Enclosure 1

Sample Test Bed
Inspection Report

CADASTRAL SURVEY MONUMENTATION MANUAL

Volume 2

DRAFT

DSC-1382-2
Sept. 1971

To: Director, DSC

From: Richard B. Case, Mechanical Engineer, Division of of Scientific Systems Development (D-440)

Subject: Field Trip Report

Covering Travel To:	Dates:
Salt Lake City, Utah	October 20-23, 1980

PLEASE number paragraphs in accordance with subjects listed below; if one or more items is not applicable, so state.

1. Purpose/Objectives of Trip
2. Persons Contacted/Interviewed
3. Subjects Discussed
4. Facts Gathered
5. Other Observations Made
6. Accomplishments or Results of the Trip

1. Purpose:

To inspect and report on conditions of Cadastral Survey Monuments located at Utah Test sites No. 1A and No. 2.

2. Persons Contacted:

Mr. Glenn Hatch, Utah State Office, Cadastral Survey.
Mr. Ross Workman, Utah State Office, Cadastral Survey.

3. Subjects Discussed:

A. Method of Inspecting monuments.
B. Condition of monuments.

4/5. Facts Gathered/Observations:

Cadastral survey monuments located in Test Sites No. 1A and No. 2 near Salt Lake City, Utah, are inspected and photographed annually to determine corrosion rates. Reference WAR No. D-61.

One monument of each type being tested was removed from Test Sites No. 1A and No. 2, during the period of October 20-23, 1980, and inspected. Monument corrosion finds along with photographs are as follows.

cc:
B. Hostrop, WO
I. Zirpel, ASO
G. Hatch, USO

Richard B. Case 11/12/80
Traveler Date

Use additional pages, if necessary
cc: Chief, Division/Branch of

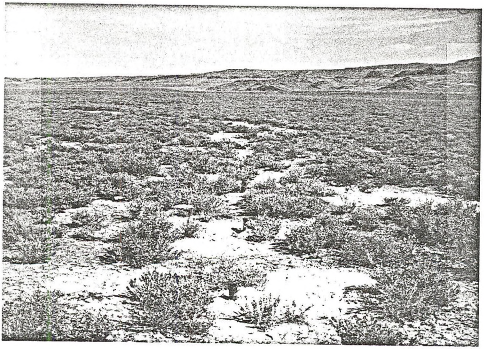
☆U.S. Government Printing Office-1978-778-

Test Site No. 1A

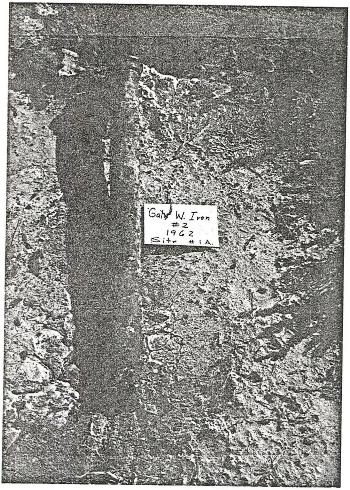
Near Salt Lake City, Utah

Soil pH - 8.0

Inspection Date - October 20-23, 1980



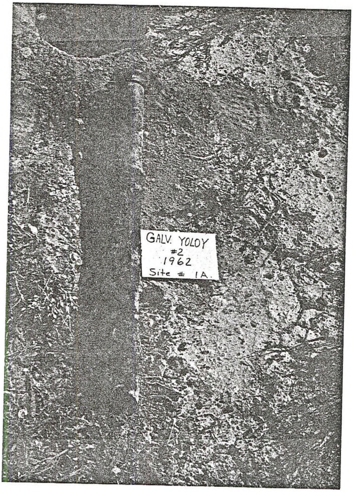
A. Galvanized Wrought Iron
Monument Test Set - No. 2
Set in 1962
Inspection Date - October 1980



Top of monument (above ground level) is rusty, but looks good.

Below ground level the monument has severe corrosion and rust buildup. The flange has corroded away and there is much metal loss on the pipe body. Corrosion appears as etched parallel lines.

B. Galvanized Yoloy
Monument Test Set - No. 2
Set in 1962
Inspection Date - October 1980

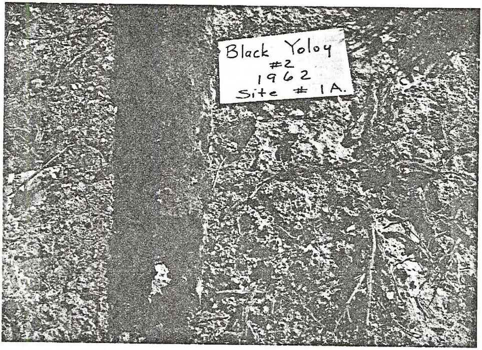


Top of monument (above ground level) looks good.

Below ground level the monument has severe corrosion with many continuous deep pits and much rust buildup. The lower two inches of the monument has corroded away.

This monument is in very poor condition.

C. Black Yoloy
Monument Test Set No. 2
Set in 1962
Inspection Date - October 1980

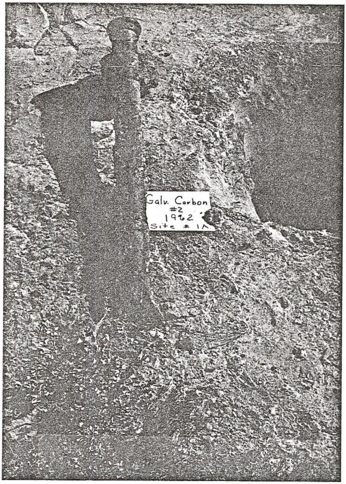


Top of monument (above ground level) is slightly rusty, but looks good.

Below ground level the monument has severe continuous pitting and much rust buildup. The lower portion of the monument is in very poor condition with thin metal and several large holes. The lower three inches of the pipe have corroded away.

Corrosion on this monument was worse than any other monument inspected.

D. Galvanized Carbon
Monument Test Set - No. 2
Set in 1962
Inspection Date - October 1980

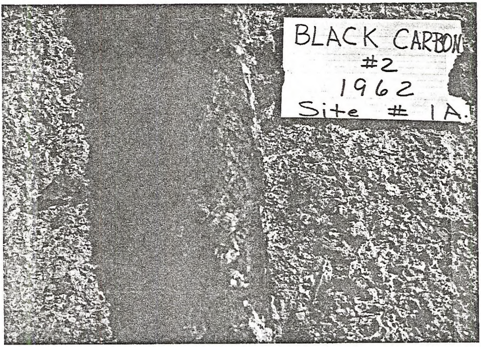


Top of monument (above ground level) looks very good.

Below ground level the monument has severe pitting and much rust buildup. The lower part of the pipe is thin and most of the flange has corroded away.

This monument is in poor condition.

E. Black Carbon
Monument Test Set - No. 2
Set in 1962
Inspection Date - October 1980

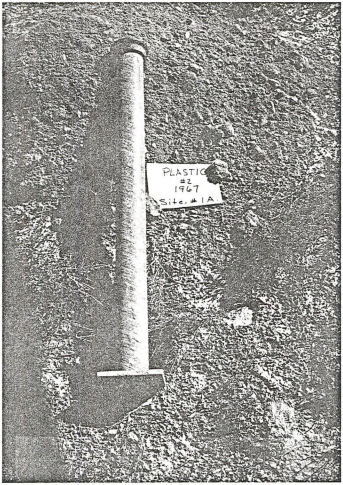


Top of monument (above ground level) is rusty but looks good.

Below ground level the monument has large continuous pitting and severe rust buildup. Holes have appeared in the lower portion of the pipe and the remaining metal is very thin. The flange and lower one to two inches of the pipe have corroded away.

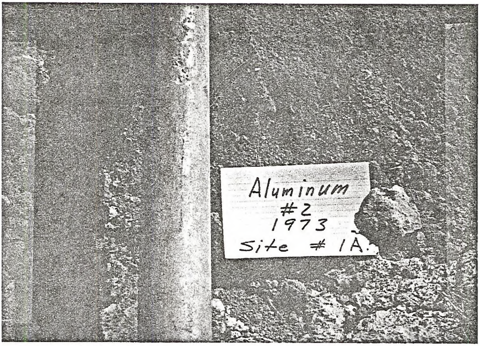
Only one other monument (Black Yoloy) had more extensive corrosion than this monument.

F. Plastic
Monument Test Set - No. 2
Set in 1967
Inspection Date - October 1980



This monument appears to be fiber glass and is in excellent condition both above ground and below ground level. The only evidence of corrosion is a small area on the foot pad.

G. Aluminum Pipe
Monument Test Set - No. 2
Set in 1973
Inspection Date - October 1980

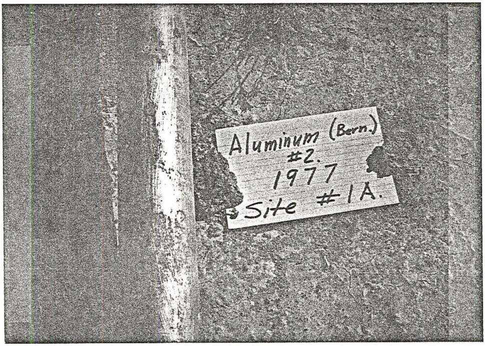


Top of monument (above ground level) is dark in color but is in very good condition.

Below ground level the monument has a few large deep pits with some dark spots. The pits are only in isolated areas and are not continuous. There is some pitting in the flange also.

This monument is in very good condition.

H. Aluminum Pipe
Monument Test Set - No. 2
Set in 1977
Inspection Date - October 1980

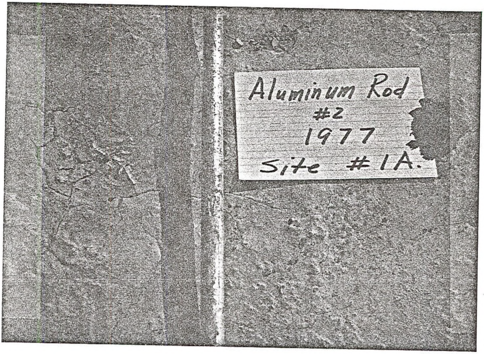


Top of monument (above ground level) is in excellent condition.

Below ground level the monument has a few small very deep pits in various parts of the pipe.

This monument is in very good condition.

I. Aluminum Rod
Monument Test Set - No. 2
Set in 1977
Inspection Date - October 1980

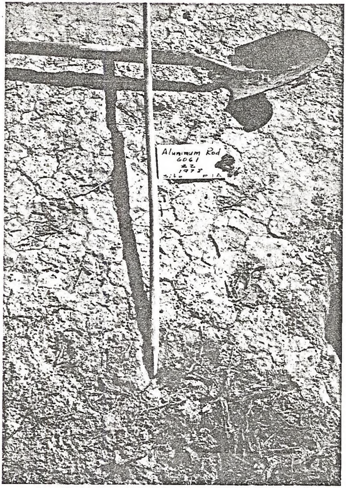


Top of monument (above ground level) is in excellent condition.

Below ground level there are many dark spots and one small area has deep continuous pits. There is also some corrosion near the point.

This monument is in very good condition.

J. Aluminum Rod (Type 6061 Al) - 3/4"
Monument Test Set - No. 2
Set in 1978
Inspection Date - October 1980

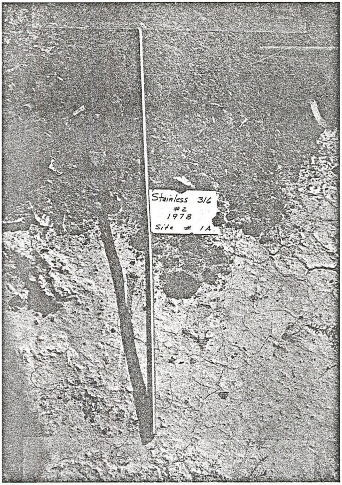


Top of monument (above ground level) is in excellent condition.

Below ground level there are a few dark spots and slight corrosion near the point.

This monument is in excellent condition.

