stories onto awnings or other appertunances located below them. Building components that remain wet for long periods of time are subject to deterioration, corrosion, and mildew.

Common procedures for joining panels of metal buildings include bolting, riveting, and screwed or friction fasteners. Of major concern is the joining of components of dissimilar metals which may result in galvanic corrosion (see section 4.4) and the formation of crevices with resultant crevice corrosion, a form of concentration cell corrosion. If rivets or bolts are used to join dissimilar metal structural components or to attach siding and roofing panels of dissimilar metals, electrical insulators can be used to minimize corrosion. The insulators, however, should not be a type of material that will absorb or retain water.

4.3 SURFACE CONFIGURATION AND TEXTURE

Roofing and siding panels are corrugated, formed, bent, or grooved in some manner to produce a product that is pleasing in appearance and provides strength, stiffness, and other desirable features. Some panels are produced that have an embossed or textured surface. While these products with textured surfaces may be pleasing in appearance, their surfaces tend to collect water, salt, dirt, mildew spores, and other undesirable contaminants. Textured surfaces are also more difficult to coat with a continuous film of coating having a uniform thickness. Thus, it is preferred that siding and roofing panels have a smooth surface consistent with fastening and interlocking requirements.

4.4 SELECTION OF MATERIALS

There is a wide choice of structural members, siding and roofing panels, and coating materials available for metal buildings. It is important that the materials and products used in metal buildings be wisely selected for appropriateness and for compatibility with each other.

One of the most important considerations in the selection of materials and products for metal buildings is the contact of dissimilar metal components, including fasteners, that may result in rapid galvanic corrosion. Galvanic corrosion occurs in the presence of an electrolyte, usually water, because of the differences in electrochemical potential between two different metals or alloys. Contact of dissimilar metals should be avoided. It is preferred that the same type of metal or metals with very similar electrochemical potentials be used whenever metal connections are necessary. When this is not possible, electrical insulators that do not absorb water should be used between two metal components which are of different metals. Conventional organic coatings provide little if any electrical insulation because they are thin and easily damaged or broken. Fasteners should be of the same material as the metal they

are joining, slightly cathodic to it, or well coated with an appropriate metallic coating.

Aluminum is attacked by alkali, and thus aluminum components should not be allowed to come in contact with concrete. On the other hand, steel is compatible with concrete and these two materials may be used together. Steel can be protected from corrosion by galvanizing. The duration of the protection provided for steel by galvanizing in a given environment is directly proportional to the thickness of the zinc coating. Galvanizing by the hot dip process can provide for relatively thick zinc coatings. Thus, it is preferable that galvanizing of steel building components be from the hot dip process rather than from electrodeposition which results in a relatively thin zinc coating.

There are many different types of coating systems available for coating previously unpainted metal panels or for recoating damaged or deteriorated panels having factory-applied coatings. It is suggested that the recommendations presented in this report be followed when selecting coating materials because of possible incompatibility problems and because coating performance may vary widely with different types of coating systems. As an example, alkyd coatings are not compatible with galvanized steel. Further, there are wide differences in the weathering characteristics of coatings of different generic types. Epoxy coatings are known to chalk over relatively short periods of time due to sunlight, and blue and pinks colors are known to fade more rapidly than other colors. It is noted that, while sunlight causes coatings to chalk and fade to various degrees, shade permits retention of moisture that can accelerate corrosion and mildew growth.

Table 3. List of Generally Acceptable and Poor Practices in Design, Construction, and Maintenance of Siding and Roofing in Metal Buildings

Acceptable Practices	Poor Practices
Locate building away from salt spray and wind-borne particulates or industrial pollution	Locate buildings in any environment
Complete roof drainage through easily maintained conduits	Incomplete roof drainage or drainage down side of building
Scheduled roof inspection and maintenance program	Repair roof leaks as they are reported
Permanent roof repairs according to Air Force guidance	Temporary repair of roof leaks with putty or plastic cement
Water from window air-conditioners conducted away from building	Water from window air-conditioners running down side of building
Use of closed type structural members or open type beams oriented so as not to collect water	Beams with open design oriented to collect water
Use of electrical insulators in nonwelded joints to eliminate crevices	Crevices in riveted or bolted joints
Metal panels with smooth surfaces except for interlocks	Metal panel surfaces with textured or embossed appearance
Contacts of similar metals or separation of dissimilar metals with electrical insulators to prevent galvanic corrosion	Contacts of dissimilar metals
Fasteners of same material as metal being joined; or slightly cathodic to joined metal; or well coated with an appropriate metallic coating	Fasteners of dissimilar metal compared to metal being joined, or inappropriate metallic coating
Use of washers with fasteners to prevent damage to metal being joined	Washers not used with fasteners
Aluminum isolated from concrete	Aluminum in contact with concrete
Hot dipped galvanizing	Electroplated galvanizing

Table 3. List of Generally Acceptable and Poor Practices in Design, Construction, and Maintenance of Siding and Roofing in Metal Buildings (Continued)

Acceptable Practices	Poor Practices
Use of recommended compatible coatings for repair	Repair of damaged or deteriorated coatings with available materials
Use of weather-resistant recommended coating systems	Finish coating of epoxy or other freely chalking product
Coatings with white, earth tone, or other fade-resistant colors	Coatings of blue, pink, or other colors that fade rapidly in sunlight

5. CONDITION ASSESSMENT PROCEDURE

The effectiveness of building maintenance procedures and base maintenance programs depends upon the quality of the assessment of the condition of building components and systems. Condition assessment takes into account both the evaluation process which includes visual inspections and use of visual standards and other criteria, and the analysis of the evaluation data to obtain a numerical rating or quantitative assessment of the condition of the building or of its components. To have an effective and reliable maintenance procedure in a cost-effective maintenance program, the assessment procedure must provide a quantitative description of condition which is reproducible and repeatable. Further, the procedure should be relatively simple, fast to conduct, and provide enough information to select an appropriate maintenance procedure. Methods of evaluating, and in some cases rating, the condition of the substrate and coating, have been described in the literature [4]. However, most of these methods are subjective and require an experienced inspector to obtain reliable information. To satisfy the necessary attributes listed above for a condition asssessment procedure, detailed inspection forms, visual standards illustrating commonly occurring deterioration conditions, and definitions have been developed for use in condition evaluation. Analytical procedures have been developed to evaluate the condition assessment data and to provide the basis for recommendations for maintenance procedures.

The condition evaluation procedure developed in this study involves a relatively quick, initial visual check of the condition of metal siding and roofing panels and, if indicated from this initial inspection, a more detailed inspection may be necessary. Based on the initial inspection, no further inspection is needed if either the siding and roofing are in good condition and maintenance is not needed or total replacement of metal panels is indicated. If deterioration of the metal panels, fasteners, drainage systems, or the coating is observed during the initial inspection and total panel replacement is not necessary, then a detailed inspection of the building is required. The purpose of the detailed inspection is to determine the type and level of the deterioration and to characterize the type of the existing coating on the metal panels.

The detailed evaluation procedure is designed to give quantitative information on the condition of the building with respect to several mechanisms of deterioration. Hence, considerable numeric information may be obtained and a procedure to incorporate this information is required so that the overall condition of the siding and roofing is assessed. A summary of the condition assessment procedure is shown in a flow diagram in figure 24.

5.1 CONDITION EVALUATION

5.1.1 Initial Check-off Inspection

The initial check-off inspection is a relatively quick look at the building. The objective of this inspection is to determine the general condition of the metal siding, roofing, fasteners, and drainage systems. As a result of this inspection, it should be known whether the building components have essentially no deterioration, some deterioration, or severe deterioration.

CONDITION ASSESSMENT PROCEDURE

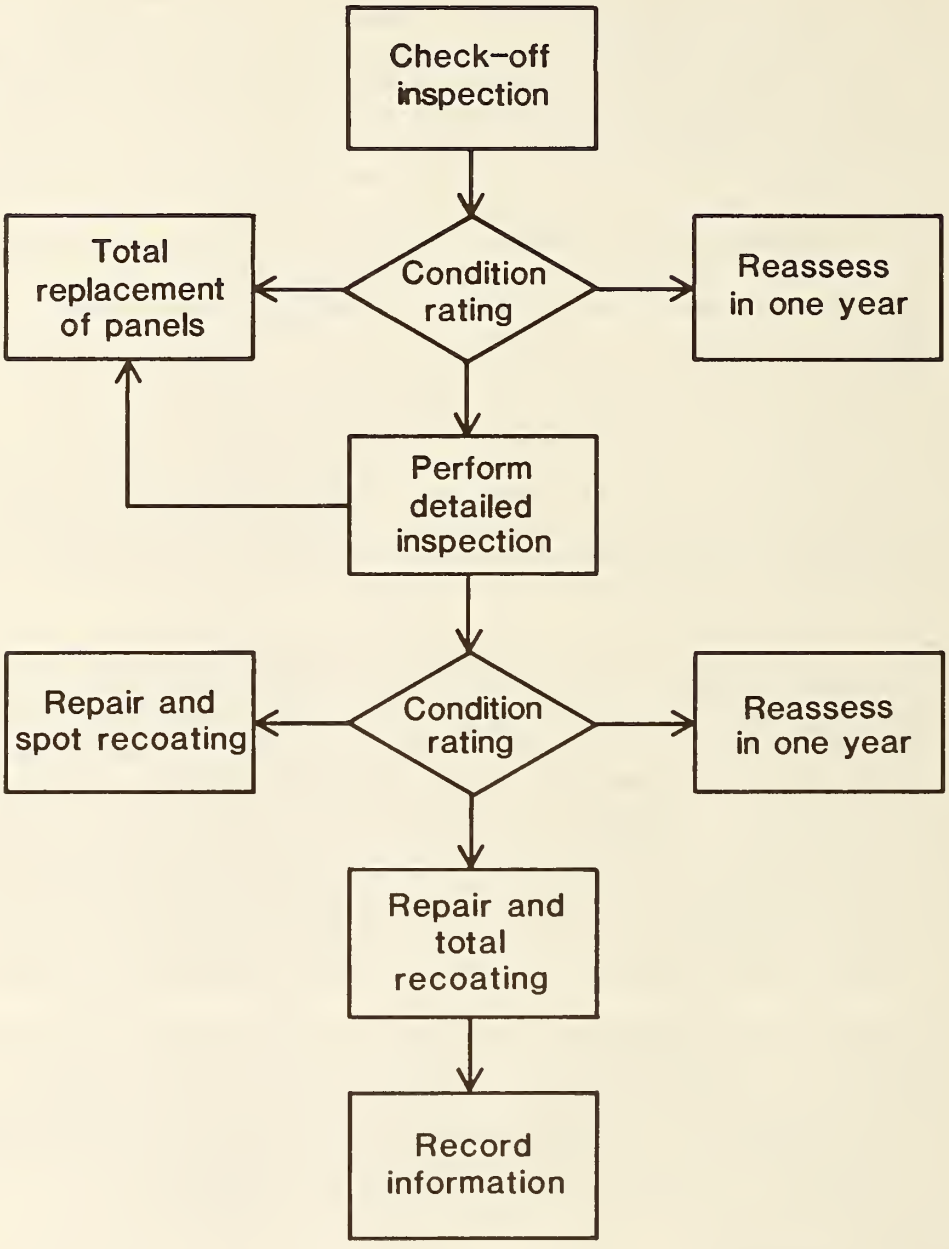

Figure 24. Condition assessment procedure

Inspection Form 1 (table 4) is used in carrying out this initial inspection. The terms listed in the left-hand column are defined in the glossary in Appendix A. Many of the conditions listed in Inspection Form 1 (table 4) are illustrated in chapter 3. In the initial check-off inspection, the only type of deterioration for which a quantitative estimate is required is panel perforation. This requirement is made so that further inspection will not be necessary when panels are badly perforated.

The recommended procedure is:

a. View each side of the building and the roof from a distance sufficient to obtain an overall view. Note any areas that appear to be substantially more deteriorated than other areas of the building.

b. Inspect the sides from close-up by walking around the entire building and looking for conditions listed on the initial check-off inspection form. Pay particular attention to suspect areas identified from a distance and to the condition of the metal panels, coatings, fasteners, downspouts, and underside of gutters.

c. Conduct a roof-top inspection for all conditions listed in the initial check-off inspection form. (It is necessary to be on the roof part of the time to do this inspection.) Particular attention should be paid to the condition of the metal at the laps, both on top and underneath, and the condition of the drainage systems, fasteners, and other construction details. Investigate areas where leaks were reported by the building occupants or evidence of leaks is present.

