CIVIL AERONAUTICS AUTHORITY

Technical Development Division

NOTE NO. 14

# SUPERFICIAL CORROSION ATTACK ON THE SURFACES OF ALCLAD SHEETS

By

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# SUPERFICIAL CORROSION ATTACK ON THE SURFACES OF ALCLAD SHEETS

## Introduction:

Some alarm has been caused by the superficial corrosion attack which is occurring in some instances on the surfaces of Alclad sheets in locations on aircraft where the sheets are exposed to exhaust gases. Such sheets are being replaced under the belief that their mechanical properties have been adversely affected.

This situation has been brought to the attention of the Aluminum Company of America by the operators concerned and has been thoroughly investigated by that Company. Mr. E. H. Dix, Jr., Chief Metallurgist of the Aluminum Research Laboratories of the Aluminum Company of America has pointed out that if the nature of the protection afforded by the aluminum coating on the strong aluminum alloy Alclad sheet were fully understood, it would be readily appreciated that the mechanical strength of the Alclad sheet has not been harmed by this mild surface attack.

In order to fully acquaint the inspection personnel of the Civil Aeronautics Authority and the inspection and maintenance personnel of the operators with the nature of this corrosion and the nature of the protection afforded by the aluminum coating on Alclad sheet, Mr. Dix was asked to write a description of these phenomena. He complied with this request and his description meets with the approval of the Division of Metallurgy of the National Bureau of Standards.

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It is the purpose of this Note to publish Mr. Dix's discussion of these phenomena for the information of all concerned. In publishing this information, however, there is no intention to infer that the matter of corrosion, even the superficial corrosion discussed herein, should be treated lightly. The intention is rather to throw more light on the subject of superficial corrosion attack on the surfaces of Alclad sheets so that it may be more fully understood. Remedial measures should be sought wherever there are evidences of this superficial attack and, in cases where there is doubt as to whether or not the mechanical properties of the sheets in question have been adversely affected, the sheets should be replaced.

Discussion (E. H. Dix, Jr.):

The Alclad sheet used for aircraft structures consists of a heat treated strong aluminum alloy base with smooth, dense nonporous surface layers of pure aluminum of uniform thickness alloyed and integral with the core. The pure aluminum surface layers on Alclad 17S-T or Alclad 24S-T sheet are effective as a corrosion preventative for two reasons. First, the high purity aluminum alloy coating in itself possesses a high resistance to corrosion. Second, this coating electrolytically protects the core so that no corrosion of the core occurs even though the coating is completely removed from fairly large areas, sometimes as great as one inch in diameter.

This electrolytic protection perhaps should be further explained. When two dissimilar metals are in electrical contact in a corroding solution current will flow from one, through the solution, to the other, the circuit being completed through an external metallic contact. This is the basic principle of electric batteries. The metal from which the current flows is known as the "anode" and that to which the current flows is the "cathode". The anode tends to dissolve in the solution but any dissolution of the cathode is prevented by the flow of current. In the case of the Alclad combination, the pure aluminum coating functions as the anode and if the core is exposed at any spot in the presence of a corroding solution tiny currents flow from the pure aluminum coating to the exposed core areas, thus preventing any corrosion attack of the core. As an example, cut edges of Alclad plate 1/4" thick have been protected from corrosion during nine years exposure to continuous salt spray in a laboratory salt spray test.

Consideration should now be given to the metallurgical details of the Alclad product. Fig. 1 illustrates schematically the cross section of a piece of Alclad sheet showing only one surface. During heat treatment the alloying elements from the core diffuse into the coating, forming what is known as a diffusion zone. Thus, as corrosion proceeds from the surface of the sheet inward, three zones of different solution potential are encountered. First, the pure aluminum coating, which electrolytically protects both the diffusion zone and core; second, the diffusion zone, which electrolytically protects the core, and finally, the core. Thus, under very severe corrosive conditions the corrosion takes the form shown in Fig. 2. The tooth-like appearance of a corroded cross section is typical. Looking down upon the surface of the corroded sheet the corrosion attack, which appears tooth-like in cross section, has the appearance of hills and valleys. (Fig. 3)

Therefore, if the surface of a piece of Alclad sheet which has been subjected to corrosive conditions is examined with a hand lense of about 10X magnification these hills and valleys may be readily distinguished providing corrosion has proceeded to the extent shown by Fig. 2. Such an appearance indicates that corrosion has proceeded only to the diffusion zone and that the Alclad principle is functioning in electrolytically protecting the core. Of course, the attack may not have proceeded far enough to give this hill and valley effect but then it should be very evident that the corrosion is superficial.