K. Stainless Steel (Type 316)
Monument Test Set - No. 2
Set in 1978
Inspection Date - October 1980



This monument is in excellent condition. The metal is bright and looks as it did when it was installed. There is no corrosion, discoloration, or pitting present.

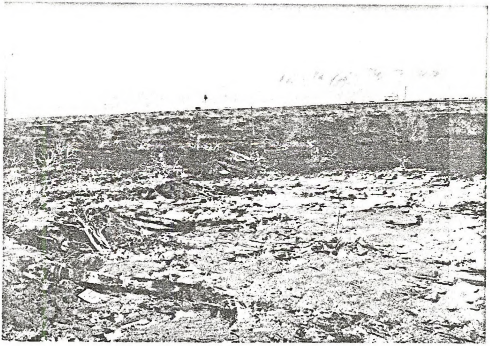
This monument is in better condition than any other monument being tested.

Test Site No. 2

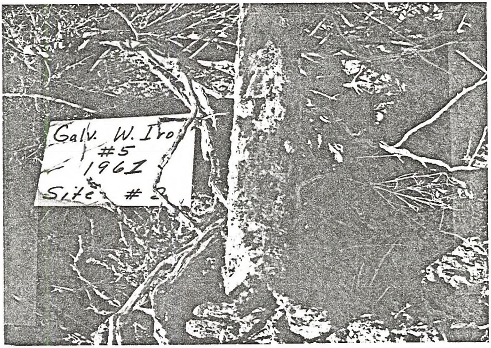
Near Salt Lake City, Utah

Soil pH - 7.5

Inspection Date - October 20-23, 1980



A. Galvanized Wrought Iron (1961 contract)
Monument Test Set - No. 5
Set in 1962
Inspection Date - October 1980

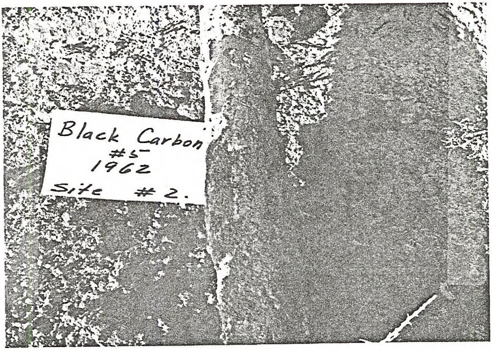


Top of monument (above ground level) looks good.

Below ground level the monument galvanizing has corroded away. The corrosion appears as parallel grooves that are etched to varying depths.

This monument is still in good condition.

B. Black Carbon
Monument Test Set - No. 5
Set in 1962
Inspection Date - October 1980



Top of monument (above ground level) has some rust spots but looks good.

Below ground level the monument has a black appearance. Corrosion is active and metal appears to be flaking off. The rust appears to be taking on a crystallization form.

This monument is still in fairly good condition.

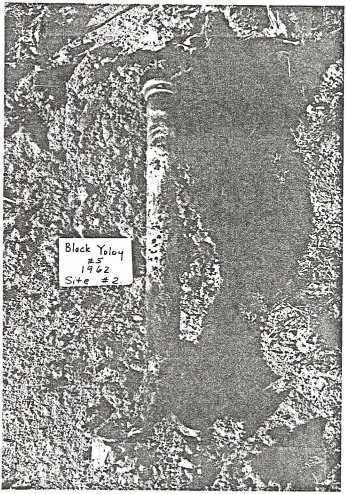
C. Galvanized Carbon
Monument Test Set - No. 5
Set in 1962
Inspection Date - October 1980

Top of monument (above ground level) is rusty but very solid.

Below ground level the monument galvanizing has corroded away and thin layers of metal appear to be flaking off in form of rust. There are many parallel grooves etched into the pipe.

This monument is still in fairly good condition.

D. Black Yoloy
Monument Test Set - No. 5
Set in 1962
Inspection Date - October 1980

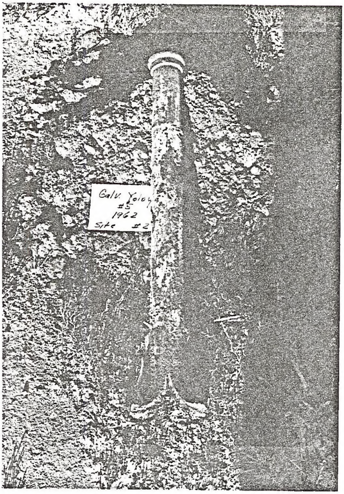


Top of monument (above ground level) is rusty but solid.

Below ground level the monument has many large pitted areas. Metal has been corroded away and much rust is present. The flange is thin and breaking away. Minor parallel grooving is present.

This monument is in fair to poor condition.

E. Galvanized Yoloy
Monument Test Set - No. 5
Set in 1962
Inspection Date - October 1980

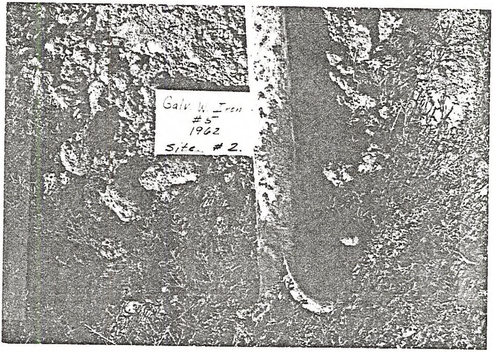


Top of monument (above ground level) is rusty but looks good.

Below ground level the monument is very rusty with small pitting. The flange is in fairly good condition.

This monument is still in good condition.

F. Galvanized Wrought Iron
Monument Test Set - No. 5
Set in 1962
Inspection Date - October 1980

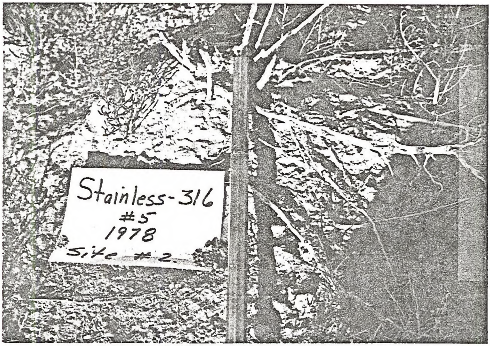


Top of monument (above ground level) is rusty but looks good.

Below ground level the monument has some pits and rusty areas. Corrosion is worse near the bottom with more pits having deeper depths. Metal is corroding away near the lower portion with parallel grooved type etching being present.

This monument is in fairly good condition except for the lower section of the pipe.

G. Stainless Steel
Monument Test Set - No. 5
Set in 1978
Inspection Date - October 1980



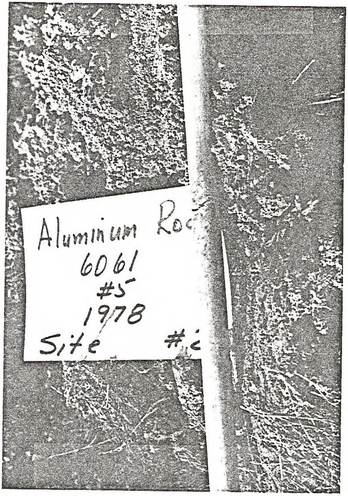
Top of monument (above ground level) is excellent.

Below ground level the monument is bright an in excellent condition. There are two small brown spots measuring approximately 1/4 inch in diameter on the lower portion of the rod.

At the ground line there appears to be slight corrosion. There is a small groove around the entire rod that measures only a few thousandths of an inch deep.

This monument is in excellent condition and looks better than any other monument that was inspected from this test site.

H. Aluminum Rod (Type 6061)
Monument Test Set - No. 5
Set in 1978
Inspection Date - October 1980



Top of monument (above ground level) has some small pits but is in very good condition.

Below ground level the monument is dark in color but looks solid and in very good condition.

At the ground line corrosion is present with continuous pitting where metal has been removed around the entire rod. The worse pits are approximately 1/32" to 1/64" deep.

This rod is in very good condition.

Enclosure 2

Sample Metallurgical Report

United States Department of the Interior
BUREAU OF LAND MANAGEMENT
DENVER SERVICE CENTER
DENVER FEDERAL CENTER, BUILDING 50
P.O. BOX 25047
DENVER, COLORADO 80225-0047

IN REPLY
REFER TO:

4500 (D-433)

May 6, 1986

Information Bulletin No. DSC-86-121

To: All State Directors
Attention: All SO Cadastral Survey Branch Chiefs

From: Service Center Director

Subject: Stainless Steel Survey Monument Evaluation

The Branch of Survey and Mapping Development has been asked to analyze an Allied manufactured stainless steel monument and compare the findings to BLM specifications. A report has been prepared to show these findings (see Attachment 1 - Stainless Steel Survey Monument Evaluation).

For your information we have attached a copy of the Chemical Analysis Report No 86156.

2 Attachments
1 - Stainless Steel Survey Monument Evaluation (1 p)
2 - Chemical Analysis Report No. 86156 (2 pp)

Distribution
WO (720), Premier, Room 201 - 1
D-430 - 1
D-433 - 1
D-553A - 1

RECEIVED
MAY 08 1986

Stainless Steel Survey
Monument Evaluation

I. Problem

The Utah State Office has forwarded an Allied manufactured (Surv-Kap) stainless steel pipe monument to Denver for evaluation. Utah requested that the Branch of Cadastral Survey Development, (D-416) determine if the stainless steel pipe monument conforms to BLM specifications.

II. Findings

A. Chemical Analysis

The stainless steel monument was forwarded to Metals Laboratories, Inc., Denver, Colorado for chemical analysis.

The pipe body complies with BLM Specification No. 9691.47 for Type 304 Stainless Steel.

The cap material does not comply with BLM's specification ASTM (B-30) Alloy 5A. See enclosed Lab. Report No. 86156, dated April 21, 1986.

B. Physical Dimensions

1. Stainless steel pipe body

Measurements were within specifications.

2. Cap

Most dimensions were within specification limits, however, the cap top thickness measured only 0.250" while the specification called for a thickness of 0.375".

III. The Allied manufactured monument is a very good monument and their pipe body conforms to BLM specifications. The Allied cap top thickness is less than BLM requires and their material, although a very good material, does not comply with BLM standards.

METALS LABORATORY, INC.
1717 E. 39th Ave.
DENVER, COLORADO
80205

DATE 4-21-86 LAB NO. 86156

CUSTOMER: Bureau of Land Management

SAMPLE: Survey Monument, Allied Mfg. - 304 SS and Brass

SUBMITTED BY: Richard B. Case

WORK REQUESTED: Chemical Analysis

Order No. - YA-558-BP6-0096
Req./Ref. No. - YA-410-86-141

These analyses indicate the pipe is AISI 304 stainless steel and the cap is a leaded low red brass, however, it it quite low in the major alloying elements except tin, and does not conform to the specifications for ASTM B-30(5A).

		PIPE
C	-	0.05%
Mn	-	1.69
S	-	0.00
Ni	-	8.5
Cr	-	18.2
Mo	-	0.10

	CAP	ASTM B-30 (5A)
Sn	5.0%	2.5-3.5%
Pb	1.58	6.3-7.7
Zn	2.4	7.0-10.0
Ni	0.51	0.80 Max.
Fe	0.01	0.35 Max.
S	0.05	0.08 Max.
Cu (bal.)	90	79.0-82.0

Duplicate tests were made in direct comparison to NBS standard materials.

CORROSION RESISTANCE:

The pipe is within the specifications and should exhibit the normal corrosion resistance of 304 stainless steel.

A comparison of the corrosion rates for the cap alloy and B30(5A) is not available. While all leaded low red brass compositions have excellent resistance to corrosion, the higher lead content of B-30(5A) could provide better long-term resistance to nitrogen oxides in rain water. Only a prolonged test would prove this, unless such information is available to the authors of Specification No. 9691.47.