5.1.2 Detailed Inspection

When items in Section I of Inspection Form 1 (table 4) are checked, then a detailed inspection of the conditions requiring repair is needed; and when items in Section II are checked, then both a detailed inspection of these conditions and characterization of the existing coating are required. These inspection procedures are described in this section. When only the items in Section III are checked, further inspection is not required.

5.1.2.1 Conditions Requiring Repair

When conditions requiring repair (i.e., those listed in Section I of the initial check-off inspection form) are observed, then a detailed inspection of the siding or roofing metal panels for that condition is required. These conditions include severe deterioration of panels (perforations in the panel or erosion of the metal at the edges) and roof leaks that may be associated with the panel laps, fasteners, and slope or drainage. In addition, inspection to determine the extent of plastic mastic material along laps and over fasteners will be required since this information is necessary in selecting a surface preparation procedure. Inspection Form 2 (table 5) is used to guide this inspection. Terms found in this form are also defined in the glossary in Appendix A.

Table 4. Initial Check-off Inspection

INSPECTION FORM 1

Building No. _____ Date _____

Inspector _____

Section I. Conditions requiring repair	sides		roof	
	absent	present	absent	present
perforations (including corrosion and serious impact damage)				
percent of panels that are perforated				
leaks				
deterioration of drainage system				
lost, damaged, or loose fasteners				

Section II. Conditions related to coating protection problems (absent or present)	sides				roof
	north	south	east	west	
corrosion					
flat surface					
edge					
bend					
undercutting					
peeling/blistering					
cracking					

Section III. Conditions related to coating surface deterioration	sides		roof	
	absent	present	absent	present
chalking				
fading				
mildew				
bleeding/soiling				

Table 5. Detailed Inspection of Panels, Fasteners, and Drainage Systems

INSPECTION FORM 2

Building No. _____ Date _____

Inspector _____

	Sides		Roof	
	yes	no	yes	no
Leaks, problems associated with				
slope				
drainage				
fasteners				
seams (plastic mastic material over fasteners, seams, etc)				
other, describe				
Drainage systems, problems associated with				
slope				
gutter capacity				
downspout capacity				
other, describe				
Fasteners				
corroded with corrosion limited to fasteners				
corroded with corrosion extending to panel				
washers cracked, degraded, or missing				
fasteners loose, damaged, or missing				

Since leaking roofs may be associated with several conditions related to design, guidelines associated with these conditions are included in this section. The design requirements for roof slope and drainage capacity were taken from the Tri-Service Manual, "Maintenance and Repair of Roofs" [5] and the Architectural Sheet Metal Manual [6]. For lap seam corrugated sheet metal roofs, a slope of at least 4 inches per foot is required. For standing seam roofs, a slope of at least 3 inches per foot is required. When these seams are soldered or a sealant is used, the requirements may change (less slope required). The manuals referenced above should be consulted for information on particular cases. Drainage system slope requirements depend on many factors, such as, anticipated rainfall intensities, slope of the roof, style of gutters, and downspout outlet opening area. Problems with drainage systems are detected by inspecting the gutters and downspouts for deterioration and the surface area adjacent to the drainage system for localized deterioration. Design criteria for particular cases can be determined from tables in the Architectural Sheet Metal Manual [6]. When roofs from adjacent buildings drain into the same gutter system, the capacity should be twice as large as the gutter criteria noted above [7].

Leaking roofs or siding panels can be associated with fasteners. Both the location of fasteners in the panels, and the condition of the fasteners and substrate adjacent to them affect maintenance decisions. This is particularly important for roofs since conditions exist which make them more susceptible to leaking than the walls of buildings. Inspection should include identification of location, type, and level of deterioration.

5.1.2.2 Detailed Inspection of Conditions Related to Coating Protection Problems

When conditions relating to coating deterioration are present (Section II, Inspection Form 1), a detailed inspection to determine the extent of the deterioration is required. Inspection Form 3 (table 6) and the visual standards and descriptions of the levels of deterioration (Appendix B) are used in this inspection.

To obtain quantitative and reproducible inspection data for the condition of buildings, well-defined standard procedures are needed. Since visual standards are successfully used to rate the level of deterioration of panels in laboratory experiments [8], the use of visual standards to provide a means of quantitative assessment of the condition of coated metal panels was considered and selected. Industry consensus visual standards for corrosion, blistering, and cracking were considered, but after comparing the types of deterioration observed during field inspections and those illustrated in the industry consensus visual standards, it was concluded that, with the exception of corrosion on flat surfaces, these standards did not represent the types of deterioration of coated metal panels seen in the field. Further, the photographs in the industry visual standards are of small areas (that is, the association between photograph and sample is approximately one to one). But since some of the types of deterioration observed can only be represented by photographs of large areas of siding or roofing, standards which represent larger areas are needed. Hence, special visual standards which include sketches and photographs were developed for use in condition assessment of buildings with metal siding or roofs. The six sets of visual standards developed in this study are: 1) for

Table 6. Detailed Evaluation of Conditions Related to Coating Protection

INSPECTION FORM 3

Building No. _____ Date _____
Inspector _____

Problem Condition (Type of Deterioration) _____
Ratio (R) of Length of Building to Width of Building _____

Side or Roof	Level of Deterioration*		Fraction of Area**		Localized Rating		Condition Rating of Sides and Roof
	Worst A	Typical B	Worst C	Typical D	Worst E=AxC	Typical F=BxD	G = E + F
North Side							
East Side							
South Side							
West Side							
Roof							
Localized Condition Rating of Sides of Building (Average of Worst Ratings of Sides)[1]							
OVERALL CONDITION RATING OF SIDES OF BUILDING (Average of Condition Ratings of Sides)[1]							

* Determined from visual standards and descriptions of levels of deterioration (Appendix B)

** Fraction of area having this particular type of deterioration (problem condition) for a given side or roof of the building

[1] Use formula (1) if necessary, see 5.2.2.2

FORM 3A
(Used when side or roof is divided into sections)

Section	Level of Deterioration		Fraction of Area		Localized Rating		Condition Rating of Sections
	Worst A	Typical B	Worst C	Typical D	Worst E=AxC	Typical F=BxD	G = E + F
1							
2							
3							
4							
5							
Localized Condition Rating of Side or Roof (Average of Worst Ratings of Sections)							
Overall Condition Rating of Side or Roof (Average of Condition Ratings of Sections)							*

*Enter into appropriate block in Inspection Form 3

corrosion on flat surfaces, 2) for corrosion along bends, 3) for corrosion along edges, 4) for undercutting (under film corrosion), 5) for peeling and blistering, and 6) for cracking. Three sketches and one photograph are used to describe each condition. The photograph is used to illustrate moderate deterioration (level of deterioration of 5) and the three sketches illustrate slight, moderate, and severe deterioration (that is, levels of 8, 5 and 2 respectively). Sketches are not included in the visual standards for the conditions which represent no deterioration (level of 10).

A detailed inspection is done for each condition related to coating protection (Inspection Form 1, Section II) found present during the initial inspection. A separate form (Inspection Form 3) is used for each condition related to coating protection. As can be observed from Inspection Form 3, each side of the building and the roof is inspected separately. The following procedure is recommended:

a. Determine the ratio of length to width of the building (R). For cases where the ratio of length to width (R) is 3 or greater, divide the side and roof into sections of about the same size and follow the inspection procedure separately for each section.

b. View a side, roof, or section of the building from a distance and identify sample areas, about 3 x 3 ft (1 x 1 m), that appear to be the worst and typical condition, with respect to the type of deterioration being considered for the evaluation. When sections of a side or roof are inspected separately, record information for each section in Form 3A (table 6). Additional forms (Form 3A) may be required during the inspection of a building.

c. Confirm that these choices of sample areas correspond to worst and typical areas for the particular type of deterioration being evaluated by inspecting the surface from a close distance.

d. For each side, roof, or section of the building, rate the two 3 x 3 ft (1 x 1 m) areas numerically using the visual standards (figures B.1 through B.6) and descriptions of level of deterioration (Appendix B) to determine the level of a particular type of deterioration. To evaluate the extent of undercutting at corroded areas, use a knife to remove loose coating. The distance the coating can easily be removed is the measure of undercutting. This is explained in the description of the level of deterioration for undercutting and shown in the visual standard (figure B.4).

e. For each side, roof, or section of the building, estimate the fraction of area that has a condition similar to the worst sample area and estimate the fraction of area that has a condition similar to the typical sample area. Make these estimates (decimal fractions) to the nearest tenth and record them on Inspection Form 3 or Form 3A. When there is doubt about whether an area should be classified as worst or typical, classify the area as worst. The sum of the decimal fractions entered on Inspection Form 3 may not always equal one.

f. Repeat this evaluation procedure for all conditions checked present in Section II of the initial check-off form (Inspection Form 1).

An example is given (table 7) for determining the level of deterioration and corresponding fraction of area information which is entered on Inspection Form 3 or 3A. In this example, the condition of peeling/blistering was observed as present in the initial inspection (Inspection Form 1). In evaluating the north side of the building, the sample area of this side representing the most severe peeling (worst) had a level of 2 (visual standards and descriptions of level of deterioration, Appendix B) and the sample area representing the typical condition of the north side of the building with respect to peeling had a level of 8 (visual standards and descriptions of level of deterioration). The portion of the area of the north side that was similar to the worst area was 20 percent or 0.2, and for the typical area, the portion of area of the north side was 70 percent or 0.7. Therefore, in this example, 10 percent or 0.1 of the area of the north side of the building was in better condition than the typical area.

5.1.2.3 Characterization of Existing Coatings

Maintenance coatings should be compatible with existing coatings and they should only be used to recoat existing coatings that have good adhesion to the substrate or previously applied coatings and are of acceptable thickness. Therefore, it is required that the type, thickness, and adhesion of the existing coating be determined. Procedures for determining these properties are described below. The information about the properties of the existing coating is recorded on Inspection Form 4 (table 8).

Information regarding the age of the building, type of metal substrate, type of existing coating, and whether a maintenance coating had been applied should be available from the records. However, if this information is not available, the following procedures can be used.

Substrate Type

Place a magnet on the metal panel. If it adheres, the substrate is not aluminum and is likely steel. To determine if steel is galvanized, scrape small area of coating and look for spangles (large crystals) on the metal surface which are characteristic of a zinc coating.

Type of Existing Coating

In order to select a maintenance coating that is compatible with the existing coating, it is necessary to identify the existing coating. Procedures for selecting maintenance coatings are discussed in section 6.3. Information about the type of existing coating, if not readily identifiable, can be obtained quickly from a relatively simple field test or in more detail from a laboratory test. In the field test, the category of paint finish can be determined by rubbing the painted surface with a cotton-tipped swab stick wetted with methyl ethyl ketone (MEK), a common paint solvent. The Director of Bioenvironmental Safety at the base

Table 7. Illustration of Analysis Procedure

INSPECTION FORM 3

Building No. 483 Date 1/30/85

Inspector MK

Problem Condition (Type of Deterioration) Peeling/Blistering

Ratio (R) of Length of Building to Width of Building 3

Side or Roof	Level of Deterioration*		Fraction of Area**		Localized Rating		Condition Rating of Sides and Roof
	Worst A	Typical B	Worst C	Typical D	Worst E=AxC	Typical F=BxD	G = E + F
North Side	2	8	0.2	0.7	0.4	5.6	6.0
East Side	divided into sections, see Form 3A				0.5	-	5.7
South Side	5	10	0.1	0.8	0.5	8.0	8.5
West Side	divided into sections, not shown				0.2	-	7.0
Roof	divided into sections, not shown				0.5	-	7.1
Localized Condition Rating of Sides of Building (Average of Worst Ratings of Sides)[1/]					0.4		
OVERALL CONDITION RATING OF SIDES OF BUILDING (Average of Condition Ratings of Sides)[1/]							6.6

[1/] Use formula (1) if necessary, see 5.2.2.2

$$\text{Overall Condition Rating} = \frac{6 + 3(5.7) + 8.5 + 3(7.0)}{8} = 6.6$$

FORM 3A

(Used when side or roof is divided into sections)

Section	Level of Deterioration		Fraction of Area		Localized Rating		Condition Rating of Sections
	Worst A	Typical B	Worst C	Typical D	Worst E=AxC	Typical F=BxD	G = E + F
1	2	8	0.1	0.9	0.2	7.2	7.4
2	5	8	0.2	0.7	1.0	5.6	6.6
3	2	5	0.1	0.8	0.2	4.0	4.2
4							
5							
Localized Condition Rating of Side or Roof (Average of Worst Ratings of Sections)					0.5		
Overall Condition Rating of Side or Roof (Average of Condition Ratings of Sections)							* 5.7

*Enter into appropriate block in Inspection Form 3

Table 8. Characterization of Existing Coating

INSPECTION FORM 4

Building No. _____
Age of Building _____ Date _____
Date of Last Coating Application _____ Inspector _____

Panel/Coating Characteristics	Siding	Roof
Metal substrate (check)		
steel		
galvanized steel		
aluminum		
Factory Coating Type (check)		
thermosetting		
thermoplastic		
bituminous		
Maintenance Coating Type[1] (check)		
thermosetting		
thermoplastic		
bituminous		
Total Coating Thickness (in mils)		
Adhesion Rating (section 5.1.2.3)		
rating		
position of failure		

[1] If more than one maintenance coating present, record the number of layers and the type for each layer.

should be consulted about the use of methyl ethyl ketone and other solvents prior to any work where these solvents may be involved. If the paint finish is unaffected by MEK the general category is thermosetting; if the swab picks up some of the finish without a dark brown discoloration the category is thermoplastic, and if the swab picks up a dark brown stain, the category is bituminous. Bituminous coatings are usually very thick compared to other organic coatings and are either black or aluminum pigmented; thus coatings with these characteristics should be suspected of containing bituminous material.