So far we have discussed theoretical considerations only. Fig. 4 (Neg. 20716C) shows the surface (photographed actual size) of a piece of Alclad 24S-T sheet which was taken from a location in a plane subjected to exhaust fumes, after 7600 hours of service. Fig. 5 (Neg. 20801) shows a cross section through this piece of sheet and reveals the extent of the surface corrosion. The tooth-like appearance of the surface coating remaining is typical of

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that previously described and schematically illustrated in Fig. 2. Corrosion had not reached the core in any place examined in this sample. Standard A.S.T.M. tensile specimens cut from the full thickness of this sheet exhibited the following properties:

| Specimen Marked | Tensile Strength psi | Yield Strength psi | Elongation % |
|---|---|---|---|
| 32199-1 | 62,690 | 45,800 | 19 |
| -2 | 62,060 | 46,100 | 18 |
| Guaranteed Minima | 56,000 | 37,000 | 16 |

Sheet thickness 0.0215"

(Physical Test No. 051138-A, May 11, 1938).

These results show that the mechanical properties after this service are well above the minimum specification values and the superficial corrosion has had no appreciable effect on the mechanical properties of this piece of sheet.

Fig. 6 (Neg. 21734B) shows three pieces of skin sheet of Alclad 24S-T taken from a plane reported to have had 8200 hours of service. The sheet was replaced because it was feared that destructive corrosion had occurred. Fig. 7 (Neg. 21735A) (natural size) shows a typical spotted condition on the Alclad surface areas. Fig. 8 (Neg. 21736) at 100X pictures a cross section through sheet showing this surface corrosion and again illustrating typical Alclad protection of the core and diffusion zone. In Fig. 6 there will be noted a number of standard A.S.T.M. tension specimens indicated on the several sheets, some of these taken through areas showing the most severe surface corrosion and others in locations where there is no visible surface attack. The results of tension tests on specimens the full thickness of the sheets taken from these locations follow:

| Specimen Marked | Tensile Strength psi | Yield Strength psi | Elongation % |
|---|---|---|---|
| | **Tests of Sheet No. 34089 - thickness 0.027"** | | |
| **Specimens from Uncorroded Areas** | | | |
| 34089-W-1 | 61,690 | 47,600 | 17.5 |
| -2 | 61,770 | 47,800 | 18.0 |
| | Ave.61,730 | 47,700 | 17.8 |
| **Specimens from Areas Showing Surface Corrosion** | | | |
| 34089-W-3 | 61,620 | 48,000 | 17.5 |
| -4 | 61,910 | 48,400 | 18.0 |
| | Ave.61,765 | 48,200 | 17.8 |
| -5 | 62,210 | 48,800 | 16.5 |
| -6 | 62,430 | 49,100 | 16.5 |
| | Ave.62,320 | 48,950 | 16.5 |
| | **Tests of Sheet No. 34090 - thickness 0.027"** | | |
| **Specimens from Uncorroded Areas** | | | |
| 34090-W-1 | 62,890 | 48,500 | 17.0 |
| -2 | 62,500 | 48,200 | 18.0 |
| | Ave.62,695 | 48,350 | 17.5 |
| **Specimens from Areas Showing Surface Corrosion** | | | |
| 34090-W-3 | 61,030 | 46,500 | 17.0 |
| -4 | 60,590 | 46,000 | 19.0 |
| | Ave.60,810 | 46,250 | 18.0 |
| -5 | 61,620 | 46,200 | 19.0 |
| -6 | 61,690 | 46,000 | 19.0 |
| | Ave.61,655 | 46,100 | 19.0 |