L. G. Platt

L. G. Platt

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
DENVER SERVICE CENTER
DENVER FEDERAL CENTER, BUILDING 50
P.O. BOX 25047
DENVER, COLORADO 80225-0047

IN REPLY
REFER TO:
9600 (D-433)

July 25, 1986

Information Bulletin No. DSC-86-155

To: All State Directors
Attention: All SO Cadastral Survey Branch Chiefs

From: Service Center Director

Subject: Allied Manufactured Brass Monument Cap

The Allied Manufacturing Company, Tucson, Arizona, has recently redesigned their brass monument cap. Two sample caps were forwarded to the Service Center for analysis.

The new caps have been analyzed and compared to BLM Specifications 9691.47. See Laboratory Report No. 86192 (Attachment 1).

Physical dimensions of the cap now meet BLM specifications, and the new brass alloy material meets the ASTM (B-30) Alloy 5A requirement.

Allied's newly designed brass monument survey cap is being certified as meeting BLM specifications.

1 Attachment
1 - Lab. Report 86192 (1 p)

Distribution
WO (720), Premier, Rm. 201 - 1
D-553A - 1
D-430 - 1
D-433 - 1

RECEIVED
JUL 30 1986

METALS LABORATORY, INC.
1717 E. 39th Ave.
DENVER, COLORADO
80205

DATE 5-29-86 LAB NO. 86192

CUSTOMER: Bureau of Land Management

SAMPLE: Survey Monument Cap - Allied Mfg.

SUBMITTED BY: Richard B. Case

WORK REQUESTED: Chemical Analysis and Estimation of Corrosion Resistance.

Order No. - YA-558-BP6-0096
Req./Ref. No. - YA-410-86-141

	CAP	B30 (5A)
Sn	3.64%	2.3 - 3.5%
Pb	5.7	6.0 - 8.0
Zn	3.1	7.0 - 10
Ni	0.69	1.0 Max.
Fe	0.02	0.4 Max.
S	0.06	0.08 Max.
Cu (Bal.)	86.8	78 - 82

Duplicate tests were made in direct comparison to NBS standard material.

CORROSION RESISTANCE:

While the analysis of this cap is not entirely within the specified limits for ASTM B30 (5A) Leaded Semi-Red Brass, the corrosion resistance should be equivalent to that of the specified alloy.

L. G. Platt

L. G. Platt

Atchmt 1

Enclosure 3

Sample of an Independent
Research Study

Enclosure 3

Sample of an Independent
Research Study

PERMANENT MONUMENTATION STUDY

WORK ASSIGNMENT RECORD D-180

by

RICHARD B. CASE

MECHANICAL ENGINEER

Office of Scientific Systems Development

U.S. Department of Interior

Bureau of Land Management

Denver Federal Center

Denver, Colorado 80225

September 1978

Table of Contents

Permanent Monumentation Study

I. Introduction:

The Division of Scientific Systems Development (SSD) was assigned Work Assignment Record (WAR) D-180 entitled "Permanent Monumentation Study - Cadastral Survey" for completion during Fiscal Year 1978. Since survey monuments are the only field evidence of the surveyor's work, BLM has long been concerned about the durability of these monuments. In recent years many new metal alloys and plastics have been developed with very good corrosive resistant properties. This study was initiated to investigate some new materials and compare them to materials currently being used for monumentation.

One phase of this study was to consider how varying soil types affected each material studied. Other factors considered were the effects of high temperature (such as a forest fire), the corrosion resistant properties, and means of locating each type monument. This report provides both technical information and durability data for currently used materials, new materials, and discontinued materials.

It should be pointed out that this study did not attempt to run accelerated testing to simulate 50 or 100 years of lapsed time.

Such testing would have been lengthy and very expensive. The results and recommendations made are based upon conventional tests conducted during an approximate six month period.

II. Study Findings:

A. Background:

In reviewing survey monumentation, the Bureau of Land Management's "Manual of Surveying Instructions" dated 1947, was first studied. The following statement was given on Page No. 247 concerning corner material:

"The Bureau of Land Management has adopted a standard iron post for monumenting the public-land surveys, which will be generally used unless exceptional circumstances warrant the use of other material. This practice is deemed so important that no substitutions are permitted excepting as provided in Section 239, and if authorized, a statement will be given in the field notes, in explanation as to why the standard iron post was not employed.

The post is made from wrought iron pipe, zinc coated 2 inches inside diameter, which is cut into lengths of 30 inches; one end of the pipe is split for about 4 or 5 inches, and the two halves are spread to form flanges or foot plates; a brass cap is securely fastened to the top. The pipe is filled with concrete."

The zinc coated iron post had apparently acquired a pretty good reputation by 1947 so the next reference reviewed was BLM's "Manual of Surveying Instruction" dated 1973. The following statement was given on page 106 in regards to monumentation materials:

CORNER MATERIAL

"4-7. The Bureau of Land Management has adopted a regulation post for monumenting the public surveys, which is used generally unless exceptional cricumstances warrant the use of other material. Substitutions are permitted only when authorized in the special instructions. In such cases a statement should be given in the field notes explaining why regulation posts were not employed.

The regulation post is made from alloyed iron pipe, zinc-coated, 2 1/2 inches outside diameter, which is cut into lengths of 30 inches. One end of the pipe is split for several inches, and the two halves are spread to form flanges. A brass cap is securely fastened to the top."

The zinc coated (galvanized) iron pipe was the standard monument used in 1973 and continues to be used today. With such a long standing excellent reputation, several BLM surveying representatives

were contacted and asked their opinion of the galvanized iron pipe monument. Some of the people contacted are as follows:

L. Bauman - Eastern States Office

P. Dennis - Utah State Office

Joe Gauron - Idaho State Office

John Jelley - Alaska State Office

Marlin Livermore - Denver Service Center

Norm McDonald - Denver Service Center

Howard Petersen - Denver Service Center

Irving Zirpel - Alaska State Office

Each individual contacted felt that the galvanized iron monument was an excellent survey marker and that it should remain in the BLM inventory. For these reasons, SSD decided to exclude this material from testing since it should obviously remain in the BLM monumentation inventory. Previous testing has been conducted on this material, however, from the Utah State Office. Weight and measurement data may be obtained from Mr. P. Dennis, Utah State Office, upon request.

Although the standard monument has an excellent reputation for durability, some unique problems have developed from using the galvanized iron monument in certain parts of the country, specifically - Alaska.

Problem: Alaskan Areas

After standard pipe monuments have been installed and backfilling is complete, a puddle of water sometime forms around the monument. In some cases the monument is found at a later date lying flat on the surface of the ground. In other cases the monument has disappeared from view, sinking below the surface of the ground.

When monuments are set, a hole has to be dug and the backfill dirt is often very dark. With vegetation removed and a dark area around the monument, it is believed that solar radiated heat may be thermally conducted to the permafrost area. Such a condition would explain the water that sometimes forms around the monuments.

Solution:

Surveying crews in Alaska have found that driving 5/8 inch diameter rods into the ground give much better results than using standard pipe monuments. Vegetation does not have to be removed when the rods are used and water puddling is significantly reduced. After a rod has been driven until it meets significant resistance, the rod is cut off at the proper height. An identification cap is then securely fastened to the rod. In some cases these rods have to be driven to a depth of approximately 35 feet to find satisfactory footing. With such lengths involved, the rods have to be cut into short sections (approximately

3 feet) and attached by screws as each section is driven down. The rod currently being used for this operation is an aluminum rod developed by Berntsen Cast Products, Madison, Wisconsin. The rod, cap, and screw materials have been analyzed by Colorado Assay Laboratory, Denver, Colorado. See results on pages 36 - 45.

B. Establishing monument materials to be studied:

Selected For Testing		
No	1.	Zinc coated alloyed iron material currently being used: (Standard Monument) This material was not selected for testing since much testing has been performed on it already and galvanizing materials are not recommended for use where sections have to be threaded for attaching.

Selected For Testing		
No	2.	Plastic Materials were considered. Materials such as Polyvinyl Chloride (PVC) and LEXAN 940 resin as manufactured by General Electric were reviewed. These materials have excellent corrosion resistant properties, but they have low melting points. Such materials would be consumed

in high temperature forest fires. For this reason plastic materials were not selected for testing.

Selected For Testing		
Yes	3.	Aluminum 6063T6 currently being used in Alaska.
		Since this is a relatively new survey monument and represents millions of dollars of survey work, this material was the first choice to be studied. Two manufacturers have supplied these monuments to BLM, (Berntsen Cast Products and Alaska Copy Center). Both products were analyzed during this study.
Yes	4.	Copper coated steel rod - This monument material has been discontinued by BLM.
		This material was selected for testing for two reasons: a. Most surveyors contacted, liked this monument.

Selected For Testing — b. The U.S. Geological Survey, (U.S.G.S.) continues to use this material.

Yes — 5. Stainless Steel Type 316 - a - new material to BLM, believed to be excellent for monumentation. This material is highly resistant to corrosion and is believed to be within a practical price range. LT. R. P. Floyd, National Oceanic and Atmospheric Administration, NOAA, National Geodetic Survey, makes the following statement concerning Stainless Steel Type 316:

> "This alloy has the optimum combination of iron, nickel, and chromium to combat corrosion in both weight loss and pit depth, and yet remain within economical reach."

The nominal chemical composition of S.S. Type 316 in per cent, is as follows:

Carbon - .08 max., manganese - 2.0 max, silicon - 1.0 max., chromium -

16.0 - 18.0, nickel - 10.0 - 14.0, molybdenum - 2.0 - 3.0.

C. Professional Surveyors and Metallurgists Opinions Concerning Various Materials

While investigating monument materials, SSD contacted several professionals. Some of the people contacted along with their comments are listed for review:

1. Mr. Frank White; Chief, Field Surveys; U.S. Geological Survey; Denver, Colorado.

   The Geological Survey uses copper coated steel rods (copperweld) and concrete posts. They prefer the concrete post. The copperweld rods are getting very expensive. The rod is costing in excess of $1.00 per foot and each coupling is approximately $2.75.

2. Lt. Richard P. Floyd; NOAA, National Geodetic Survey; Rockville, Maryland.

   NOAA, National Oceanic and Atmospheric Administration, has gone to a Stainless Steel Type 316 Bench Mark for all vertical control. Concrete posts are still used for

corner markers. Lt. Floyd considers the Stainless Steel Type 316 (S.S. - 316) to be much superior to either aluminum or copper weld monuments in regards to corrosion resistant properties.

3. Mr. Ed Escalante; Bureau of Standards; Washington, D.C.

Mr. Escalante stated that Stainless Steel Type 316 (S.S. - 316) is superior to aluminum alloys in resisting corrosion. S.S. - 316 can accept a wider p H range (hydrogen ion activity) and would have a longer life in salts. The only draw-back to using S.S. - 316 over aluminum alloys would be cost and weight. Mr. Escalante further stated that S.S. 316 was slightly magnetic when cold drawn for rods as would be used for monumentation.

4. Dr. R. Dodd; Metallurgical Engineering; University of Wisconsin.

Dr. Dodd thinks the aluminum monument is a good unit; however, he feels the S.S. 316 would make a superior monument.

D. Test Results:

All test data taken to support the findings of this report have been recorded on the following pages for review. Particular attention has been given to areas where dissimilar metals are joined.

INFORMAL BLM OFFICE

- TESTING -

In order to have an elementary working knowledge of some of the materials being used as survey monuments, SSD has conducted a very informal salt test. Monument materials currently being used, a monument that has been discontinued, and a new material were partially submerged in a salt solution and monitored for several months. Periodic inspections were made using only a magnifying glass for inspection. The results are as follows:

Materials Tested:

Stainless Steel Type 316 (New Material)

Copper Coated Steel Rod (Discontinued)

Aluminum Rod with Attachment Screw (Currently being used)

Salt Test:

Test started 4-11-78

1st Inspection: 5-3-78

1. Stainless Steel Type 316 Plate

Part below water surface - Looked excellent, just like the day the test started.

Part above the water line was coated with salt which was removed for inspection. Some brown discoloration was present, but there was no evidence of pitting or erosion.

2. Copper Coated Steel Rod

Water solution was brown-slightly discolored.

Part below water line - Cooper looked very bright as if it had been cleaned. There was no evidence of erosion or pitting. The steel center has a dull appearance, but did not show evidence of pitting or erosion.