The laboratory test is used to determine if the existing coating is of the thermoplastic or thermosetting type and whether it contains bituminous material. This information can be obtained in the following way. Take a small sample of the coating that represents its entire thickness and place it in a glass container. Add a small amount of mineral spirit solvent to the sample. If the solvent turns into a dark color, the coating most likely contains bituminous material. Using one layer of the existing coating at a time, place the sample in mineral spirit solvent. If the layer dissolves, it is a thermoplastic type coating. However, it may be a thermoplastic type coating and not dissolve in mineral spirits but in some other solvent. To further test this coating, obtain two more samples. Again using one layer at a time, add toluene to the container having one sample and methyl ethyl ketone to the container having the other sample of coating. As a result of this further test, if the layer dissolves in either of these two solvents it is a thermoplastic type coating; if the coating does not dissolve and only softens slightly, it is a thermosetting type coating [9]. Repeat the procedure for all layers. In some cases after weathering, thermoplastic coatings may change properties so that they are insoluable in the two solvents, thus from this test method they appear to be a thermosetting type coating. For maintenance purposes, these weathered thermoplastic coatings may be treated as a thermosetting type coating. It may not always be possible to test just one layer because it may be difficult to separate one layer from another, but an effort should be made to test each layer of coating. Report the type of factory coating and maintenance coating. If more than one maintenance coating had been applied, information on the type of each of them should be obtained and recorded in Inspection Form 4.

Adhesion Rating

The adhesion rating of the existing coating is determined according to a procedure described in ASTM D 3359. This procedure is described in the following way. First, using a sharp knife, make cuts in the shape of an "X" in the coating. Make sure that the cuts extend through the coating to the metal substrate. The length of each cut should be about 1 inch and the smaller angle between the cuts should be about 30 degrees. Probe a point of the cut within the 30 degree angle with the pointed end of a knife to determine if the coating can be readily removed. Apply a piece of pressure-sensitive adhesive type of tape across the cut area in the direction in which the 30 degree angles point. Rub over the tape

and press firmly with a finger. Remove the tape by peeling it as close to an angle of 180 degrees as possible or as close to parallel to the substrate as possible. When the tape removes coating more than one third the distance from the cut intersection to the end of the cut, the adhesion is judged to be poor. Otherwise the adhesion is considered to be good. Also determine the location of the interface at which the failure occured, that is at the metal substrate or between coating layers. Record both the adhesion rating (good or poor) and the position of failure on Inspection Form 4 (table 8). Make at least two adhesion measurements on each side, roof, or section of the building when determining the properties of the existing coating.

Thickness Measurement

This measurement can either be made with a magnetic thickness guage [10] (providing that the substrate is magnetic) or by removing a sample of coating and measuring the thickness with a micrometer. Record the measurement in mils (thousands of an inch). This measurement represents the entire thickness of the existing coating. If more than one maintenance coating is present, record the number of layers on Inspection Form 4 (table 8).

5.2 ANALYSIS OF CONDITION EVALUATION INFORMATION

5.2.1 Information From Initial Check-Off Evaluation

The recommendations for maintenance of metal siding and roofing are made based on the inspection of the condition of the building and the analysis of condition evaluation information. When a sizable portion of the panels in the building (about 25 percent) are perforated (this includes deterioration at the edges and damage), then total replacement of the siding and/or roofing panels is recommended. This approximate percentage or sizable portion of panels will depend on considerations such as desired service life of the building and likelihood of other panels soon needing replacement. As noted previously, when other problems listed in Sections I or II of Inspection Form 1 are checked, then detailed inspections are required. When conditions listed in Section III of Inspection Form 1 are present, then the decision to recoat is based solely upon aesthetic reasons. If the decision is made to recoat, then characterization of the existing coating as to type and other properties (Inspection Form 4) is required so that a compatible maintenance coating system may be selected.

5.2.2 Information from Detailed Evaluation

5.2.2.1 Conditions Requiring Repair

From the inspection of the condition of metal panels, fasteners, and drainage systems as noted in Inspection Form 2, the type and extent of problems is determined. The information regarding the type and extent of problems is used without further analysis to select the proper maintenance repair procedure.

5.2.2.2 Conditions Related to Coating Deterioration

Because of the amount of data that may be accumulated in this part of the inspection (Inspection Form 3) some analysis of the data is needed before decisions can be made regarding selection of maintenance systems. The objective of this analysis is to determine whether total recoating or spot recoating is needed, as well as to determine the degree of surface preparation required.

The following analysis is recommended when using Inspection Form 3.

For each side of the building and for the roof, multiply the level of deterioration of the worst sample area (Column A) by the fraction of area represented by the worst sample area (Column C) and enter in Column E. Next, multiply the level of deterioration of the typical sample area (Column B) by the fraction of area represented by the typical sample area (Column D) and enter in Column F. Sum these two numbers for each side and for the roof (Inspection Form 3).

When the sides or roof are divided into sections of about the same size during the detailed inspection, the evaluation of condition is done separately for each section (Form 3A). The condition rating of a side or roof (Column G, Form 3) is the average value for the condition ratings of the sections (Form 3A).

The next step is to determine the overall condition rating of the sides or the roof of the building for a given problem condition. If the length of the building is less than twice the width, the overall condition rating of the sides is the average of the condition rating for each side. If the length of the building is twice or more than the width, a weighted overall condition rating of the sides is determined by the following expression:

$$\frac{(L_1 \times R) + (L_2 \times R) + W_1 + W_2}{2R + 2} \qquad (1)$$

where L_1 = condition rating for one long side,
L_2 = condition rating for other long side,
W_1 = condition rating for one short side,
W_2 = condition rating for other short side, and
R = ratio of $\frac{\text{length}}{\text{width}}$ of building, where R is closest integer.

The overall condition rating for the sides and the roof are kept separate. The conditions are often different and maintenance and repair procedures may vary.

Repeat this evaluation for each condition (Section II of Inspection Form 1) for which a detailed inspection was carried out.

An illustration of the analysis procedure of the example partly described in Section 5.1.2.2 is found in table 7.

5.2.2.3 Characterization of Existing Coating

As was the case for the information obtained in the detailed inspection of the panels, fasteners, and drainage system, no further reduction of the data obtained in the characterization of the existing coating is needed. This information will be used directly in determining the recommended maintenance procedure to ensure the selection of compatible coatings and application over sound existing coatings.

5.3 SELECTION OF TYPE OF MAINTENANCE PROCEDURE

As stated above, the condition assessment procedure was designed so that decisions could be made regarding the type and extent of maintenance procedure required. The following procedures for selection of the type of maintenance are recommended. From the initial check-off inspection, one of the following actions is necessary: 1) if no maintenance required, reinspect in one year, 2) detailed inspection of conditions requiring repair before recoating, or 3) detailed inspection of conditions relating to coating deterioration.

When any of the conditions requiring repair are present (Inspection Form 2) the condition should be corrected. Recommended specific maintenance procedures are discussed in Chapter 6.

The rating of problems related to coating deterioration is used to select the coating procedure in the following way. If the overall rating for any of the six types of deterioration related to coating protection as identified in Section II of Inspection Form 1, for the sides or roof as determined in (Column G, Inspection Form 3) is less than 8, then total recoating of the sides or roof is recommended. If the overall ratings for all six types of deterioration are greater than 8 (Column G, Inspection Form 3) and any of the localized worst ratings (Column E), are greater than or equal to 0.2, then spot repainting of the sides or roof is recommended. If all the overall ratings for all six types of deterioration are 8 or greater and the localized worst ratings are all less than 0.2, then maintenance coatings are not recommended and reinspection is necessary in one year. Information from the characterization of existing coatings (Inspection Form 4) is used in the selection of a maintenance coating system.

5.4 RECORDKEEPING

Two kinds of records should be kept. One relates to the assessment and the other to the maintenance. Following the condition assessment, the first part of the record form (table 9) should be completed. The maintenance that was performed should be described in the second part of the record form. Careful record keeping will, in time, contribute to more cost effective selection of maintenance procedures.

Table 9. Record Keeping Form

Building No. _____ Inspector _____
Age of Building _____ Date _____

Information from Inspection/Assessment	Side	Roof
Metal Panels		
metal substrate (steel, galvanized steel, or aluminum)		
perforations/impact damage		
leaks in panels or at laps		
replacement recommended		
other		
Fasteners		
corroded		
corroded with corroded adjacent panel		
loose, damaged, or missing		
cracked, degraded, or missing washers		
leaks at fasteners		
other		
Drainage system		
deteriorated gutters		
deteriorated supports for gutters and downspouts		
deteriorated downspouts		
other		
Coating		
factory coating type		
maintenance coating type(s)		
date of most recent recoating		
total thickness of coating (mils)		
adhesion of coating (good or poor)		
coating surface deterioration		
chalking		
fading		
mildew		
soiling		
other		
Rating of substrate and coating condition		
corrosion - flat surface		
corrosion - bend		
corrosion - edge		
corrosion - undercutting		
peeling/blistering		
cracking		
Description of Maintenance Procedure		
Repairs (narrative description)		
Maintenance coating		
total or spot recoating		
surface preparation		
primer type and thickness		
topcoat type and thickness		
Describe problems encountered during maintenance		

5.5 SUGGESTED CONDITION RATING PROCEDURE FOR EXTERIOR SURFACES OF METAL BUILDINGS

A procedure is suggested or proposed to determine a condition rating for the exterior surfaces of coated metal buildings. This suggested procedure takes into consideration repairs, all six types of deterioration related to coating protection (Section II or Inspection Form 1), fasteners, drainage systems, and the appearance of coated metal panels. The condition ratings previously discussed (sections 5.2.2.2 and 5.3) pertain to only one type of deterioration related to coating protection for the sides or the roof. Procedure to incorporate all the factors to be considered in assessment of the condition of the exterior surfaces of metal buildings were not found in the literature. The suggested condition rating procedure may be useful as a guide for maintenance program planning at the base or command level since it takes into account the factors affecting the condition of the exterior surfaces of metal building systems. Rating schemes have been devised to obtain overall condition ratings for other systems such as roofing and paving [11, 12]. The overall condition ratings are being used in maintenance management programs. Since the overall ratings for these two systems are base on a scale of 100 (very good condition) to 0 (very poor condition), a scale of 100 to 0 was considered appropriate for the suggested condition rating for the exterior of coated metal buildings.

Because of the number and range of conditions requiring repair and also the number and range of conditions related to coating protection, it is difficult to determine a method to combine the individual condition assessment ratings and findings into one rating which represents the overall condition of a building. The major problem in selecting a procedure for combining the condition ratings for all the problem conditions for which the condition assessment is carried out for metal siding and roofing into an overall rating is weighting or determining the relative importance of the types of deterioration. The procedure described below for determining the overall condition rating of buildings with metal siding and/or roofing using the information from the condition assessment is based upon the limited inspections done in conjunction with this project. It is suggested as a starting point for determining an overall building rating and it is expected that the procedure will be improved as condition assessment data become available. This procedure was not used in the condition assessment presented in this report. It is proposed for possible future consideration in maintenance management programs.

Each group of problem conditions listed in the initial check-off inspection form (Inspection Form 1) will be used to determine the overall rating. Starting with 100, subtract assigned numbers based on the condition assessment data to determine the overall building condition rating. This preliminary procedure is described below:

° Start with a value of 100 for the condition rating.

- subtract 30 if there are leaks.
- subtract 10 if there are problems with the drainage system.
- subtract 10 if there are problems with the fasteners that involve problems with the adjacent metal panels.