| Specimen Marked | Tensile Strength psi | Yield Strength psi | Elongation % |
|---|---|---|---|
| **Tests of Sheet No. 34092 - thickness 0.027"** | | | |
| **Specimens from Uncorroded Areas** | | | |
| 34092-W-1 | 65,460 | 57,100 | 13.5 |
| -2 | 65,100 | 56,600 | 14.0 |
| | Ave.65,280 | 56,850 | 13.8 |
| **Specimens from Areas Showing Surface Corrosion** | | | |
| 34092-W-3 | 65,770 | 56,800 | 14.0 |
| -4 | 65,410 | 56,100 | 14.0 |
| | Ave.65,590 | 56,450 | 14.0 |
| -5 | 65,590 | 57,200 | 13.5 |
| -6 | 64,240 | 56,100 | 13.0 |
| | Ave.64,915 | 56,650 | 13.3 |

(Physical Test No. 090138-A. Sept. 1, 1938)

From these data it will be noted that the mechanical properties are typical of Alclad 24S-T, with the exception of specimens taken from sheet 34092, which show high tensile and yield strengths, with a corresponding decrease in elongation, which is typical of the effect of cold work after heat treatment. The comparison between the properties of specimens taken from the corroded areas and those from corresponding uncorroded areas of each sheet shows no significant change in properties and proves conclusively that the superficial corrosive attack, as illustrated by these samples, has not affected the mechanical strength of the sheet.

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The purpose of this entire discussion has been to avoid alarm over some surface corrosion of Alclad sheet. It should not be inferred from this discussion that where such corrosion is occurring it would not be expedient to use some protective measures, at least until the condition which, as we understand it, is sucking exhaust fumes into the center sections of the ship, can be corrected. Likewise, there may be occasions where there is a collection of a heavy deposit of dirt or other material at crevices, especially where uncoated strong alloys are in contact with Alclad sheet. If corrosion is suspected at such areas more thorough inspection should be recommended.

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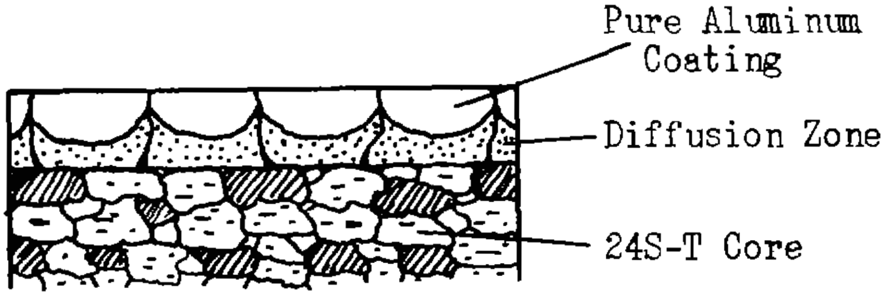


Fig. 1
Schematic cross section of
Alclad 24S-T sheet.

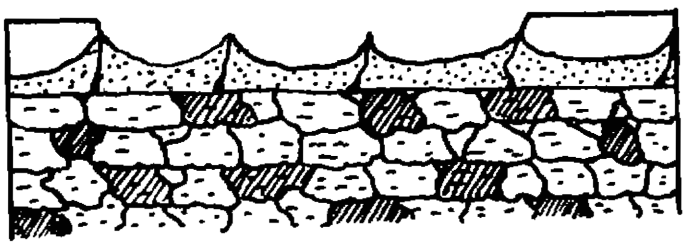

Fig. 2
Schematic cross section showing
corrosion attack extending to the
diffusion zone.