Part at the water line had a coating of salt built up.

Part above water line - appeared to be green in color and had a salt residue. There was no evidence of pitting or erosion.

Note: A copper colored residue was on top of the water and a brown sediment was on the bottom of the container.

3. Aluminum rod with attachment screw.

Below the water line much pitting was evident. The depth of pitting was unknown. Most pitting appeared to be near the screw, but no pitting was apparent at the screw interface. The screw looked good.

Above the water line - No apparent pitting or eroison. Some salt residue was present.

2nd Inspection: 7-11-78

1. Stainless Steel Type 316 Plate

Part below water surface - Looked very good and bright. There was one small discolored spot near the shear plane of plate.

Part above water line - Coated with salt which had to be removed for inspection. Some brown discoloration was centered around the water line. One small pit was near the shear plane of plate. Several discolorations were on the shear plane of the plate.

Note: There was a very slight discoloration of the water solution near the bottom of jar.

2. Copper Coated Steel Rod

The water solution was brownish - slightly discolored. A dark deposit had covered the bottom of the jar. A bright copper colored scum was on top of the water.

Part below water line - The copper had taken on a darker appearance. The steel had a gray appearance and showed evidence of eroison. Machine markings were no longer present and the steel had a soft look.

The part at the water line had a coating of salt built up.

The part above water line appeared to be green in color and also had a salt residue. There was no evidence of pitting or erosion.

3. Aluminum Rod with Attachment Screw

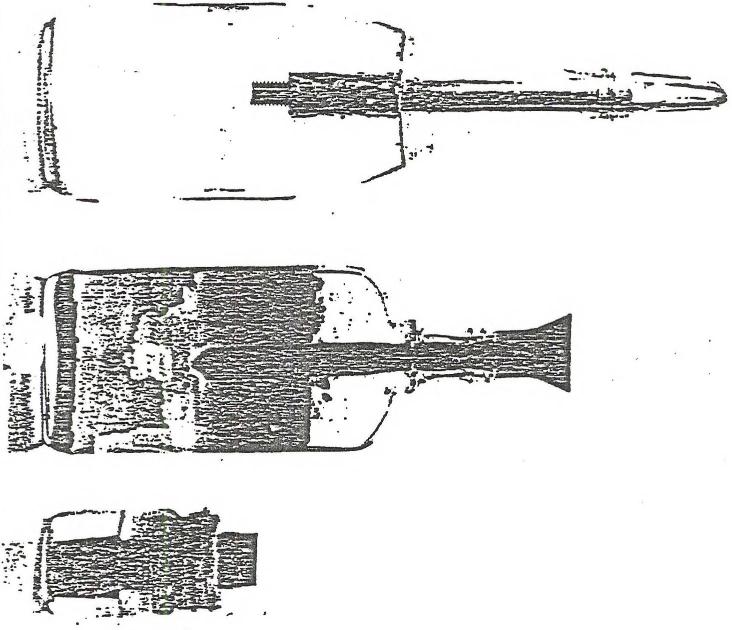
The water solution had a light colored sediment in bottom of container. Several pieces of light colored particles rested on bottom of container. Particles were very bright and had appearance of metal.

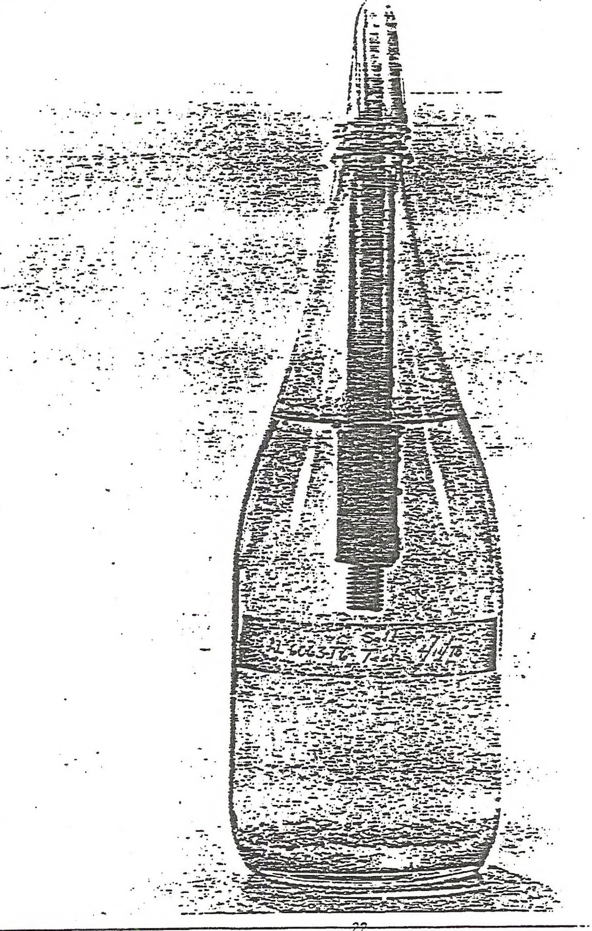
Below the water line, there was pitting. The pitting was most concentrated near screw and near water line. The depth of pitting was unknown. The weight loss was unknown.

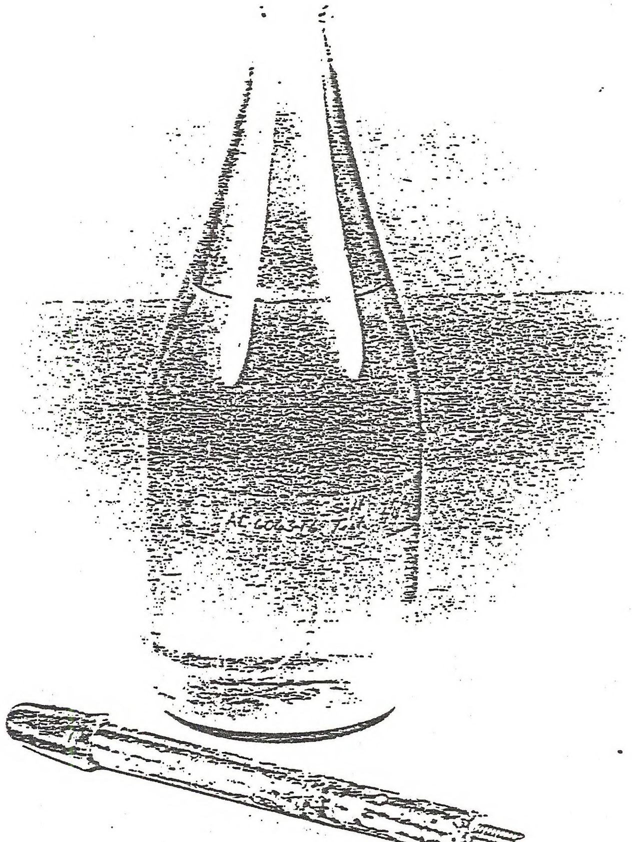
Above the water line - A few pits were present. A salt residue was also present.

C. Test Sample Photographs

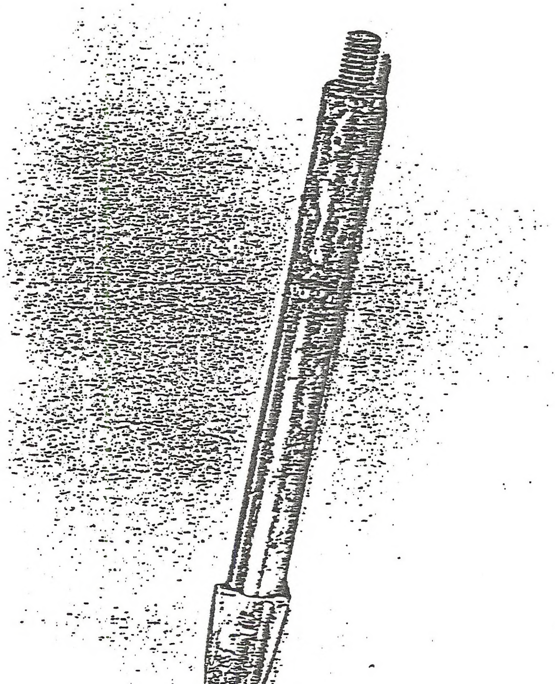
In the first photograph, the aluminum sample is located in the large bottle on the left side. The copper coated steel sample is in the center bottle, and the stainless steel sample is in the small bottle on the right side.

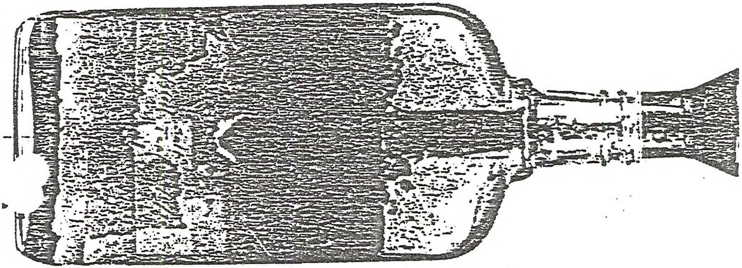


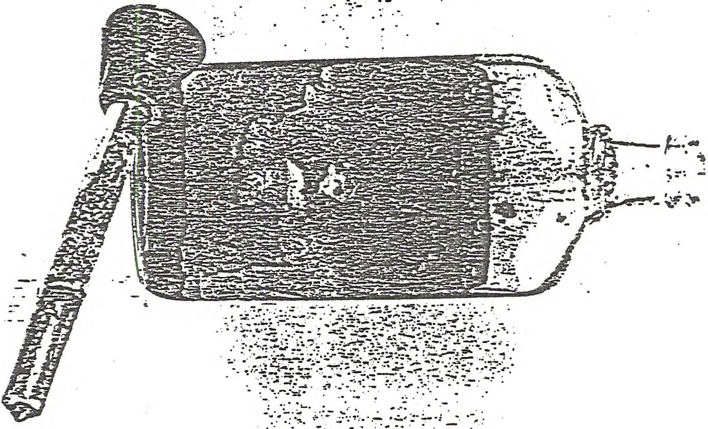



AL 6063-T6 Test

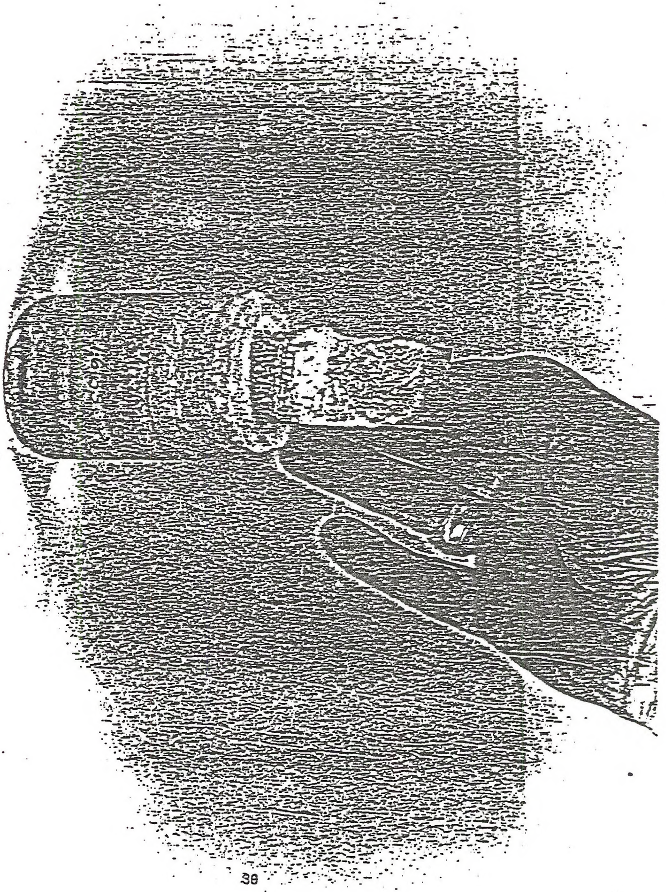
Note the pitting on the aluminum sample

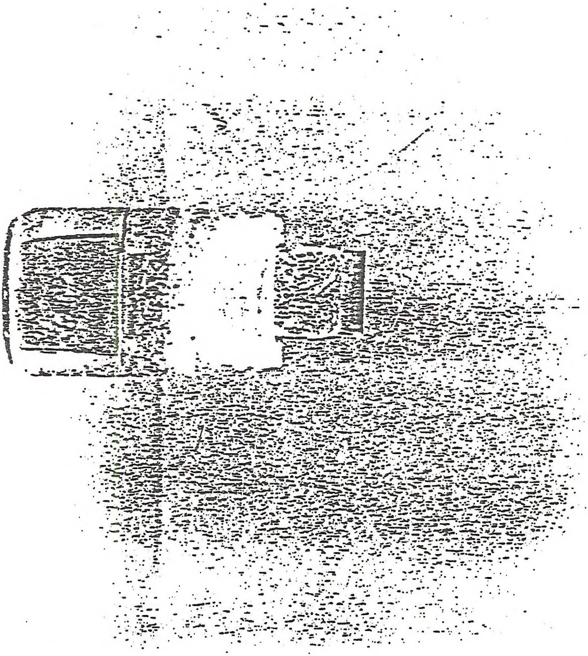




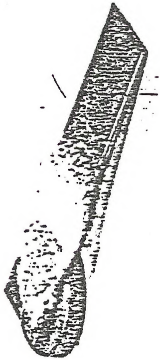


The steel tip portion of the copper coated steel rod had started to corrode away....