- subtract 5 if there are problems with the fasteners that do not involve problems with the adjacent metal panels.
  (If it is thought that leaks and problems associated with drainage systems or fasteners are minor, then the numbers subtracted from 100 can be less than those used above.)
- subtract twice the difference between 10 and the condition rating for all four types of deterioration listed in section II of the initial check-off inspection form (Inspection Form 1) that are related to corrosion. Do this separately for the sides and roof. If a detailed inspection was not done for a particular type of deterioration, because that type of deterioration was not present, then the rating for that type of deterioration is taken as 10.
- subtract the difference between 10 and the condition rating for peeling/blistering and cracking. Do this separately for the sides and roof.
- subtract 5 from the overall building rating obtained above if chalking and/or fading is present.
- subtract 5 if mildew is present.
- subtract 5 if the surface is discolored by bleeding or soiling.

Using this procedure, the overall rating could be less than zero. However, this situation is not likely. Using this procedure, the overall rating may be skewed toward 100 and an overall rating of 80 or less may indicate that the building requires maintenance.

6. PRELIMINARY RECOMMENDED MAINTENANCE PROCEDURES

In this chapter, preliminary repair and coating maintenance system recommendations are made for frequently encountered problem conditions observed during inspections of buildings with metal siding and roofing on Air Force Bases. It is planned that these preliminary recommendations will be revised and interim criteria developed for the selection of maintenance coating systems upon completion of another phase of this study which deals with laboratory and field evaluations of coating systems. These preliminary recommendations are based on information currently available. No testing has been done to validate these recommendations. This information was primarily obtained from the literature, current government documents, manufacturers' recommendations, and from field surveys of the condition of metal siding and roofing.

These preliminary recommendations were based on the following assumptions and requirements: 1) a desired ten year service life (assumming no extraordinary circumstances), 2) environmentally acceptable and readily available procedures and materials, and 3) maintainable systems. Since most of the siding and roofing panels observed at Air Force bases during the field study were factory coated steel with or without maintenance coatings, these preliminary recommendations address these types of panels. Many factors, such as materials, labor, downtime of buildings, service-life of maintenance procedures, aesthetic requirements, and desired service-life of buildings enter into the overall cost of maintenance procedures. Cost analyses were beyond the scope of this study. Information on economic studies cam be found in references 13 and 14.

In this chapter, maintenance procedures for each of the problem conditions discussed in Chapter 5 are included. These procedures are in the following order: inspection schedules, repair procedures, and coating maintenance procedures. Coating procedures for buildings that have and have not had maintenance type coatings are grouped together because many of the procedures are the same. Based on the assessment of the condition of the metal siding and roofing and existing coating characteristics, the appropriate section in this chapter can be consulted to determine the recommended maintenance procedures. For example, if it is determined from the condition assessment that the building needs recoating, and that the metal panels are galvanized and have an organic maintenance coating, recommendations for this condition would be found in section 6.3.2.

6.1 INSPECTION SCHEDULES

It is recommended that buildings be inspected at least once a year. Exceptions to this recommendation are for buildings somewhat deteriorated, that is the overall rating (Inspection Form 3) is 8 or slightly greater, and for buildings located in a particulary corrosive environment, then a six month interval between inspections is recommended.

6.2 REPAIR PROCEDURES

6.2.1 Complete Replacement of Panels

When the decision to replace siding or roofing panels is made, new construction design specifications should be used for selection of materials and design criteria [15-18].

6.2.2 Repair of Perforated or Severely Impact Damaged Panels

When a panel is perforated or in any way degraded to the extent that metal is missing, then the panel should be repaired or replaced depending on the extent of the perforations or damage. Replacement panels should be of similar configuration and material. When recoating of the entire building is the only way to match the appearance of the replacement panels with the existing panels, follow appropriate recommendations given in this chapter. These recommendations depend on the condition of the existing panels.

6.2.3 Repair of Leaks

Although sides of buildings can leak, the problem is usually associated with the roof and recommendations in this section are oriented towards roof leaks. However, appropriate recommendations could also be applicable for siding leaks. The cause of roof leaks is usually associated with the slope of the roof, fasteners, drainage systems, and perforations in the roof panels. Recommendations for repair of perforated panels were made in the previous section (Section 6.2.2).

For leaks associated with inadequate slope of the roof, it is recommended that the roof be replaced with a type that is designed for low slope. Because of lapped seams and fasteners in some types of low-sloped metal roofs, leaks may occur if water is allowed to stand on the roof. When replacement is not possible, a possible temporary solution is to use glass fabric set in an elastomeric coating over areas associated with leaks, such as at fasteners and lapped seams (coating system 1, Appendix C.2). Another possible temporary solution is to adhere an elastic sheet material over the areas with leaks.

The use of sprayed polyurethane foam roofing systems has been suggested for use in some instances by the Naval Civil Engineering Laboratory [19,20]. Control and quality of materials and workmanship is essential in the application of these systems. It has been reported that properly applied polyurethane foam roofing systems can provide maximum roof integrity and thermal efficiency [19].

6.2.4 Repair of Fasteners

Leaks at fasteners are usually associated with loose or missing fasteners, missing or deteriorated washers, deteriorated fasteners, or rusted metal panels around the fasteners. If there is no rust of the metal panels at the fasteners, replace missing or deteriorated washers and tighten or replace missing fasteners. When rubber washers are used care should be taken to not over-tighten the fasteners. When localized rust of metal panels is evident at fastener locations, surface preparation is required to remove rust (surface

preparation procedure 1, Appendix C.1) and an appropriate primer, and topcoat if necessary, (tables 10, 11 and 12) should be applied at these areas before following repair procedures given above. For cases of severe rusting of metal panels at fasteners, panel replacement is necessary. Temporary repairs could be made using glass fabric and elastomeric coating or an adhered elastic sheet described in previous section.

6.2.5 Repair of Drainage Systems

When drainage systems are found to be inadequate to remove water quickly, corrections should be made. A determination must be made as to whether the problem is due to gutter or downspout capacity or gutter slope. Guidelines for design of drainage systems are given in the Architectural Sheet Metal Manual [6]. When components of drainage systems, such as gutter, downspouts, supports or hangers, are severely corroded they must be replaced with components having adequate capacity. Deteriorated, damaged, loose, or missing components or sections of these components should be repaired or replaced depending on their condition.

6.3 MAINTENANCE COATING PROCEDURES

The selection of a maintenance coating system which includes substrate preparation depends upon the condition of the existing coating and the metal substrate. Generally, when surface corrosion and coating deterioration are present a maintenance system dealing with corrosion must be considered. For example, if there is overall surface corrosion, it is recommended that the existing coating be removed regardless of its condition.

As indicated in figure 24 (condition assessment procedure) either spot or total recoating is recommended depending on the detailed inspection and condition ratings (Inspection Form 3). Spot recoating is defined as spot surface preparation, priming, and topcoating. Total recoating includes surface preparation and either spot priming and total recoating or total priming and topcoating.

Preliminary recommendations for surface preparation and maintenance coating selection for conditions commonly found at Air Force Bases are briefly described in sections 6.3.1 through 6.3.5 and listed in tables 10 through 12. Surface preparation procedures and maintenance coating systems are described in detail in Appendix C.1 and C.2 respectively.

6.3.1 Coating Maintenance Systems for Metal Protected by Galvanizing without an Organic Coating

6.3.1.1 Total Recoat

Red rust is the type of deterioriation generally expected for galvanized metal panels without an organic coating. The recommendation for surface preparation is to spot abrasive blast or to power tool clean (surface preparation procedure 1, Appendix C.1) the surface to remove localized corrosion products or abrasive blast (surface preparation procedure 2, Appendix C.1) to remove general overall corrosion. A recommended coating system is an organic zinc-rich primer and

Table 10. Maintenance Coating Procedures for Steel Panels Protected by Galvanizing and Non-bituminous Maintenance Coating

Coating Characteristics[a]			Problem Conditions			Preliminary Recommended Maintenance Procedures			
Adhesion						Surface Preparation[b]		Coating[c]	
Rating	Location of Failure	Coating Type	Bend or Edge Corrosion	Surface Corrosion	Peeling/Blist or Cracking	Description	Procedure[d]	Description Primer/Topcoat	System[e]
good	--	thermoset	yes	no	no	spot clean	1	epoxy-Zn/latex	2
good	--	thermoplastic	yes	no	no	spot clean	1	latex/latex	3
good	--	either	yes/no[f]	yes	yes/no[f]	remove[g]	2 or 3[h]	epoxy-Zn/latex	2
poor	metal	either	yes/no[f]	yes/no[f]	yes/no[f]	remove[g]	2 or 3[h]	epoxy-Zn/latex	2
poor	between coatings	either	no	no	yes	remove[g]	4	latex/latex	3

[a]When the thickness of the existing maintenance coating is more than about 30 mils or 0.030 in.(0.750 mm), it should be removed before recoating even though the adhesion may be good.

[b]These surface preparations are preliminary recommendations for the combinations of problem conditions described in the table. Other procedures will be tested in Phase II of the study.

[c]The maintenance coating systems are preliminary recommendations for the combinations of problem conditions listed in the table. Other coating systems will be tested in Phase II of the project.

[d]Surface preparation procedures are described in detail in Appendix C.1.

[e]Maintenance coating systems are described in Appendix C.2.

[f]Yes/no means that it makes no difference whether the condition is present or not for the purpose of selecting a maintenance coating system.

[g]The choice will depend on the severity of coating deterioration, degree of corrosion, and environmental restrictions.

[h]Use procedure 2 when the surface is badly rusted and procedure 3 when the surface has little or no rust.

Table 11. Maintenance Coating Procedures for Steel Panels Protected with Bituminous Factory Coating or Bituminous Maintenance Coating with or without Non-bituminous Topcoat

Coating Characteristics[a]				Problem Conditions			Preliminary Recommended Maintenance Procedures			
	Adhesion						Surface Preparation[b]		Coating[c]	
Asbestos Present	Rating	Location of Failure	Thickness (mils)	Bend or Edge Corrosion	Surface Corrosion	Peeling/Blist or Cracking	Description	Procedure[d]	Description Primer/Topcoat	System[e]
no	good	--	< 30	yes	no	no	spot clean	1	latex/latex	3
no	good	--	> 30	yes	yes/no[f]	yes/no[f]	remove[g]	2 or 3[h]	epoxy-Zn/latex[i]	2
									or latex/latex[i]	3
no	good	--	any	yes/no[f]	yes	yes/no[f]	remove[g]	2 or 3[h]	epoxy-Zn/latex	2
no	poor	metal	any	yes/no[f]	yes/no[f]	yes/no[f]	remove[g]	2 or 3[h]	epoxy-Zn/latex	2
									or latex/latex[i]	3
no	poor	between coatings	< 30	no	no	yes	remove topcoat[j]	---	latex/latex	3
yes	good	--	any	yes	no	yes/no[f]	see footnote[k]	---	over-rust[l]	4 or 5[m]
yes	good	--	any	yes/no[f]	yes	yes/no[f]	replace or recoat[k]	---	over-rust[l]	4 or 5[m]
yes	poor	metal	any	yes/no[f]	yes/no[f]	yes/no[f]	replace siding	---	---	---
yes	poor	between coatings	any	no	no	yes/no[f]	see footnote[n]	---	---	---

[a] Compatibility of maintenance coatings with existing coating will be determined in most cases by compatibility with the bituminous material in the existing coating.

[b] These surface preparations are preliminary recommendations for the combinations of problem conditions described in the table. Other procedures will be tested in Phase II of the study.

[c] The maintenance coating systems are preliminary recommendations for the combinations of problem conditions listed in the table. Other coating systems will be tested in Phase II of the project.

[d] Surface preparation procedures are described in Appendix C.1.

[e] Maintenance coating systems are described in Appendix C.2.

[f] Yes/no means that it makes no difference whether the condition is present for the purpose of selecting a maintenance coating system.

[g] The choice will depend on the severity of coating problems, depth of corrosion, and environmental restrictions.

[h] Use procedure 2 when the surface is badly rusted and procedure 3 when the surface has little or no rust.

[i] Coating system 2 is recommended when surface rust is present, and coating system 3 is recommended when there is little or no surface rust.

[j] Surface preparation procedures to remove only the peeling outer layer will be evaluated during phase II of the project.

[k] Only surface preparation procedures that meet regulations can be specified.

[l] Primers that are reported to be effective on rusty surfaces and are compatible with the existing coating will be tested for this application in phase II of the work. Selection of a topcoat will depend on the type of primer chosen.

[m] Coating systems 4 and 5 will be investigated in Phase II of the study.