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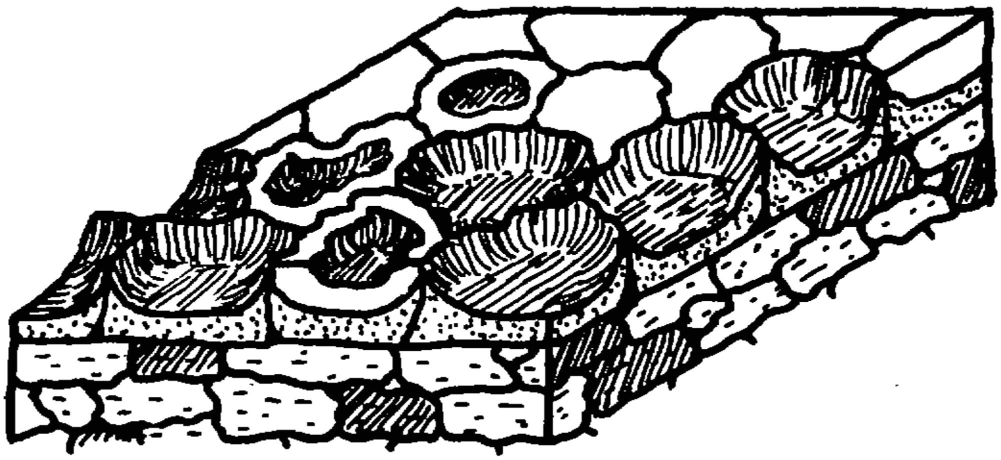

Fig. 3
Schematic block diagram showing appearance of hill and valley corrosion on surface of Alclad 24S-T sheet.

Fig. 4    Actual size.
This photograph shows the stained and roughened appearance of the Alclad 24S-T sample from the center section of a plane. The staining was largely superficial because most of it could be removed by cleaning.

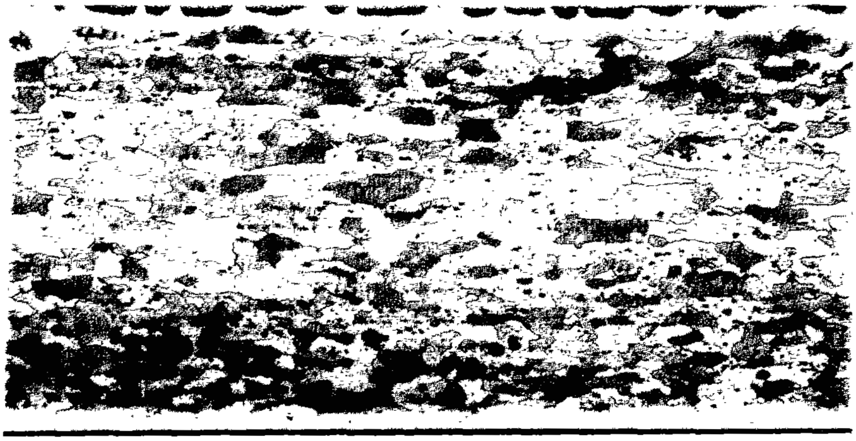


Fig. 5 Mag. 100X Etch: $HF-HCl-HNO_3$

This micrograph shows a complete cross section of the Alclad 24S-T sheet from the center section of a plane. The surface of the Alclad sheet which was exposed to the action of the exhaust gases is at the top of the micrograph. The roughening of the surface was the result of pitting that was confined entirely to the high purity coating layer. The pitting extended approximately half way through the coating.