The stainless steel sample looked very good. The solid particles on the top and middle of the sample were salt build-up. This was easily removed and the metal looked very good beneath the salt deposit.



FORMAL LABORATORY

ANALYSIS

Purchase Document

YA 530-PH8-655

For Professional Laboratory Analysis

ORDER FOR SUPPLIES OR SERVICES

1

MARK ALL PACKAGES AND PAPERS WITH ORDER AND/OR CONTRACT NUMBERS

Bureau of Land Management
Bldg. 50, Denver Federal Center
Denver, CO 80225

DATE OF ORDER	CONTRACT NO.	ORDER NO.
5/11/78	CMP	YA530-PH8-655

ACCOUNTING AND APPROPRIATION DATA: YA 140 4520 0125 1488

REQUISITIONING OFFICE: SSD

REQUISITION NO./PURCHASE AUTHORITY: SSD-78-95

CONTRACTOR (Name and address, including ZIP code):
TO→ Colorado Assay Lab.
2244 Broadway
Denver, CO 80205

SHIP TO (Consignee and address, including ZIP code):
Bureau of Land Management, D-140
780 Simms
Lakewood, CO 80215

TYPE OF ORDER: PURCHASE ☒ — REFERENCE YOUR ... PLEASE FURNISH THE FOLLOWING ON THE TERMS SPECIFIED ON BOTH SIDES OF THIS ORDER AND ON THE ATTACHED SHEETS, IF ANY, INCLUDING DELIVERY AS INDICATED. THIS PURCHASE IS NEGOTIATED UNDER AUTHORITY OF Section 302 (c)(3) FPAS Act

DELIVERY ☐ — EXCEPT FOR THE BILLING INSTRUCTIONS ON THE REVERSE, THIS DELIVERY ORDER IS SUBJECT TO INSTRUCTIONS CONTAINED ON THIS SIDE ONLY OF THIS FORM AND IS ISSUED SUBJECT TO THE TERMS AND CONDITIONS OF THE ABOVE-NUMBERED CONTRACT.

F.O.B. POINT	GOVERNMENT B/L NO.	DELIVERY TO F.O.B. POINT ON OR BEFORE	DISCOUNT TERMS
na	na		net

SCHEDULE

ITEM NO.	SUPPLIES OR SERVICES	QUANTITY ORDERED	UNIT	UNIT PRICE	AMOUNT	QUANTITY ACCEPTED
1.	Perform quantitative analysis and qualitative analysis on the following:	1	job		est. 800.00	
	a. Survey Cap A (short neck) Berntsen; Rod A (Berntsen); Screw A (machined ends) Berntsen					
	b. Survey Cap B (long neck) Alaska; Rod B (Alaska); Screw B (rough cut ends) Alaska					
2.	Statement from the Lab to answer the following questions:					
	Condition A — Assume that Rod A sections are attached with Screw A					
	Condition B — Assume that Rod B sections are attached with Screw B					
	Will corrosion occur more rapidly with Condition A or Condition B?					

SIZE CLASSIFICATION: ☐ SMALL BUSINESS ☐ OTHER THAN SMALL BUSINESS — TOTAL FROM CONTINUATION PAGES

SEE BILLING INSTRUCTIONS ON REVERSE

GRAND TOTAL: 800.00

GROSS SHIPPING WEIGHT — INVOICE NO.

UNITED STATES OF AMERICA
BY (Signature)
NAME (Typed): Nancy Hanson, Purchasing Agent
TITLE: CONTRACTING/ORDERING OFFICER 234-5869

INVOICES TO:
Bureau of Land Management, Bldg. 50, Denver Federal Center, Denver, CO 80225

STANDARD FORM 147, JUNE 1966 — 147-105

..OR SUPPLIES OR SERVICES

..HEDULE—CONTINUATION

MARK ALL PACKAGES AND PAPERS WITH ORDER AND/OR CONTRACT NUMBERS

DATE OF ORDER	CONTRACT NO (If any)	ORDER NO.	PAGE NO.
5/11/78	OMP	YA530-PE8-653	

ITEM NO.	SUPPLIES OR SERVICES	QUANTITY ORDERED	UNIT	UNIT PRICE	AMOUNT	QUANTITY ACCEPTED
3.	Give galvanic action comparison in regards to the following three combinations:					
	A. Cooper coated steel rod (supplied)					
	B. Aluminum/stainless screw combination from Step 2, Condition A (supplied)					
	C. Stainless steel type 316 rod/brass combination (brass cap supplied only)					
	Which combination would be better in terms of corrosion resistance?					
	A. Consider each bombination in an acid type soil with a PH of 4.3.					
	B. Consider each combination in an alkaline type soil with a PH of 8.2.					
	C. Consider each combination in salt water.					

TOTAL CARRIED FORWARD TO 1ST PAGE

STANDARD FORM 148, JUNE 1964

REQUISITIONER

Test Results from

Colorado Assay Laboratory

Denver, Colorado

EDMUND E. PHILLIPS, VICE PRES. - GEN. MGR.   M. E. PHILLIPS, SECRETARY

THE COLORADO ASSAYING COMPANY

(Incorporated)

ASSAYERS AND CHEMISTS

2244 BROADWAY

DENVER, COLO. 80201

OUR MOTTO:— *"What there is in it, no more, no less."*

August 18, 1978

Bureau of Land Management, D-140
Att. Mr. Dick Case
780 Simms
Lakewood, Colorado 80215

Contract No. GLP   Order No. YA530-PH8-655

Part 1 - a   Page 1

SPECTROGRAPHIC ANALYSES

ELEMENTS PRESENT	APPROXIMATE PERCENTAGES Survey Cap A	Rod A	Screw A -- all-Berntsen
Aluminum	Major (92.)	Major (98.)	- -
Boron	- -	.001%	- -
Beryllium	.01-.02%	.0005	- -
Columbium	- -	- -	.008%
Cobalt	- -	- -	.2
Chromium	.05	.02-.03	15.-20.
Copper	.1	.03	.3
Gallium	.002	.002	- -
Germanium	- -	- -	.001-
Iron	.2	.25	Major (70)
Lead	.01	.003	.02
Magnesium	5.-10.	1.	- -
Manganese	.1	.01	2.
Molybdenum	.002	.001	.5
Nickel	.03	.05	8.-10.
Silicon	.3	.5	.5
Titanium	.1	.03-.05	.01-.02
Vanadium	.005	.01	.03
Zinc	.02-.03	trace	trace

CHEMICAL ANALYSES

	Survey Cap A	Rod A	Screw A
Manganese			1.47%
Iron			70.95
Silicon	.20%		0.57
Nickel			8.54
Molybdenum			.51
Chromium			17.15
Copper			.28
Magnesium	7.04		

August 18, 1978

Bureau of Land Management - D-140 Contract No. GMP Order No. YA530-PH8-655

Part 1.-b (page 2)

SPECTROGRAPHIC ANALYSES

ELEMENTS PRESENT	APPROXIMATE PERCENTAGES		
	Survey Cap B	Rod B	Screw B - all Alaska
Aluminum	Major (93.)	Major (98)	- -
Boron	- -	.001-%	- -
Beryllium	.01-.02%	.0005	- - - -
Columbium	- - - -	- - - -	- - -
Cobalt	- -	- -	.4%
Chromium	.005-.01	.007-.01	15.-20.
Copper	.01	.03	.05-.1
Gallium	.002	.003	- -
Germanium	- -	- -	trace
Iron	.15-.2	.25-.3	Major (70.)
Lead	.002-.005	.002-.005	.03
Magnesium	5.-10.	1.	- -
Manganese	.1	.02-.03	2.
Molybdenum	trace	trace	.1
Nickel	.01	.05	10.
Silicon	.3	.5	.5
Titanium	.1	.03-.05	.02
Vanadium	.005	.01	.06
Zinc	.01	.005-.01	trace

CHEMICAL ANALYSES

Manganese			1.32
Iron			69.46
Silicon	.15%		.66
Nickel			10.23
Molybdenum			.08
Chromium			17.77
Copper			.05
Magnesium	6.23%		

EDMUND E. PHILLIPS, VICE PRES. - GEN. MGR. M. E. PHILLIPS, SECRETARY

THE COLORADO ASSAYING COMPANY

(Incorporated)

ASSAYERS AND CHEMISTS

2244 BROADWAY

OUR MOTTO — *"What there is in it, no more, no less."*

DENVER, COLO. 80201 August 18, 1978

Bureau of Land Management, D-140 Contract No. C&P Order No. YA530-PH8-655

Part 2. (page 3)

A Statement to answer the following question:

Condition A — Assume that Rod A sections are attached with screw A

Condition B — Assume that Rod B sections are attached with screw B

Will corrosion occur more rapidly with Condition A or Condition B ?

Rods A and B are similar in chemical composition, however, Rod A is claimed to have received a heat treatment, designated "T-6" to make it more resistant to stress corrosion or stress corrosion cracking.

Screw A and Screw B are both 18-8 type austenic stainless steels. Screw A contains a higher percentage of Molybdenum which should increase the "Passivity" of this stainless steel under a wide variety of soil conditions affording less tendency towards galvanic corrosion of the aluminum rod.

THE COLORADO ASSAYING COMPANY
(Incorporated)
ASSAYERS AND CHEMISTS
2244 BROADWAY
OUR MOTTO: "What there is in it, no more, no less."
DENVER, COLO. 80201

August 18, 1978

Bureau of Land Management, D-140 Contract No. C&P Order No. YA530-PH8-655

Part 3 (first part) (page 4)

Give galvanic action comparison in regards to the following three combinations:

A. Copper coated steel rod

B. Aluminum rod - stainless screw combination from Step 2, Condition A (Berntsen)

C. Stainless Steel type 316 rod - bronze Cap combination

A. - The Copper coating is fairly resistant to corrosion. If the copper coating is broken through and the steel rod exposed in soils of acidic or salt conditions, the corrosion rate will be extreme. The two metals are 6 groups apart (out of 17 groups) in the Galvanic series for sea water. The EMF voltages are plus .522 volts for copper to cuprous, plus .345 volts for copper to cupric and minus .44 volts for iron to ferrous, for a difference of .78 to .96 volts to pressure corrosion action. In a basic environment iron is nearly passive and the copper salts formed will deposit on the iron usually as a basic copper carbonate coating which insulates the iron from further corrosion, or retards its corrosion.

B. The 18-8 series of stainless steels are noted for passivity, that is, they do not corrode readily and generally do not cause other metals to corrode. This passivity is most likely due to a trace of oxide coating. The presence of oxygen in soils and in sea water assure passivity.