[n] Maintenance procedures for this condition will be investigated during Phase II of the study.

Table 12. Maintenance Coating Procedures for Steel Panels Protected by Thin Organic Factory Coatings with or without Non-bituminous Maintenance Coating

Coating Characteristics[a]			Problem Conditions			Preliminary Recommended Maintenance Procedures			
Adhesion						Surface Preparation[b]		Coating[c]	
Rating	Location of Failure	Coating Type	Bend or Edge Corrosion	Surface Corrosion	Peeling/Blist or Cracking	Description	Procedure[d]	Description Primer/Topcoat	System[e]
good	---	thermoset	yes	no	no	spot clean	1	epoxy-Zn/latex	2
good	---	thermoplast	yes	no	no	spot clean	1	latex/latex	3
good	---	either	yes/no[f]	yes	yes/no[f]	remove[g]	2 or 3[h]	epoxy-Zn/latex	2
poor	any	either	yes/no[f]	yes/no[f]	yes/no[f]	remove[g]	2 or 3[h]	epoxy-Zn/latex	2
poor	factory coating	either	no	no	yes	see footnote[i]	---	latex/latex	3

[a]When the thickness of existing coating is more than about 30 mils or 0.030 in.(0.750 mm) , it should be removed before recoating.

[b]These surface preparations are preliminary recommendations for the combinations of problems conditions described in the table. Other procedures will be tested in Phase II of the study.

[c]The maintenance coating systems are preliminary recommendations for the combinations of problem conditions listed in the table. Other coating systems will be tested in Phase II of the project.

[d]Surface preparation procedures are described in Appendix C.1.

[e]Maintenance coating systems are described in Appendix C.2.

[f]Yes/no means that it makes no difference whether the condition is present for the purpose of selecting a maintenance coating procedure.

[g]Selection of surface preparation depends on severity of coating deterioration, degree of corrosion, and environmental restrictions.

[h]Use procedure 2 when the surface is badly rusted and procedure 3 when the surface has little or no rust.

[i]Surface preparation procedures to remove only the peeling outer layer will be evaluated during Phase II of the project.

an acrylic latex topcoat (coating system 2, Appendix C.2). If it is desired to coat the galvanized steel when there is no red rust, and if the galvanized surface has been exposed to the weather for more than one year, then a latex maintenance primer and topcoat (coating system 3, Appendix C.2) may be used. If exposed less than one year, treat the surface with a wash primer (MIL-P-15328) and apply latex maintenance primer and topcoat. The recommended surface preparation for new or weathered rust free galvanizing is to water wash the surface or if an oily or greasy film is present to solvent wash the surface followed by washing with water.

6.3.1.2 Spot Recoat

If localized rust is present and it seems appropriate to only recoat those areas (because of, for example, limited desired service life or limited resources), then the recommendation is to spot abrasive blast or power tool clean the areas that are rusted and apply a zinc-rich epoxy coating. The overall recoated appearance may be uneven in texture and differ in color compared to other areas of the metal panels.

6.3.2 Coating Maintenance Systems for Steel Panels Protected by Galvanizing and an Organic Maintenance Coating

6.3.2.1 Total Recoat

Peeling of existing coatings is the most likely problem encountered in this category. In most cases, the maintenance organic coating should be removed. Several alternatives are suggested for coating removal. They include controlled or careful abrasive blasting (which will remove some of the galvanizing), water blasting (which does not always remove all the organic coating), a combination of abrasive and water blasting, and chemical removal. Each of these three procedures have limitations and will be investigated in phase II of this project. It is noted that galvanizing protects steel from corrosion and generally should not be removed. However, when there is some corrosion of the steel panel, then abrasive blasting may be the best choice to remove the corrosion and coating. If the coating adhesion is poor, then water blasting is probably the best choice. If abrasive blasting is not permitted because of environmental restraints, then chemical removal may be considered. The Director of Bioenvironmental Safety at the base should be consulted about chemical removal prior to any work involving chemicals.

Preliminary recommendations for coating maintenance procedures are summarized in table 10. These maintenance coating systems and others will be tested in Phase II of this project.

6.3.2.2 Spot Recoat

When peeling of loose maintenance coating is localized, then hand scraping to remove the peeling coating is recommended. If there is no red rust, then a latex system is recommended. When there is localized corrosion of the base steel, then spot abrasive blasting or power tool cleaning is recommended. When

the galvanizing is lost or removed, a zinc-rich epoxy primer is recommended. The topcoat should be the same type as the existing coating or a latex coating. The area of existing coating overlapped by spot recoating should be compatible with the maintenance primer or maintenance topcoat if applied over the existing coating. Do not use zinc-rich epoxy over coatings soluble in methyle ethyl ketone (thermoplastic type coatings, see section 5.1.2.3), instead use wash primer MIL-P-15238 with TT-P-645 primer when existing coating is soluble in methyl ethyl ketone.

6.3.3 Coating Maintenance Systems for Steel Panels Protected by a Bituminous Coating

6.3.3.1 Total Recoat

When metal panels that are protected with bituminous factory coatings are to be recoated, it must be determined whether these existing coatings contain asbestos. The Director of Bioenvironmental Safety at the base should be consulted in order to identify if coatings contain asbestos, and prior to any work dealing with coatings containing asbestos. The surface preparation for coatings containing asbestos may be different (surface preparation will also depend on the adhesion rating and coating thickness) than for those that do not contain asbestos. If a decision is made to remove asbestos containing coatings, regulations concerning asbestos removal must be followed. Presently, there is limited information on the performance of primers for use over minimally prepared rusty metal surfaces that are compatible with bituminous containing coatings. Primers for this application will be identified and tested in phase II of this project.

Several maintenance coating systems have been recommended for use with bituminous coated panels. Recommendations for surface preparation and maintenance coatings for various conditions are given in table 11. In this table, recommendations are made with the assumption that asbestos containing material will not be removed during surface preparation.

6.3.3.2 Spot Recoat

The following surface preparations and maintenance coatings are recommended for spot recoating of panels containing bituminous material:

When the coating does not contain asbestos, loose coating material and/or corrosion products should be removed by hand cleaning, power tools, or spot water or abrasive blasting (surface preparation procedure 1, Appendix C.1). When the coating contains asbestos, then localized surface preparation can only be done in accordance with safety requirements and approval of the Director of Bioenvironmental Safety at the base. After removal of rust and loose coating, a maintenance latex primer is recommended. When there is no surface preparation or it is minimal, due to the existing coating containing asbestos, an over-rust primer should be used at locations where corrosion is present. It is important that this primer be compatible with bituminous coatings. A latex topcoat is recommended to minimize incompatibility of the new topcoat

with existing bituminous material. Organic solvents and topcoats tend to reduce the adhesive and cohesive properties of existing bituminous coatings.

6.3.4 Coating Maintenance Systems for Steel Panels Protected By Thin Organic Factory Coatings with or without a Maintenance Coating

6.3.4.1 Total Recoat

The systems described in table 12 are recommended for maintenance of metal panels with thin organic factory coatings. Corrosion at bends in the panels was the most often observed problem. Improved techniques for removing corrosion need to be developed and current technology will be evaluated during Phase II of the project. The use of power tools or water blast for removal of corrosion at bends is recommended at this time. Prime areas where corrosion was removed prior to total recoating.

6.3.4.2 Spot Recoat

The preliminary recommended procedure for spot recoating metal panels protected by a thin organic factory coating is removal of corrosion products, dirt, and grease (surface preparation procedure 1, Appendix C.1), application of a primer over the base metal, and a topcoat. The topcoat should be compatible with and match the factory applied coating. The applicable maintenance coating procedures are given in table 12. In case a matching topcoat cannot be found, then total recoating may be necessary.

6.3.5 Maintenance Coating Systems for Buildings with Only Surface Coating Deterioration

From the initial check-off inspection (Inspection Form 1), it will be determined if the coating surface is deteriorated (chalking, fading, mildew, or bleeding/soiling). Surface preparation for deteriorated coatings where corrosion is not present is given in surface preparation procedure 1, Appendix C.1. After proper surface preparation, application of a maintenance acrylic latex coating is recommended. Satisfactory performance of acrylic latex coatings over urethanes, thermosetting factory coatings, polyesters, and bituminous coatings were observed during the field study. Other coating systems will be evaluated in phase II of this project.

7. SUMMARY

The Air Force has a large number of buildings with factory coated sheet metal siding and roofing. Although annual maintenance costs may exceed $40 million, there are no current directives for exterior maintenance of these buildings. Hence, various maintenance coating sytems are being used and some of these fail prematurely. This work was initiated to provide guidance in maintenance of these types of buildings. The objective of the work is to assist the Air Force in developing criteria for recoating buildings constructed with factory coated metal siding and roofing. The work was divided into two phases. The objective of the first phase is to 1) develop standard procedures for assessing the condition of the exterior surfaces of buildings and 2) make preliminary recommendations, based on existing information, for maintenance coatings procedures. The results of Phase I described in this report will be used as a basis of a manual for field use which will be prepared by the Naval Civil Engineering Laboratory. The objective of the second phase is to modify the condition assessement procedures, as indicated by field use, perform laboratory and field tests to evaluate and revise the preliminary maintenance recommendations and to evaluate other candidate maintenance procedures and materials, and develop interim criteria for the selection of maintenance coating systems.

The types of metal siding and roofing materials commonly encountered at Air Force bases are described. Most of the siding and roofing panels were hot-dipped galvanized (zinc coated) steel with an organic coating. A field study was conducted to obtain information about the condition of metal siding and roofing at many Air Force bases in various geograhic locations in the United States. Problems were identified with coated metal panels on buildings which had been exposed to weathering over different periods of time. The performance of various types of factory applied and maintenance coatings was assessed. The condition of fasteners and drainage systems was also observed and determined.

Procedures to identify or characterize existing coatings on metal panels are recommended. Visual standards which include sketches and photographs were developed for use in condition assessment of coated metal siding and roofing. Industry standards for corrosion, blistering, and cracking did not represent the types of deterioration of coated metal panels observed in the field.

The quantitative condition assessment procedure that was developed is divided into two parts. First, the condition of the siding and roofing of the building is evaluated from one site inspections using inspection forms, visual standards, and descriptions of levels of deterioration; and second, based on the evaluation data and analytical procedures which were developed, appropriate maintenance procedures are determined. The preliminary recommended maintenance procedures include those for the repair of panels, fasteners, and drainage systems, and for maintenance coating selection. Maintenance procedures include selection of appropriate surface preparations and primers for a wide range of existing coatings, problem conditions, and maintenance coatings.

The benefits of the quantitative, reproducible condition assessment procedure includes improved data for use by base engineers to prioritize maintenance work, more effective use of engineering time, accumulation of data to determine service-life of maintenance procedures, and selection of proper maintenance procedures.