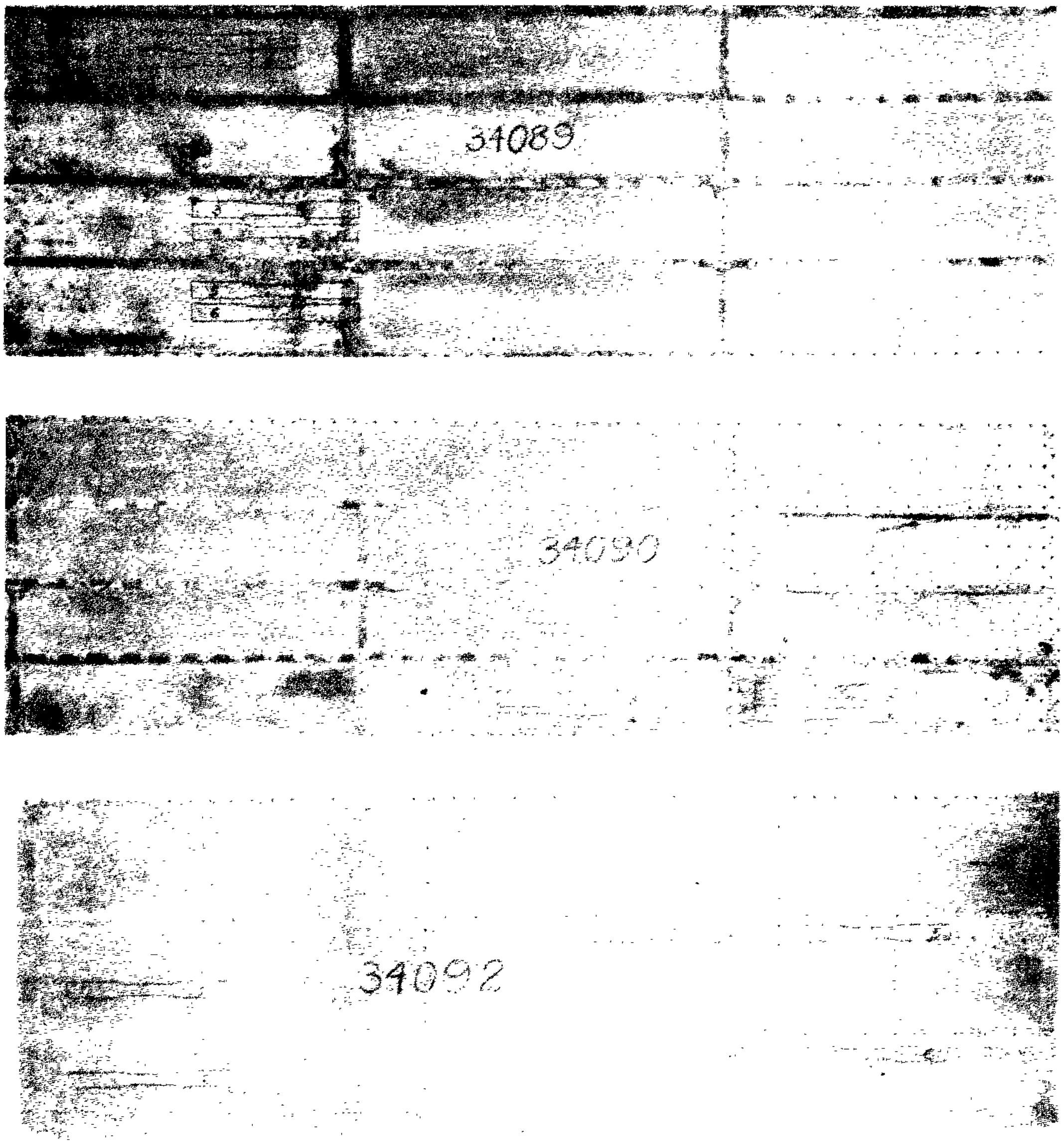


Fig. 6

This photograph shows the corroded areas on the inside surfaces of three samples of the Alclad 24S-T skin covering removed from a plane after 8200 flying hours. The locations of the tensile specimens from the corroded and uncorroded portions of the samples are indicated in the photograph. The corrosion attack occurred largely at the faying surfaces and in areas where a large amount of dirt had accumulated.


Fig. 7
This shows the characteristic appearance of the surface of the Alclad 24S-T skin covering in an area which had corroded from exposure to exhaust fumes and moisture. Actual size.

Mag. 100X

Etch:
HF-HCl-$HNO_3$

Fig. 8
This shows a full cross section through a corroded portion of the sheet similar to that shown in Fig. 7. The corrosion attack was limited to the high purity coating and did not penetrate the diffusion zone. The peaks in the coating represent areas where the diffusion along the grain boundaries in the coating was greater than that through the boundary of the grain.