Unusual conditions that strip away the oxide coating will leave these stainless steels "active" and moderately "Cathodic" to Aluminum and

August 18, 1978

Bureau of Land Management, D-140 Contract No. G.P Order No. YA530-PH8-655

Part 3. (first part) (page 5)

B. the aluminum rod will be subject to galvanic corrosion.

No oxygen, all oxygen consumed, organic compounds and reducing acids present, are conditions that may cause stainless steels to become active.

C. The stainless steel type 316 is rated best or near best for corrosion resistance under most natural conditions, including sea water and should NOT cause galvanic corrosion of the bronze cap.

REFERENCE

Corrosion Resistance of Metals and Alloys - second edition - 1963 an American Chemical Society Monograph No. 158, edited by F. L. LaQue and H. R. Copson is compiled from the results of research and testing of a large number of research reports on the subject of corrosion by many authors. Opinions given in this report are substantiated by these works.

Guides to Testing were obtained from parts of A. S. T. M. standards

A reliable reference guide to Metal Corrosion in soils will be found in two Bureau of Standards publications:

K. H. Logan, Underground Corrosion, USBS circular C 450, 1945

M. Romanoff, Underground Corrosion, USBS circular 579, 1957

THE COLORADO ASSAYING COMPANY

(Incorporated)

ASSAYERS AND CHEMISTS

2244 BROADWAY

"What there is in it, no more, no less."

DENVER, COLO. 80201 August 18, 1978

Bureau of Land Management, D-140 Contract No. GMP Order No. YA530-PH8-655

Part 3. (second part) (page 6)

A. Consider each combination in an acid type soil with a pH of 4.3

B. Consider each combination in an akkaline type soil with a pH of 8.8

C. Consider each combination is salt water.

Which combination would be better in terms of corrosion resistance ?

- - - - - - - - - - -

Soils of any given pH may occur with a very large number ofvarying salts contents and conditions. For these tests the pH 4.3 solution selected contained by weight 1% magnesium sulphate, 1% Ammonium Acetate and Acetic acid to produce the proper pH value.

The pH 8.8 solution chosen contained 1% Magnesium sulphate, 1% sodium bi-carbonate and sufficient sodium carbonate to produce the proper pH value.

A 20% sodium chloride "Salt" solution was used.

Tests were conducted in covered beakers for 73 days or 1/5 year. The corrosion action was accelerated somewhat by holding the temperature to 100 to 110 degrees Farenheit. 100 cc. of solution was used to cover the metal samples. The solutions were changed weekly. The pH was checked every second day and adjusted if needed. the 100 cc volume was maintained. Twice each week, 2nd and 5th day, 10 drops of 3% hydrogen peroxide were added for oxygen replenishment comparing to near surface soil conditions. Solutions were NOT agitated to compare with soil conditions.

Samples were wiped clean and weighed before testing for corrosion. The natural outside oxidized surfaces were not destroyed, while the cut-off ends were aired for two days.

THE COLORADO ... COMPANY

(Incorporated)

ASSAYERS AND CHEMISTS

2244 BROADWAY

"What there is in it, no more, no less."

DENVER, COLO. 80201 August 18, 1978

Bureau of Land Management, D-140 Contract No. C&P Order No. YA530-PH8-655

Part 3. (second part) (page 7)

After the 73 day corrosion period had elapsed, samples were brushed clean with nylon bristle toothbrush, dipped in acetic acid solution as needed, then dried and weighed for loss of weight.

The samples used were "A" (A is from part 3 - first part) copper coated steel rod sections, approximately 5/8 inch diamater by 1 inch long with steel exposed at each end. These tests of "A" show what happens after the copper coating is breached. The copper coating is near 0.050 inch thick.

"B" samples are aluminum rod about 1 inch long, 5/8 inch diamater threaded inside to receive a 3/8 inch stainless steel screw (or stud bolt) 1 1/3 inches long and turned into the aluminum rod 1/2 inch.

"C" samples consist of 2 inch long pieces of 5/8 inch Type 316 Stainless Steel rod and a ring of bronze (cap) about 1/3 inch long and 1 inch O. D. placed around the steel rod.

The "corrosion rates" are expressed in "mpy" or mils per year. One mil equals 0.001 inch.

CORROSION TESTS - RESULTS

	pH 4.3	pH 8.8	20% Salt solution
A Steel	1,293. mpy	10.23 mpy	42.64 mpy
A Copper	1. to 2. mpy	1. mpy	2.-3. mpy (estimated)

Note: The copper dissolved in the pH 8.8 test deposits tightly on the steel surfaces as a greenish basic copper carbonate partially protecting the steel from further corrosion. Where not protected the steel was pitted to a depth of 12 to 15 thousandths inch in the 73 days.

EDMUND E. PHILLIPS, VICE PRES. - GEN. MGR. M. E. PHILLIPS, SECRETARY

THE COLORADO ASSAYING COMPANY

(Incorporated)

ASSAYERS AND CHEMISTS

2244 BROADWAY

OUR MOTTO: — "What there is in it, no more, no less."

DENVER, COLO. 80201 August 18, 1978

Bureau of Land Management, D-140 Contract No. C&P Order No. YA530-PH8-655

Part 3. (second part) (page 8)

CORROSION TESTS - RESULTS cont.

	pH 4.3	pH 8.8	20% Salt Sol.
B. Screw an 18-8 St. St.	0.055 mpy	0.0135 mpy	0.05 mpy

Note: The screw (or stud bolt) portion inside the aluminum rod, in the pH 4.3 solution showed slight pitting of the o.d. threads, probably due to exclusion of oxygen by built-up corrosion products from the aluminum and from the reducing acid, allowing the stainless steel to become "active".

B. Aluminum Rod	(12.35 mpy)	(1.78 mpy)	(7.63 mpy)

Note: The mils per year corrosion rate is meaningless for the aluminum rod. The corrosion was in the form of severe pitting. Pitting was more severe near the ends of the rod pieces and near the steel screw areas.

The rod in pH 4.3 sol. had pits up to 40 and 75 thousandths inch deep per the 73 days - equal to a possible 0.375 inch per year. All of the outer surface was lightly corroded.

The rod in the pH 8.8 sol. had pits in the 0.030 to 0.035 inch depth per the 73 days.
The outside original surface of the rod showed traces of shallow pitting.

The rod in salt solution had pits up to 0.025 inch deep per 73 days. About one-fourth of the original outside surface was corroded away.

C. Type 316 St. St. rod	0.0074 mpy	0.0125 mpy	0.0198 mpy
C. Bronze Ring from Cap	58.74 mpy	0.632 mpy	3.15 mpy

Notes: None of the 316 stainless steel rods showed evidence of pitting during this 73 day test. They probably would eventually.

Corrosion of the Bronze was somewhat uneven, but general.

EDMUND E. PHILLIPS, VICE PRES. - GEN. MGR

H. E. PHILLIPS, SECRETARY

THE COLORADO ASSAYING COMPANY
(Incorporated)
ASSAYERS AND CHEMISTS
2244 BROADWAY
DENVER, COLO. 80201

OUR MOTTO.— "What there is in it, no more, no less."

August 18, 1978

Bureau of Land Management, D-140 Contract No. GEP Order No. YA530-PH8-655

Part 3. (second part) (page 9)

CORROSION RESISTANCE - Summation:

A: pH 4.3 soil condition is rapidly destructive to the copper coated steel rod after the copper cover is breached in any way. The Copper is about 0.050 inch thick and will afford protection for a limited number of years.

The Aluminum rod will be rapidly corroded away, mostly by pitting.

The 316 type stainless steel rod is far more corrosion resistant under these lightly acid soil conditions.

The bronze cap is subject to chemical corrosion if wetted by or submerged/in an acid soil.

B: pH 8.8 soil condition will corrode the copper-steel pin and the aluminum rod at a moderate rate.

The corrosion rate of the type 316 stainless steel rod is extremely low and the bronze cap is corroded at a low rate.

The type 316 stainless steel rod and bronze cap combination is much superior for corrosion resistance under this basic soil condition.

C: Salt In a salt solution, the copper coated steel will be fairly slowly corroded until the copper is breached, then corrosion of the steel is rapid.

The aluminum rod suffers fairly rapid destruction due to severe pitting corrosion.

THE COLORADO ASSAYING COMPANY

(Incorporated)

ASSAYERS AND CHEMISTS

2244 BROADWAY

"What there is in it, no more, no less."

DENVER, COLO. 80201

August 18, 1978

Bureau of Land Management, D-140 Contract No. C&P Order No. YA530-PH8-655

Part 3. (second part) (page 10)

The type 316 stainless steel rod shows a high resistance to salt solution corrosion and is the most corrosion resistant under these conditions. The bronze cap is only moderately resistant to salt corrosion.

Sea water is reported to be less destructive to most metals than a sodium chloride solution.

Type 316 stainless steel is reported to have high resistance to sea water corrosion, however, some pitting will eventually occur.

COMMENT

Soils of pH 4.3 and 8.8 under natural conditions can be reasonably expected to cause metal corrosion at a significantly lower rate than the rates shown by this test series. Soils of pH 4.5 to 8.5 are generaly much less corrosive and aluminum rod should have fairly good resistance to corrosion within this range.

Every variation in soil composition, temperature, moisture content, solution circulation, presence of unusual foreign materials, oxygen levels, etc. contribute to varying corrosion rates. Each different metal, alloy and physical makeup of a metal or alloy may experience different corrosion rates in the same enviriomment.

Respectfully submitted,

THE COLORADO ASSAYING COMPANY

Edmund E. Phillips

IV Standard Galvanized Iron Monument Report

Zinc Coated Alloyed Iron Monument

Field Report from Yuma, Arizona

While running tests for the various rod materials used in Alaska, an interesting side light occurred that was felt worthy of mentioning in this report.

On May 5th, 1978, Mr. Marlin Livermore, and Mr. H. Petersen, Cadastral Survey Department D-130, brought in two standard galvanized monuments for SSD inspection. The two markers had been installed in the Yuma, Arizona desert in 1970. Cap identification was Lot 22, Section 29 of Township 8 South, Range 18 W. These monuments were in deteriorated condition. The zinc coating was almost all gone. Extensive rust covered most of the pipe section of the monuments and extensive pitting and erosion were evident. The brass cap looked fine and all markings could easily be identified.

A pH test was run on a soil sample taken from one monument near the Cap Area. The pH of this soil was pH-9 indicating a strong alkaline type soil condition.

Conclusion: If galvanized iron monuments are used in strong basic type soils, they must be concrete filled. Stainless steel type 316 should also be considered for use in this type soil.

ıII.

- Test Result Summary -

Activity	Stainless Steel Type 316	Aluminum Alloy Currenty Used	Copper Coated Steel Discontinued
Acid Test Colorado Assay	.0074 mpy*	12.35 mpy	copper - 1.5 mpy steel - 1,293 mpy
Alkaline Test Colorado Assay	.0125 mpy	1.78 mpy	copper - 1.0 mpy steel - 10.23 mpy
Salt Test Assay Colorado Assay	.0198 mpy	7.63 mpy	copper - 2.5 mpy steel - 42.6 mpy
Informal BLM Salt Test	No evidence of corrosion	Extensive Pitting	Uniform corrosion of steel
'eight of Material	5/8" Rod - 1.04/ft Sp. G. - 7.8	5/8" Rod - .368/ft Sp. G. - 2.7	5/8" Rod - approx. 1#/ft
** Cost of 5/8" Bar Stock per foot	$1.60/foot Jessop Co. Washington, Pa	$.60/foot Reynolds Aluminum Denver, Colorado	$1.28/foot Crown Metal Wyano, Pa
Melting Points approx.	2650° F Note: Common Bronze melting point approx. - 1800° F	1150° F	copper - 1980° F steel - 2750° F
How to locate Monument	Metal Detector (Magnet should be installed in cap)	Metal Detector (magnet reqd. in cap)	Metal Detector only

*mpy - mils per year corrsion rate. (one mil equals 0.001 inch)
** Cost does not include screws or machining operations.