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APPENDIX A. GLOSSARY OF TERMS

abrasive	material used for blast-cleaning, such as sand, grit, or shot
adhesion	bonding strength; adherence of coating to substrate
asphalt	a dark brown to black cementitious material in which the predominating constituents are bitumens which occur in nature or are obtained in petroleum processing
bend corrosion	corrosion of the base metal that can be seen from the top side of the paint film that is associated with the factory formed bends
binder	resin; non-volitale part of vehicle; film forming portion of paint
bitumen	a class of amorphous, black or dark-colored cementitious substances, natural or manufactured, composed principally of high molecular weight hydrocarbons, soluble in carbon disulfide, and bound in asphalts, tars pitches and asphaltites
bituminous	containing or treated with bitumen
blast cleaning	cleaning by abrasives which are propelled at high speed and can be done either dry or with abrasive in a water stream (wet blasting)
bleeding	movement of colored extractables from subsurface layers of coating film to exposed surface
blistering	formation of dome shaped projections in paint film from local loss of adhesion and lifting of paint film from the underlying surface
chalking	formation of loose powdery material on the surface of cured paint film caused by deterioration of the binder due to weathering
checkings	light breaks in the film which do not penetrate to the previously applied coating or substrate
condition assessment	systematic evaluation of condition of a building and incorporation of evaluation information to determine overall assessment rating

corrosion	oxidation of metal to form salts, e.g., for steel, iron oxide salts commonly called rust
cracking	breaks in paint film which extend through to the structural surface (for example to the surface of the metal in sheet siding)
delamination	peeling of one or more coats of paint film from undercoat or base substrate
dry film thickness	depth of cured film on substrate, usually expressed in mils, (.001 in); often written as DFT
edge corrosion	corrosion of base metal that can be seen from top side of the paint film and is confined to areas near the edges of the metal panels
emulsion paint	paint with resin dispersed in water vehicle, often called latex paint
erosion	gradual wearing away
fading	reduction in brightness or change in color as a result of weathering
feathered edge	tapering of edge of paint film to produce smooth transition from top of paint film to adjacent substrate
flaking	paint delamination in thin scale-like particles
flash rusting	rusting of steel shortly after cleaning
flat surface corrosion	general corrosion over all or a portion of the surface; corrosion not localized along edges or bends
flexibility	elongation; extent to which a material will stretch before undergoing permanent damage
fog coat	thin or mist coat (about 0.5 mil dry film thickness)
galvanized steel	zinc coated steel, from dipping in molten zinc or by electrocoating
gloss	luster; sheen; brightness
hydroblasting	water blasting; cleaning with water at extremely high pressures

incompatibility	inability of a coating to perform well over another coating because of bleeding, poor bonding, or lifting of old coating; inability of a coating to perform well on a substrate
latex	natural or synthetic binder for water emulsion paints
mildew	fungal growth on paint film that can cause discoloration, usually a dark brown or black, and ultimate decomposition of a coating's binder
millscale	bluish layer or iron oxide formed on surface of steel by hot rolling
mistcoat	fog coat; a thin coat (about 0.5 mil dry film thickness) applied to existing paint for bonding of a subsequently applied topcoat
near-white blast	a good grade of abrasive blast cleaning
needle gun	hand held pneumatic tool containing small needles which are driven against metal surface to remove paint, corrosion products, etc
nonvolatile vehicle	resin; binder; film-forming componenets of all paints
organic coating	coating (paint) with organic binder, generally of petroleum or vegetable origin
overall rating	rating describing overall condition of building, to be used in determining priority of maintenance work
peeling	paint curling or stripping from substrate
perforations	small holes in metal panels caused by corrosion, impact damage, etc
pigment	solid, opaque, frequently colored component of paint
pitting	formation of small, deep or shallow cavities formed in steel by rusting
pinholing	formation of small holes through coating from improper application of paint
plastic mastic	repair material often used to fix leaks on roofs around fasteners and lap joints
polymer	large molecule formed by reaction of smaller molecules; often makes up binder

pot life	time interval after mixing of components during which the coating can be satisfactorily applied
primer	prime coat; first coat on a substrate, formulated to provide good adhesion and usually containing inhibitive pigments when formulated for metals
rotary-peening machine	portable, pneumatic, power driven tool for removing paint and corrosion from metal surfaces using a rotating head fitted with tungsten carbide-tipped flaps
spangles	the flowery crystals formed in galvanizing or hot dipped zinc coatings on the surface of sheet steel; their size, luster, and smoothness may vary depending on galvanizing conditions
spreading rate	area covered by a unit volume of a coating at a specified thickness
standing seam roof	metal sheets are fastened to the roof deck by means of cleats which are attached to roof deck at one end of a sheet and folded into the seam (unsoldered) at the end of another sheet
thermoplastic coating	coating type in which the binder does not chemically react to form a cross-linked film
thermosetting coating	coating type in which the binder reacts with another component of the binder to form a cross-linked film
undercutting	blistering and/or peeling of paint from underfilm corrosion in areas of a paint defect
vehicle	liquid portion of paint; resin and solvent components of a paint
wash primer	a thin primer with phosphoric acid and rust inhibitor for improving adhesion of a primer to metal or as a hold coat after blasting

APPENDIX B. VISUAL STANDARDS AND DESCRIPTIONS OF LEVELS OF DETERIORATION

For each of the problem conditions listed in Section II of the initial check-off inspection form (Inspection Form 1) there is a set of visual standards. The visual standards are complemented by a brief description for each level of deterioration of each problem condition category. Presented in this appendix are six visual standards (figures B.1 through B.6) and corresponding descriptions of levels of deterioration for problem conditions dealing with flat surface corrosion, edge corrosion, bend corrosion, undercutting, peeling/blistering, and cracking. The level of deterioration of a particular problem condition determined from the visual standards and the description of levels of deterioration are used in the detailed evaluation of the condition of metal panels (Inspection Form 3).

For each set of visual standards, there is a photograph that illustrates moderate deterioration (rating or level of deterioration of 5) for a particular problem condition and sketchs of three levels of deterioration. The levels of deterioration or the extent of the problem represented by the sketches are severe or "2" level, moderate or "5" rating, and slight or "8" rating. There are not any sketches in the visual standards for the "10" rating since by definition the "10" rating corresponds to no visible deterioration.

The descriptions for each level of deterioration for problem condition categories flat surface corrosion, edge surface corrosion, bend corrosion, undercutting, peeling/blistering, and cracking are given below.

Flat Surface Corrosion

Level of Deterioration	Description of Level of Deterioration
10	no corrosion is visible on surface of coating or substrate and no corrosion is present on substrate when film is removed
8	a rating of 8 corresponds to slight corrosion (fraction of area corroded is 0.03%) visible on surface of coating or substrate
5	a rating of 5 corresponds to moderate corrosion (fraction of area corroded is 0.3%) visible on surface of coating or substrate
2	a rating of 2 corresponds to severe corrosion (fraction of area corroded is 3%) visible on surface of coating or substrate

Edge Corrosion

Level or Deterioration	Description of Level of Deterioration
10	no corrosion of edges visible from surface or when coating is removed
8	discontinuous corrosion along edges, 1/16 in.(1.6 mm) or less in width
5	continuous corrosion along edges, 1/16 in. (1.6 mm) or less in width
2	continuous corrosion along edges, 1/16 in. (1.6 mm) or more in width

Bend Corrosion

10	no corrosion associated with the factory formed bends that is visible from the surface
8	discontinuous corrosion 1/16 in.(1.6 mm) or less in width on 25% of bends
5	discontinuous corrosion 1/16 to 1/8 in. (1.6 to 3.2 mm) in width on 50% of bends
2	continuous corrosion 1/8 in.(3.2 mm) in width on 50% of bends

Undercutting

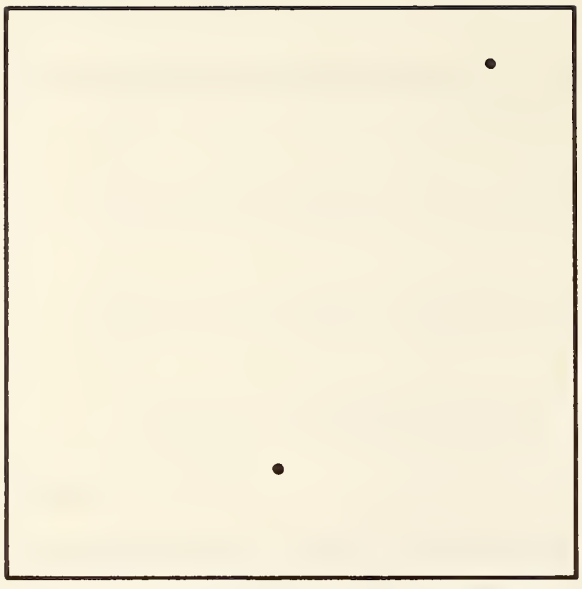
10	paint film is adhered tightly to metal substrate adjacent to defect.
8	adjacent to coating defect, paint film can be removed for a distance of 1/16 in. (1.6 mm) or less from defect.
5	adjacent to coating defect, paint film can be removed for a distance of 1/16 to 1/8 in.(1.6 to 3.2 mm) from defect
2	adjacent to coating defect, paint film can be removed for distance greater than 1/8 in.(3.2 mm) from defect

Peeling/Blistering

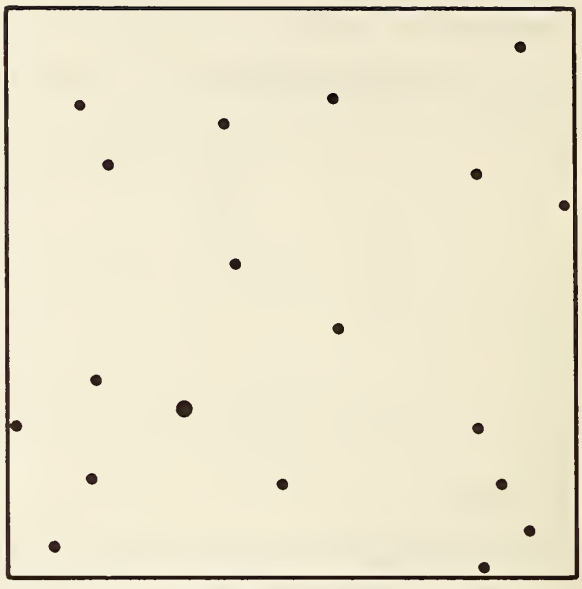
Level or Deterioration	Description of Level of Deterioration
10	no peeling or blistering of paint film
8	peeling and/or blistering of paint film that is confined to 0.05% of the area
5	peeling and/or blistering of paint film that is confined to 0.5% of the area
2	peeling and/or blistering of paint film that is confinded to 5% of the area

Cracking

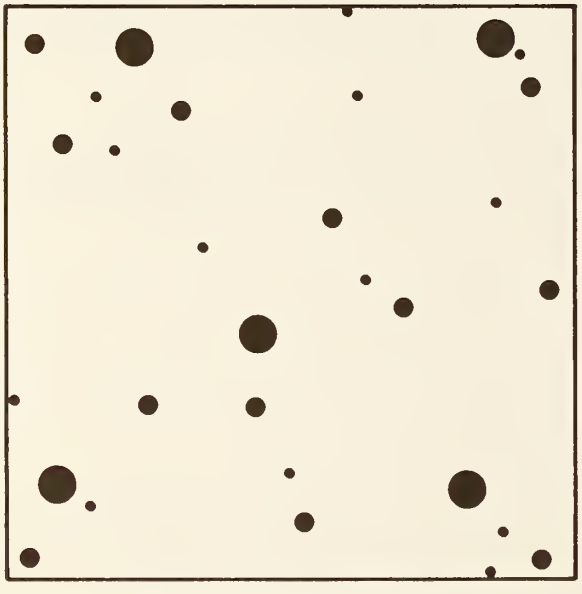
10	no cracking of paint film visible to naked eye
8	slight cracking of paint film, cracks do not extend to substrate and cover 0.05% of the area
5	moderate cracking of paint film, cracks do not extend to the substrate and cover 0.5% of the area
2	severe cracking of paint film, cracks extend to the substrate and cover 5% of the area



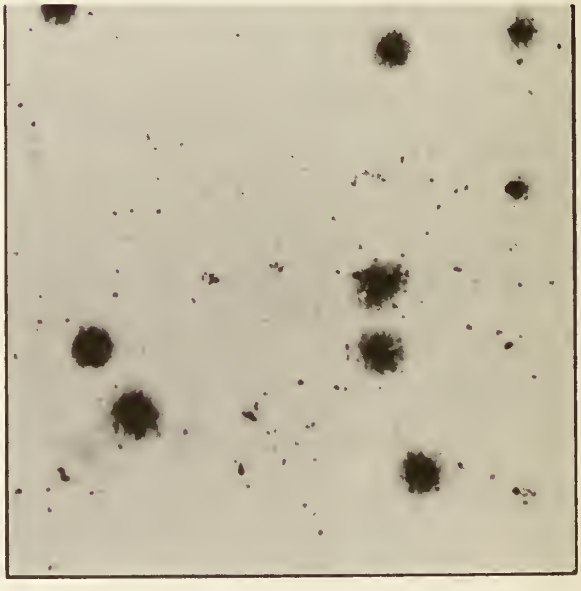
Level 8, (0.03% of area)



Level 5, (0.3% of area)

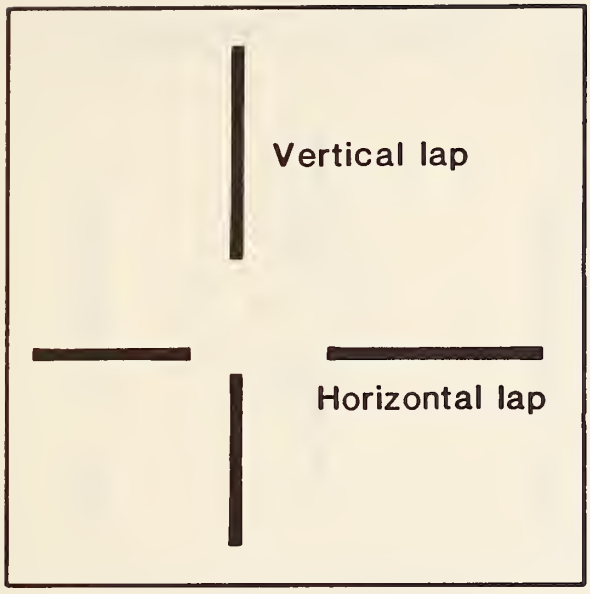


Level 2, (3% of area)

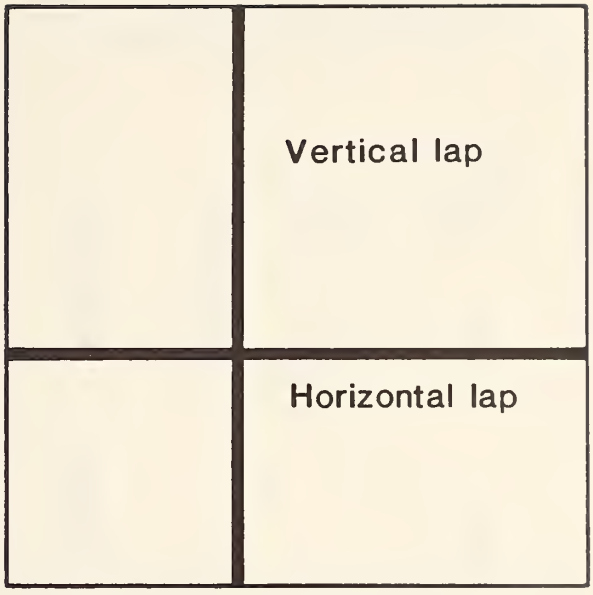


Level 5, photograph

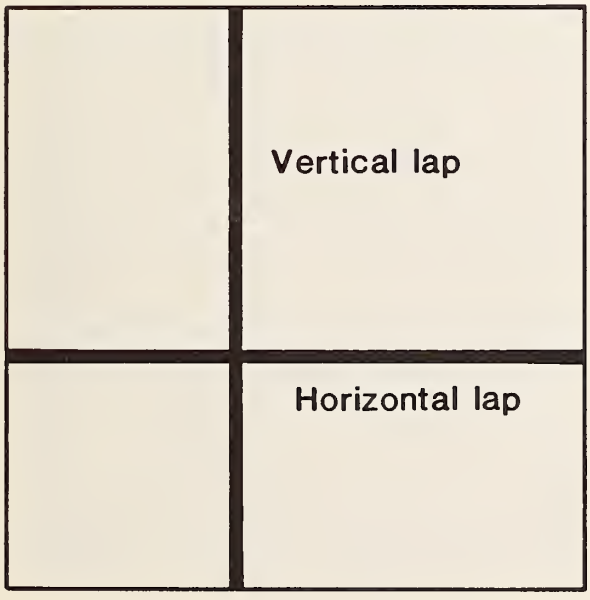
Figure B.1. Visual standards for flat surface corrosion (sketches actual scale)



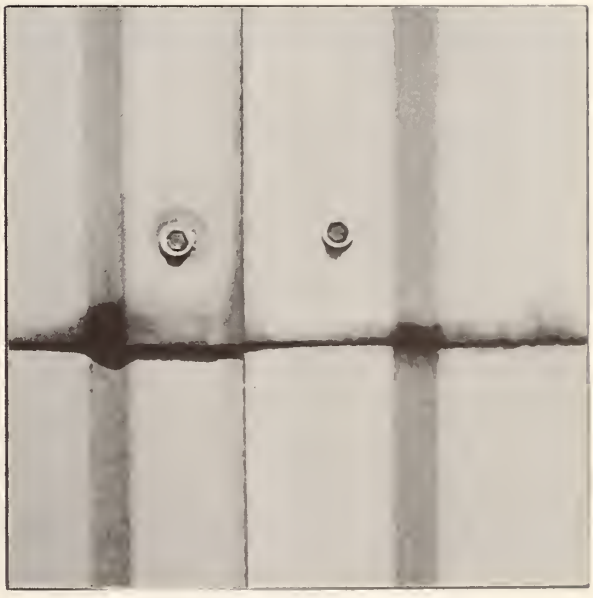
Level 8, discontinuous corrosion
1/16 in. or less in width



Level 5, continuous corrosion
1/16 in. or less in width

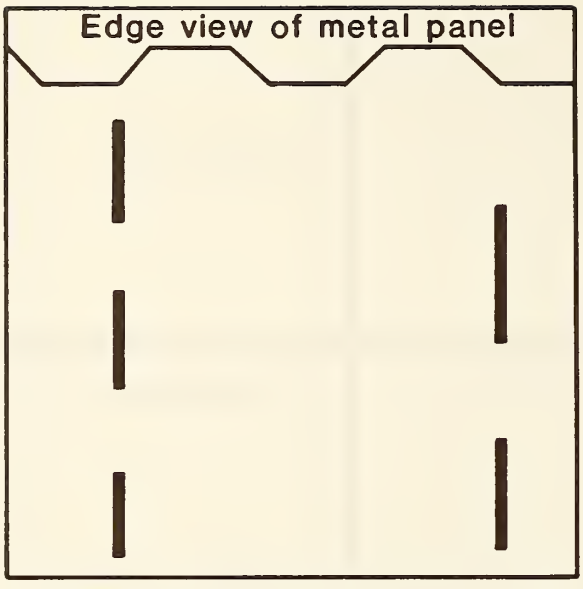


Level 2, continuous corrosion
1/16 in. or more in width

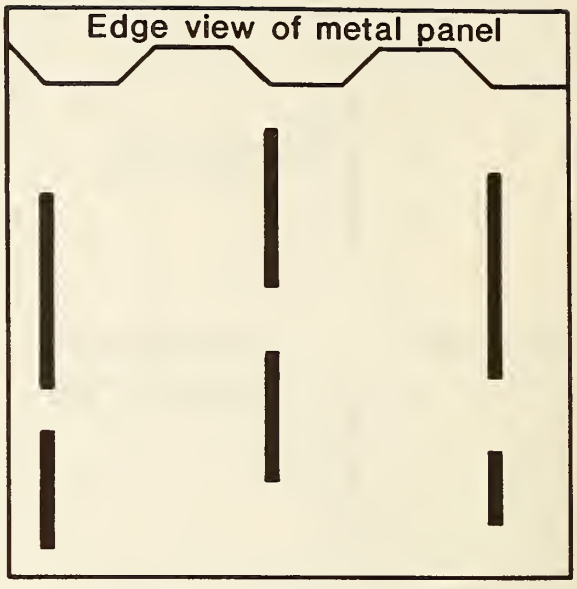


Level 5, photograph

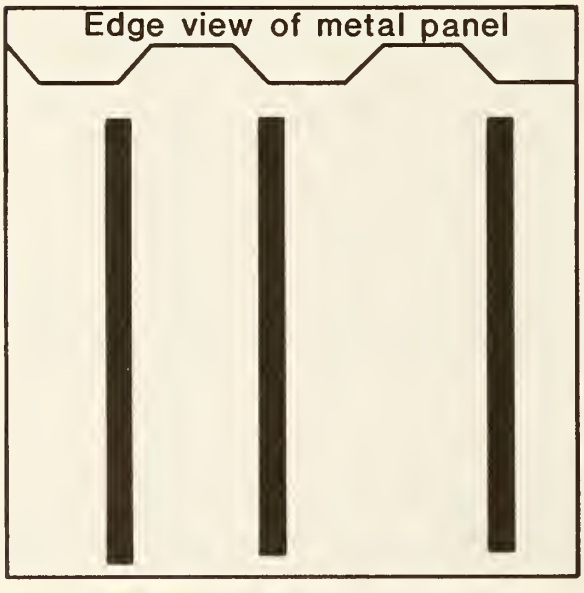
Figure B.2. Visual standards for edge corrosion at vertical and horizontal laps and at the top and bottom of metal panels (sketches actual size)



Level 8, discontinuous corrosion 1/16 in. or less in width on 25% of blends



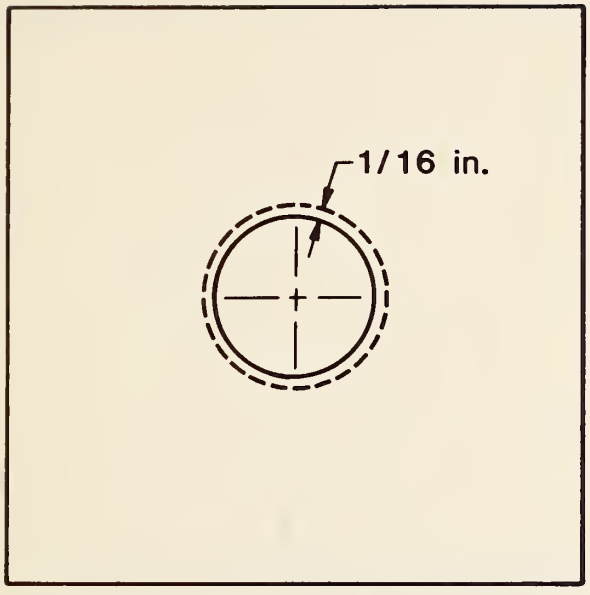
Level 5, discontinuous corrosion 1/16 to 1/8 in. width on 50% of blends



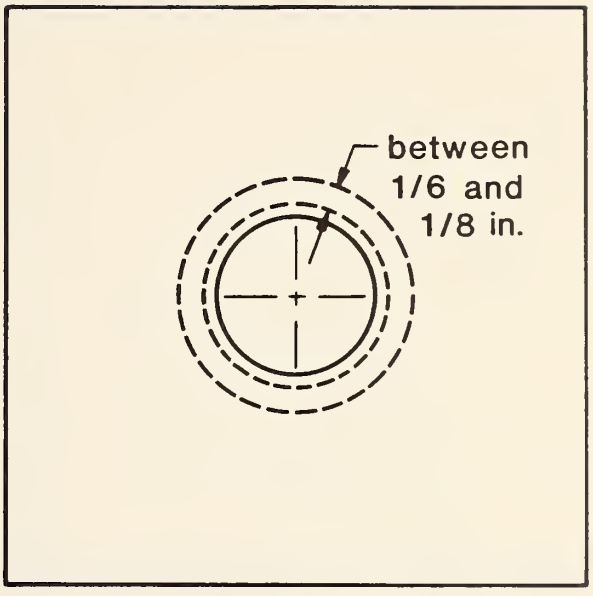
Level 2, continuous corrosion 1/8 in. or more in width on 50% of bends

Level 5, photograph

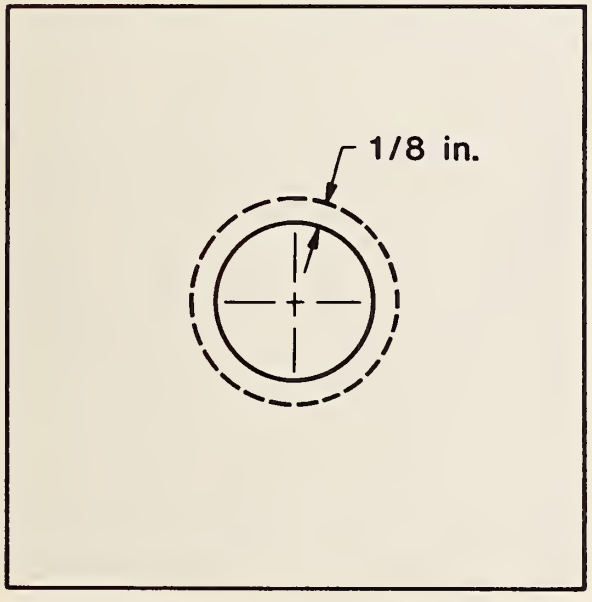
Figure B.3. Visual standards for bend corrosion (not to scale)



Level 8, paint film can be removed 1/16 in. from defect



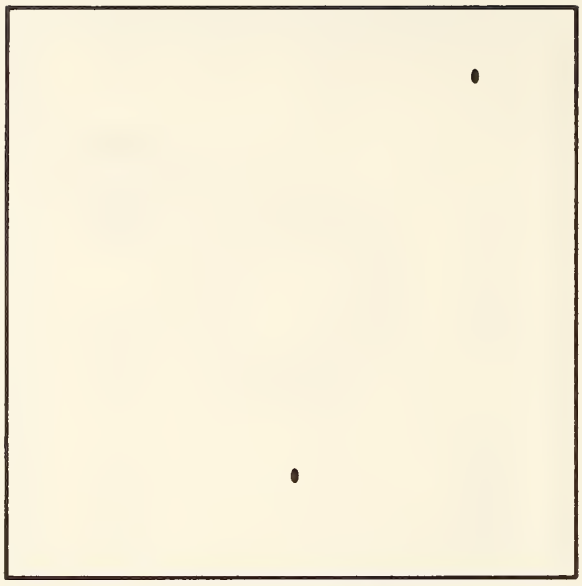
Level 5, paint film can be removed from between 1/16 and 1/8 in. from defect