Reference Material
Statements

Reference Material:

During the course of this study, SSD found interesting information in a textbook for metal uses entitled "Engineering Metallurgy" written by Dr. Bradley Stoughton, Ph. B., B.S., D. Eng., Former Dean of Engineering, Lehigh University; Mr. Allison Butts, A.B., S.B., Head Department of Metallurgical Engineering, Lehigh University; and Mr. Ardrey Bounds, B.S., M.S., Chief Metallurgist, Superior Tube Company.

Reference to Aluminum, Page 284.

> "The resistance of aluminum to weathering or corrosion is due to the protective action of the superficial film of oxide (Al_2O_3) which forms and prevents the action from penetrating deeper and progressing into the metal. A film so thin as to be invisible is sufficient to arrest further oxidation under ordinary conditions. In the presence of chlorine or salt water, however, the film may be broken down and corrosion may result."

Reference to Stainless Steel, Page 237.

> "The outstanding characteristic of the stainless steels is their ability to form an oxide film, usually invisible, which acts as a

constant protection against further corrosion of the underlying metal. .... In contrast to the films on ordinary steel, the film is quite stable, extremely tough and continuous, and very adherent. If this film, basically composed of chromium oxide, is broken by scratching, abrasion, or chemical action, it re-forms quickly and continues its protective action."

VI. Conclusions:

This study has concentrated primarily on three materials. Aluminum alloy currently being used, copper coated steel rod that has been discontinued, and stainless steel Type 316 which is a new material to be considered for use. In this brief study, the following conclusions have been reached:

1. Aluminum Alloy - 6063 - T6

   The current aluminum alloy monument being used is a good monument; however, there are some disadvantages with using this marker.

   A. The marker will not last well in salt environments or possibly strong acid soils.

   B. The marker has a low melting point - approximately 1150° F.

   C. The marker should not be used in any soils containing copper.

   D. If the Alaskan Copy Center manufactured cap is used, it should have a small air relief hole drilled into the cap sleeve.

   E. The aluminum rod bends easily.

2. Copper Coated Steel Rod (Copperweld)

- Discontinued Monument -

Laboratory tests showed that this material does not hold up well in salt environments or acid environments. It should be further pointed out that the National Geodetic Survey has discontinued the use of this monument. On the other hand, all surveying personnel contacted seemed to like the material and had not witnessed any problems with the monument. The U.S. Geological Survey still uses the copperweld rod.

3. Stainless Steel Type 316 - A new material being considered for use.

This material is believed to be superior to both aluminum and copperweld in resisting corrosion. S.S. 316 is protected over a wider pH range and can be used over a wide range of temperatures. "These alloys are highly resistant to many acids, including hot and cold nitric acid. They have excellent toughness at temperatures as low as liquid helium (- 452)° F. and are useful for parts subjected to severe stress at elevated temperatures."

Reference: Mark's Handbook for Mechanical Engineers, Seventh Edition. Stainless Steel Type 316 would be stronger than the aluminum rods and would resist bending better. The attachment screws could be the same metal as the rod sections and eliminate dissimilar materials. For this reason the drive point currently being used with the aluminum rod could be eliminated. The first rod section could have only a sharpened point. Although the cold rolled bar is slightly magnetic, the permanent magnet 1/4" x 1/2" currently being used with the aluminum cap, should be continued.

The following disadvantages are mentioned:

1. If the standard brass cap* is used, there would be dissimilar materials where the cap is attached to the rod. Since brass and bronze are high in copper content, reference is given to the attached report prepared by the Bureau of Standards. The coupling of stainless steel to brass or bronze is not expected to present a problem.

2. Stainless Steel Type 316 is heavier than aluminum.

	Specific Gravity	Weight lbs/ft^3	Weight of 5/8" Rod per linear foot
Aluminum	2.7	165	0.368 lbs
Stainless Steel	7.8	489	1.04 lbs

* The cap submitted for testing was supplied by the Alaskan State Office. Colorado Assay refers to this cap as bronze; however, BLM refers to it as brass. Both bronze and brass are high copper alloys.

3. Stainless Steel Type 316 is more expensive than aluminum or copper coated steel.

Aluminum 5/8" Bar Stock - $0.60 per foot.

Copperweld 5/8" Bar Stock - $1.28 per foot.

S.S. - 316 5/8" Bar Stock - $1.60 per foot.

Recommendations:

The aluminum rod monument currently being used is a good material for resisting corrosion and has added advantages of light weight and low cost. In spite of these conditions, however, SSD recommends replacing the monument with a new Type 316 stainless steel material. This alloy has better corrosion resistant properties than aluminum and remains within an economical price range. The rod diameter and length should remain the same as currently used. The proposed rod sections should be attached by screws of the same material (SS - 316) and the drive point presently being used could be eliminated. Although a stainless steel Type 316 cap would be preferred, the standard brass rod cap could be used satisfactorily. Ref: Bureau of Standards report concerning stainless steel coupled with high copper alloys, Pages 61 - 65. Rod caps should be designed so that pressure is relieved from the cavity above the rod, when the cap is driven into position. A small hole drilled

into the cap sleeve near the cap flange would satisfy this requirement. The cap locating magnet should continue to be used.

It is believed that the increased life afforded by the proposed monument should justify the added weight and cost.

In conclusion, S.S.D. feels that monumentation study should be a continuing effort. BLM should continue to search for better materials to upgrade and improve Cadastral Survey monuments.

The Galvanic Coupling of Some Stainless Steels to Copper — Underground*

E. ESCALANTE and W. F. GERHOLD
National Bureau of Standards, Washington, D. C.

On site underground tests at 6 widely differing sites were made of 26Cr-6.5Ni, Type 304 (18Cr-8Ni) and Type 409 (less than 11 Cr ferritic) coupled to commercially pure copper. Galvanic current tests were made over 3 to 4 years and retrieved specimens were examined in the laboratory. When exposure conditions made Cu anodic to the stainless, local corrosion was minimized. Pitting occurred on some stainless specimens at some sites. Type 409 pitted more than other alloys and copper was cathodically protected by stainless in some cases. Chloride-containing, poorly aerated soils (400-15,500 ohm cm) in a tidal marsh caused greatest attack. Cu lost 3 mils and pits formed were 1 to 5 mils deep; 409 perforated and lost 30% weight at one site and other alloys at the site pitted to less than 30 mils. Data indicate no increase in attack on stainless steels coupled to Cu over that on uncoupled specimens in same environments.

LABORATORY STUDIES have indicated that, in general, the galvanic coupling of stainless steel to copper is not detrimental to the stainless steel.[1] Since underground applications for stainless steel are increasing, questions about its durability when coupled copper soil have been raised. This paper is primarily concerned w the effects on the underground corrosion of three types of stainl steels when galvanically coupled to copper.

*Presented during Corrosion/75, April 14-18, 1975, Toronto, Ontario, Canada.

Materials

The three types of stainless steels, used in the anneal condition, chosen for this study are listed in Table 1. T 26Cr-6.5Ni alloy is a two phase stainless steel—ferrite plus austeni Type 304 austenitic stainless steel is a more conventional 18Cr-9 alloy with many industrial and household applications. Type 40 a single phase ferritic alloy with a chromium content of less th 11%.

Commercially pure copper in the as-rolled condition was us for making the galvanic couples.

Soils

The six test sites chosen for this study were representative soils found throughout the United States, and are listed in Table A brief description of the sites follows:

- Site A — A semi-arid region located in the northwestern p of the United States. The soil is alkaline, of volcanic ash origin, a normally has a high resistivity. The resistivity value listed in Table

Reprinted from MATERIALS PERFORMANCE, Vol. 14, No. 10, pp. 16-20 (1975) October

Stainless Steel	Major Elements, % Cr	Ni	C	Mn	Ti	Fe
26Cr-6.5Ni Alloy	26.5	6.2	0.015	0.49	–	bal.
Type 304	18.2	9.8	0.048	1.5	–	bal.
Type 409	10.75	0.81	0.058	0.47	0.60	bal.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
C	Clay	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
D	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
E	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
G	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.1

[illegible]

was measured in water-saturated soil, leading to an abnormally low reading.

- Site B — Located in the eastern part of the United States. The soil is a well aerated acid loam which supports an abundant growth of vegetation.
- Site C — A large clay pit on level ground. The soil is a poorly aerated, acid clay, located about 100 meters from the ocean. The resistivity at this site is low throughout the year.
- Site D — Located a few hundred meters from the ocean. The soil is composed of a well aerated, acid sand whose resistivity is the highest of all the sites.
- Site E — Located about 60 meters from the ocean. The sand in this site is of neutral pH and is under water only during abnormally high tides.
- Site G — Located beside the mouth of a stream leading into the Chesapeake Bay. The land is a poorly aerated, acid tidal marsh where the characteristic odor of hydrogen sulfide can often be detected when the soil is disturbed.

Experimental Procedure

Specimen Preparation

Stainless steel specimens sheared from 1.6 mm sheet were supplied by several companies. Those specimens to be galvanically coupled to copper were cut to 2.5 cm by 30.5 cm strips, whereas those that were to serve as noncoupled controls were provided in 20.3 cm by 30.5 cm panels. Insulated 14 gauge (2 mm diameter) stranded copper wire was soldered through a 0.2 cm hole near one end of the strip specimen. The joint was then coated with coal tar epoxy. The stainless steel panels had no provision for electrical contact, since they were used as noncoupled controls for weight loss analysis. These panels were weighed to within 2 milligrams before and after burial. Surface preparation of the stainless steel consisted of degreasing in trichloroethylene vapor, then passivating in 30% by volume concentrated (67%) nitric acid at 60 C for 25 minutes. This was followed by rinsing in water and air drying.

Copper sheet 1.6 cm in thickness was sheared to 2.5 cm by 30.5 cm strips for the couples, making the area ratio 1:1. Insulated 14 gauge wire was soldered to the copper at a point midway between the ends of the specimen. Again, as at all contact joints, the area was coated with coal tar epoxy.

Exposure

Four specimens of each couple and control system were buried at every test site about 30 cm apart in trenches approximately 0.8 m deep and 0.6 m wide. The strip specimens and their corresponding copper electrodes were placed parallel to the trench, approximately 30 cm apart, with the electrical leads extending above ground. After backfilling, the electrical leads were connected to terminal strips on a post where corresponding couples were electrically connected together.

Electrical Measurements

Galvanic current and couple potential (versus Cu-$CuSO_4$) determinations were made using a solid state zero impedance circuit illustrated in *Figure 1* for the current measurements and a high impedance (10^{14} ohm) precision potentiometer for voltage measurements. The half cell was placed in a remote area (approximately 15 m away) and shielded from light to minimize photo-potential effects.

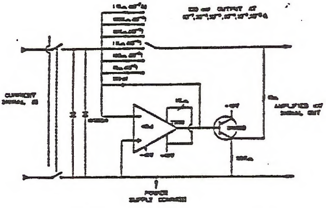


FIGURE 1 — Zero impedance current amplifier.

Data were gathered at each site at regular intervals with the initial measurements made within 48 hours of burial. Except for Site A, successive determinations were made at 4 month intervals for the first 2 years, and then once or twice a year thereafter as time permitted. At Site A, measurements were usually made once a year. Soil resistivities were also determined regularly at the sites using a 4-pin Wenner bridge,[2] with the exception of Site A where a Shepard cane[3] was used.

Examination

At the end of the exposure period, the specimens were excavated and returned to the laboratory where they were cleaned with tap water and visually examined in order to observe any significant effects that might be obliterated by the final cleaning process. This last treatment consisted of ultrasonically cleaning the stainless steel in a 10% nitric acid bath at 50 C for 30 minutes, followed by rinsing in water and air drying. The stainless steel specimens were then visually examined thoroughly. The control specimens were weighed to determine weight loss.

Results and Discussion

In order to develop a better understanding of the effect of galvanically coupling copper to stainless steel, the results will be presented in three parts. The first part will describe the results on the noncoupled panels. This will be followed by a section on the effect of the copper on the stainless steel strips as compared to the noncoupled panels. Finally, the observed effects on the galvanically coupled copper will be discussed.