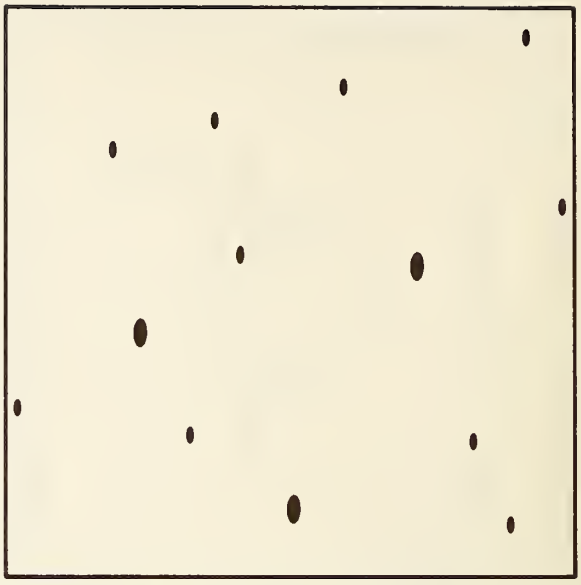
Level 2, paint film can be removed 1/8 in. from defect

Level 5, photograph

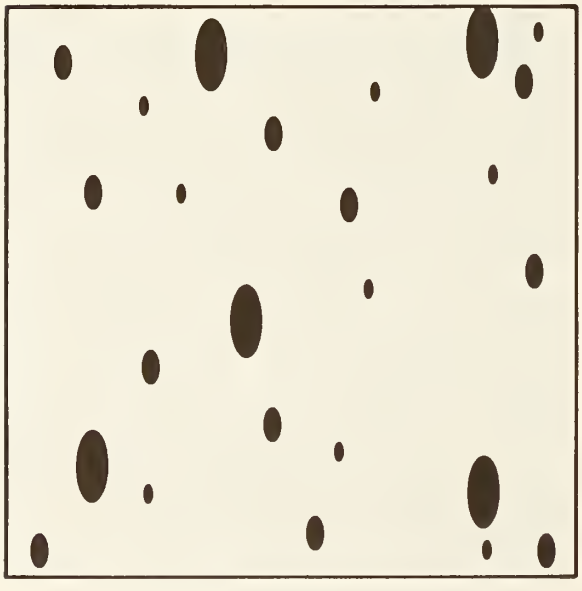
Figure B.4. Visual standards for undercutting. In the evaluation of the condition of metal panels, undercutting may affect the level of deterioration of the types of deterioration shown in the other visual standards, figures B.1, B.2, B.3, B.5 and B.6.



Level 8, (0.05% of area)



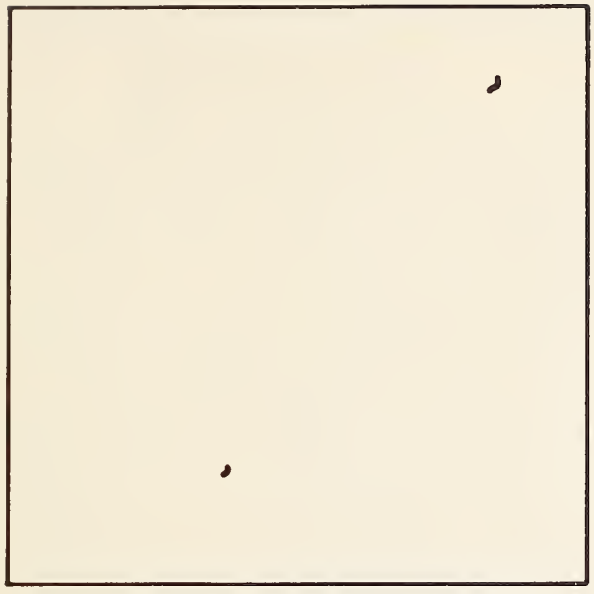
Level 5, (0.5% of area)



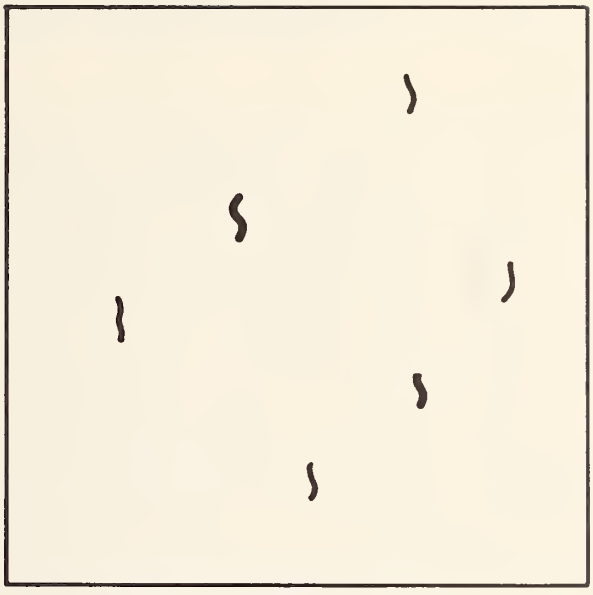
Level 2, (5% of area)

Level 5, photograph

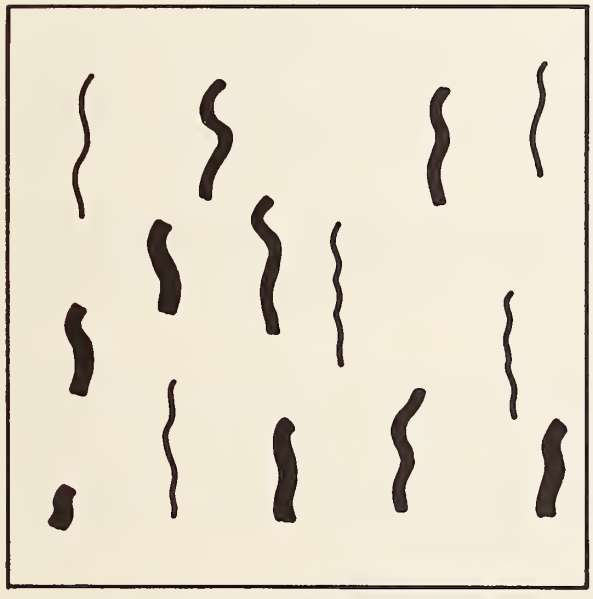
Figure B.5. Visual standards for peeling/blistering (sketches actual scale)



Level 8, (0.05% of area)



Level 5, (0.5% of area)



Level 2, (5% of area)

Level 5, photograph

Figure B.6. Visual standards for cracking (sketchs actual scale)

APPENDIX C. SURFACE PREPARATION AND MAINTENANCE COATING SYSTEMS

C.1 SURFACE PREPARATION

Procedure 1 - This procedure is used to remove localized loose paint, localized corrosion products, dirt, grease, chalk and mildew from metal panels. For example, this system could be used to clean along bends of metal panels when deterioration is confined to the bend area. Removal of localized corrosion products and loose paint can be done either by spot abrasive blasting or by using power tools. The types of power tools used include needle guns, rotary-peening machines, and power sanders. In addition to localized abrasive blasting or power tool cleaning, it is necessary to remove dirt, grease, chalk, and mildew from the remaining coating surface before recoating. Dirt and chalk can usually be removed by water blasting. If blasting with water does not remove the dirt and chalk, and if environmental regulations permit, a 5% solution of trisodium phosphate can be substituted for the water. Solvent washing is generally used to remove grease. It is noted that the use and disposal of solvents, cleaning solutions, and paint materials should meet the approval of the Director of Bioenvironmental Safety for the base. Mildew can be removed by washing the surface with a 1% solution of sodium hypochlorite. A combination of spot abrasive blasting or power tool cleaning and water blasting has been reported to be effective in most cases for surface preparation of metal substrates with localized corrosion or peeling [C1].*

Procedure 2 - Complete removal of coatings and corrosion products is usally done by abrasive blasting [C2]. The desired degree of coating and corrosion removal is usually specified using surface preparation standards of the Steel Structures Painting Council's Standards (SSPC)[C3] or the National Association of Corrosion Engineers Standards (NACE) [C4].

Procedure 3 - Water blasting, either with or without abrasive, is also used to remove corrosion products and existing coatings [C5]. Rust inhibitors are usually added to the water to prevent flash rusting. SSPC or NACE standards are used to specify the degree of surface cleaning desired.

Procedure 4 - This surface preparation system is for removing loose paint from galvanized surfaces. When there is no evidence of corrosion of the base steel, it is desirable not to remove the protective zinc coating. Surface preparation procedures currently being used for this condition include blasting with soft abrasives such as walnut shells, chemical removal, and water blasting. These procedures will be investigated during phase II of this project.

Procedure 5 - This system is for the special case when just the outer layer of existing coating film is peeling from the adjacent layer and there is essentially no corrosion of the base metal. Water blasting is sometimes used in this situation and will be investigated in phase II of the project.

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* Figures in brackets preceeded by C indicate references listed at the end of this appendix.

C.2 MAINTENACE COATING SYSTEMS

System 1. Elastomeric - This coating system may be used on roofs and is usually applied to obtain a 20-30 mils or 0.020-0.030 in.(0.500-0.750 mm) dry film thickness. In cases where leaks have occurred at fasteners and laps, the use of a glass fabric set in a 20-30 mil or 0.020-0.030in.(0.500-0.750 mm) layer of elastomeric coating is recommended at these locations prior to application of an elastomeric coating over the entire surface. The binders in these types of elastomeric coatings are commonly acrylics or urethanes.

System 2. Epoxy-zinc/acrylic latex topcoat - This system consists of an epoxy-zinc (zinc-rich epoxy) primer (Naval Ship Technical Manual, Chapter 631)* and an acrylic latex maintenance topcoat (MIL-P-28578)*. Each of these coatings should be applied to obtain a 2-3 mil or 0.002-0.003 in. (0.050-0.075 mm) dry film thickness.

System 3. Acrylic latex maintenance primer and topcoat - This system consists of an acrylic latex maintenance primer (MIL-P-28577)* and an acrylic latex topcoat (MIL-P-28578)*. The dry film thickness of each coating should be from 2 to 3 mils or 0.002-0.003 in.(0.050-0.075 mm).

System 4. Over-rust primer- When surface preparation is minimal, the use of an over-rust primer may be appropriate. Primers for use over rusty steel are available. Their performance will be evaluated for use with existing bituminous containing coatings in Phase II of the project. Compatible topcoats will also be tested in Phase II.

System 5. Moisture curing urethane primer and aliphatic urethane topcoat - When environmental conditions, low temperature below 50°F (32°C), do not permit the use of latex systems, a urethane system may be used in some cases as a maintenance coating.

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* Military specification

C.3 REFERENCES

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C3. Pictorial Surface Preparation Standards for Painting Steel Surfaces, SSPC-VIS-1, Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburg, PA 15213, 1967.

C4. TM-01-70 Visual Standards for Surfaces of New Steel Air-Blast Cleaned with Sand Abrasive, National Association of Corrosion Engineers, P.O. Box 218340, Houston, TX 77218, 1970.

C5. Bennett, J., "Water Blast Cleaning," in Good Painting Practices Steel Structures Painting Manual, Vol. 1, Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburg, PA 15213, 1982, p. 64.

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

Recommendations and guidelines are presented for condition assessment and maintenance of the exterior surfaces of factory coated metal siding and roofing. The metal siding and roofing products commonly encountered on Air Force installations are addressed. The types of deterioration of metal buildings and appropriate methods of repair and maintenance procedures are related to the materials and construction practices used. The results of field observations of the condition of many types of coatings on metal siding and roofing in varying states of deterioration are reported. A quantitative condition assessment procedure was developed for exterior surfaces of metal buildings and consists of two parts. First, the condition of the siding and roofing of the building is evaluated using inspection forms, visual standards, and descriptions of levels of deterioration. In the second part, recommended maintenance procedures are determined using the evaluation data and analytical procedures which were developed. Visual standards and detailed coating failure descriptions were developed in order to identify and catergorize the condition of the metal siding and roofing of buildings. Preliminary repair and coating maintenance system recommendations were made for frequently encountered problem conditions observed during inspections of buildings with metal siding and roofing on Air Force bases. The preliminary recommendations include those for surface preparation and selection of maintenance coatings. The recommendations were based on the types of existing coatings and metal materials, their condition, and whether the selected maintenance coatings are compatible with the existing coatings and selected surface preparation procedures.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Coating; condition assessment; maintenance coatings; metal roofing; metal siding; roofing; siding; surface preparation; visual standards

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