Noncoupled Stainless Specimens

Because corrosion of the stainless steel sheet was generally not uniform over the surface, it is difficult to describe with one measurable quantity. Therefore, measured terms such as electrochemical data, weight loss, and depth of attack are tabulated along with pertinent visual observations. In addition, photographs of the specimens are included for more complete characterization.

The weight loss determinations and visual observations for the noncoupled stainless steel panels are listed in Table 3. The most severely attacked panels from each system and site are shown in Figure 2. From these, it is clear that the 26Cr-6.5Ni stainless steel

System	Stainless Steel	Observation	Site A Washington	Site B Loch Raven	Site C Cape May	Site D Wildwood (Dry Sand)	Site E Wildwood (Dry Sand)	Site G Patuxent
10(1)	26Cr-6.5Ni Alloy	wt loss(3) (mdd)	0.001	0.000	0.010	<0.001	0.100	0.002
		visual(4)	etched (<1 mil)	no attack	pitted (25 mil) edge (70 mil)	etched (<1 mil)	perforated	pitted (5 mil)
55(2)	Type 304	wt loss(3) (mdd)	0.000	0.000	0.237	<0.001	0.254	0.018
		visual(4)	no attack	no attack	edge tunneling gen. corrosion	scattered etching (<1 mil)	severe edge tunneling	pitted (22 mil)
60(2)	Type 409	wt loss(3) (mdd)	0.007	0.001	0.567	0.102	0.303	1.288
		visual(4)	perforated	pitted (5 mil)	perforated, gen. corrosion	perforated	perforated, tunneling	perforated, gen. corrosion

(1) Three year exposure.
(2) Four year exposure.
(3) Average of four specimens per system at each site.
(4) 1 mil = 0.025 mm.

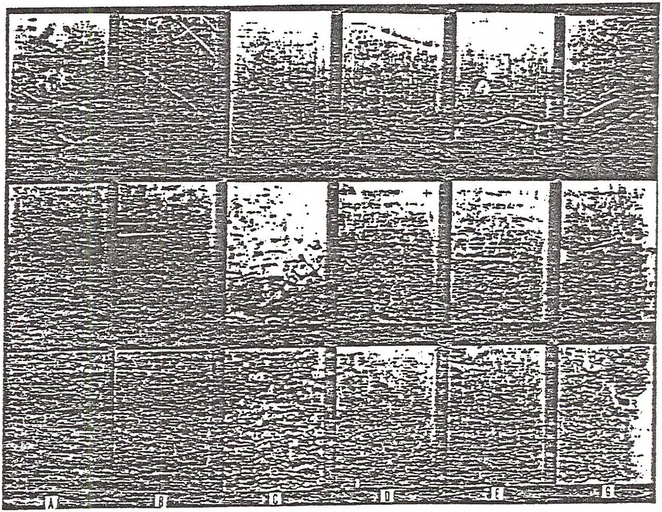


FIGURE 2 — Noncoupled stainless steel control panels. Top: 26Cr-6.5Ni alloy, 3 year exposure; middle: Type 304, 4 year exposure; and bottom: Type 409, 4 year exposure. Sites: A, B, C, D, E, and G.

System	Stainless Steel	Observation	Site A Washington mA (V)	Site B Loch Raven mA (V)	Site C Cape May mA (V)	Site D Wildwood (Dry Sand) mA (V)	Site E Wildwood (Wet Sand) mA (V)	Site G Patuxent mA (V)
42(3)	26Cr-6.5Ni Alloy	electrochemical(5)	-0.0002 (-0.111)	-0.004 (-0.004)	+0.005 (-0.148)	+0.004 (-0.138)	-0.120 (-0.021)	-0.004 (-0.427)
		visual(6)	no attack	no attack	few pits (3 mil)	edge pits (1 mil)	corrosion under solder	few pits (7 mil)
91(4)	Type 304	electrochemical(5)	-0.0001 (-0.081)	-0.027 (+0.001)	-0.010 (-0.120)	+0.003 (-0.163)	-0.018 (-0.101)	+0.017 (-0.443)
		visual(6)	no attack	no attack	scattered etching	scattered etching	no attack	pitted (30 mil)
92(4)	Type 409	electrochemical(5)	+0.002 (-0.059)	-0.022 (-0.007)	+0.046 (-0.258)	+0.003 (-0.147)	+0.013 (-0.158)	+0.158 (-0.497)
		visual(6)	one edge pit (22 mil)	no attack	perforated (10% wt loss)(7,8)	pitted (2 mil)	perforated (5% wt loss)(7,8)	perforated (30% wt loss)(8)

(1) Negative current indicates stainless steel is cathode.
(2) Potential vs Cu-$CuSO_4$.
(3) Three year exposure.
(4) Four year exposure.
(5) Four specimens per system at each site—average of minimum of 20 readings.
(6) 1 mil = 0.025 mm.
(7) One specimen lost.
(8) Approximate weight loss based on visual observation. All other specimens in Table < 2% weight loss maximum.

alloy suffered little corrosion during the 3 year exposure. It is also apparent that Types 304 and 409 underwent considerable damage in 4 years at Sites C, E, and G located near the ocean. The damage on Type 304 at Site E is not readily visible in Figure 2. However, edge tunneling extends into the sheet for 5 or 6 cm. Stainless steel Type 409 was perforated at every site with the exception of Site B (a well aerated loam), where 0.1 mm (5 mil) pits developed.

Coupled Stainless Specimens

The results on the stainless steel strips galvanically connected to copper are listed in Table 4. Figure 3 displays the most severely damaged stainless steel strips from each system and site. Analysis of the electrochemical potential data of the couple discloses that potential by itself is a poor indicator of the state of the corrosion action. Soil characteristics such as the degree of aeration, chemical constituents, resistivity, etc. can vary so much from one location to another that the nature of the reactions which affect the potential are drastically modified.[4] The galvanic current, however, denotes the rate of oxidation or reduction taking place at the electrodes. In Table 4, a *negative* current indicates that, on the average, stainless steel was cathodic to copper, and thus, receiving some electrochemical protection. The magnitude of the current gives a measure of the degree of protection or deterioration that can be expected. In addition to the chemical reaction on the surface of the electrodes brought about by the galvanic coupling, secondary reactions not directly related to the couple are also taking place. These are the results of local cells that can form on an individual electrode. In some instances, these local cell reactions are the cause of a large fraction of the observed corrosion. However, if the galvanic couple impresses a sufficiently large current density, then, these local cells can be overridden, as is normally the case with cathodic protection.

From Table 4 it is evident that where the current is negative, little or no attack occurred on the stainless steel. With a positive current, some form of corrosion took place. The only notable exception is the 26Cr-6.5Ni alloy at Site E where the average current was negative. In this case, the stainless steel did pit under the solder. This corrosion under the solder suggests that the contact was poor, resulting in an inaccurate current determination for that specimen. Of the coupled stainless specimens, the 26Cr-6.5Ni alloy Type 304 developed less corrosion than the Type 409. This can be seen in Figure 3. The effect of copper on corrosion of the stainless steel was small. There was no clear indication that the coppe adversely affected the stainless steel in any case. However, there evidence that the copper protected the stainless steel in a fe instances. For example, the uncoupled Type 304 stainless ste panel underwent deep edge tunneling attack at Sites C and E whic was not observed on the same material when coupled to coppe Similarly, Type 409 control panels developed pits at Site B whic were not found on the strips coupled to copper. These effects ca be confirmed by comparing Tables 3 and 4.

Coupled Copper Specimens

The visual observations noted on the copper electrodes a listed in Table 5. From Table 4, it was observed that as the potenti of the galvanic couple becomes more noble (more positive corrosion of the copper increased. The galvanic couple potentials Site B were around zero and caused the most corrosion seen on t copper. In all cases, corrosion on the copper was low and estimated to be less than 1% loss in weight in the worst instanc The observed corrosion for the copper was the lowest in those cas where the couple potential was most negative.[5] In these situatior the copper was often cathodically protected by the stainless ste The corrosion of copper when connected to stainless steel was lea at Site G.

Summary and Conclusions

The effect on corrosion of galvanically coupling copper 26Cr-6.5Ni alloy, Type 304, and Type 409 stainless steel was sma There was no observable increase in corrosion of the coupl stainless steel compared to the same material uncoupled at any the 6 sites after 3 or 4 year exposure. In fact, the evidence is that some instances, copper protected the stainless steel. In general, t highest deterioration of the stainless steel was observed at Sites C, and G which are chloride-containing soils. In addition, Sites C and are poorly aerated. The corrosion effects of the coupled copp were minimal, but increased as its potential became more noble.

Acknowledgment

The authors are grateful for the cooperation and financ support of the American Iron and Steel Institute, and Committee of Stainless Steel Producers.

Special thanks are extended to Mr. R. J. Carpenter, Chief of

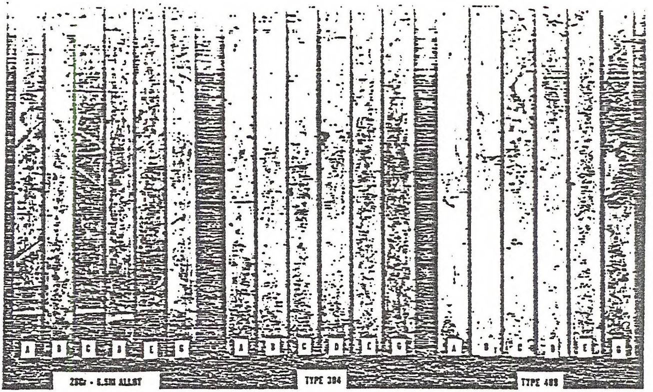


FIGURE 3 — Coupled stainless steel strips. 25Cr-6.5Ni alloy—3 year exposure. Types 304 and 409—4-year exposure.

TABLE 5 — Visual Results[1] of Copper Connected to Stainless Steel

System	Material	Site A Washington	Site B Loch Raven	Site C Cape May	Site D Wildwood (Dry Sand)	Site E Wildwood (Wet Sand)	Site G Patuxent
42[2]	Copper (connected to 25Cr-6.5Ni Alloy)	slight cluster etching (<1 mil)	pitted (5 mil)	gen. corrosion (3 mil)	gen. corrosion (2 mil)	gen. corrosion (2 mil)	etched (<1 mil)
91[3]	Copper (connected to SS Type 304)	etched & few pits (2 mil)	pitted (5 mil)	gen. corrosion (2 mil)	gen. corrosion (3 mil)	gen. corrosion (1 mil)	etched (<1 mil)
92[3]	Copper (connected to SS Type 409)	etched (<1 mil)	pitted (5 mil)	gen. corrosion (2 mil)	gen. corrosion (2 mil)	gen. corrosion (1 mil)	etched (<1 mil)

(1) 1 mil = 0.025 mm.
(2) Three year exposure.
(3) Four year exposure.

Electronics Instrumentation Section, NBS, for his design of the current amplifier, and to members of the Corrosion and Electrodeposition Section, specifically Dr. W. P. Iverson and Mr. W. J. Schwerdtfeger for their helpful discussions and assistance, and Mr. B. T. Sanderson and Mr. J. L. Fink who have helped gather data at various phases in the program.

References

1. Paul, G. T., Moran, J. J. Corrosion Resistance of Metals and Alloys, LaQue, F. L., Copson, H. R., ed., p. 385, Reinhold Publishing Corp., New York (1963).
2. Wenner, F. A Method of Measuring Earth Resistivity, Natl. Bur. Standards, U.S., Bull. No. 12, p. 469 (1915-1916).
3. Shepard, E. R. Natl. Bur. Stand. J. Res., Vol. 6, No. 4, p. 683 (1931).
4. Baboian, R., Haynes, G. S. Galvanic Corrosion of Ferritic Stainless Steels in Sea Water, ASTM STP 559, p. 171-184 (1974).
5. Schwerdtfeger, W. J. IEE, Trans. on Ind. and Gen. Appl., Vol. IGA-3, No. 1, p. 66 (1967).

BLM Library
D-553A, Building 50
Denver Federal Center
P. O. Box 25047
Denver, CO 80225-0047