[redacted]

CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION

This document contains 107 pages
This is 16 of 81 copies
Document No. C-3.210.1 Series A

This [redacted] affecting the Na- [redacted] of the Espionage Act, U. S. C. 30, 31, and 32. Its [redacted] to an unauthorized person is prohibited by law.

CLINTON ENGINEER WORKS
TENNESSEE EASTMAN CORPORATION

Contract No. W-7401-eng-23

DECLASSIFIED

CLASSIFICATION CHANGED TO:
BY AUTHORITY OF: Jid 1160
BY: B R Green 1-30-58

# CORROSION AND SOLVENT RESISTANCE OF METALS AND MATERIALS

## ABSTRACTS AND INDEX

August 10, 1945

[redacted]

# CORROSION AND SOLVENT RESISTANCE OF METALS AND MATERIALS

## Preface

In order to simplify the use of the material contained in this report, it has been broken down into four sections; namely, (1) Table of Contents, (2) Abstracts, (3) Appendix A, (4) Index.

The material in the table of contents is grouped and classified according to the type of corrosive medium. The index, on the other hand, is grouped and classified with respect to the type of constructional material (this includes metals, alloys, silicone grease, refractory materials etc.).

All information which has been found in the literature is, consequently, crossed indexed in both the table of contents and the index.

The table of contents gives, specifically, media, materials used, report number and page number of the abstract.

TABLE OF CONTENTS (pages 1 to 15, incl.)

The table of contents is sub-divided into 13 main sections, designated by Roman numerals, and the sub-sections are designated by capital letters. The classification of the 13 sections is as follows:

I Acid, Hydrochloric
II Acid, Hydrofluoric
III Acid, Malonic
IV Acid, Nitric
V Acid, Oxalic
VI Acid, Sulfuric
VII Solid, Tuballoy Tetrabromide
VIII Chlorine, or Chlorine Containing Compounds
IX Fluorides Containing Compounds of Tuballoy
X Gunks
XI Oxides of Tuballoy
XII Hydrogen Peroxide and Mixtures thereof
XIII Miscellaneous

ABSTRACT (pages 16 to 89, incl.)

The abstracts follow the table of contents and contain all the essential data given in the original reports, such as: duration of test, temperature, conditions (vacuum, agitation, aeration, etc.), methods used in the test and the results obtained. Preceding each abstract, the report number, file number (technical library), author and date of publication are given.

APPENDIX

In order to keep these abstracts up to date, it will be necessary to prepare appendices as new test reports become available. These appendices will generally follow the same form that is used herein with the exception that a complete material index will be included with each appendix.

Appendix A, the first of such appendices, has already been prepared and is included herein (see pages 90 to 101, incl.).

INDEX (pages 102 to 107, incl.)

The last section, the index, contains an alphabetical list of constructual materials and the page reference to the abstract.

[redacted]

This document contains 107 pages
This is 16 of 81 copies
Document No. C-3.210.1 Series A

CLINTON ENGINEER WORKS
TENNESSEE EASTMAN CORPORATION

Contract No. W-7401-eng-23

# CORROSION AND SOLVENT RESISTANCE OF METALS AND MATERIALS

## Introduction

The information contained in this report has been abstracted from all the reports available on the area. Some of these reports were not written in too much detail, therefore the excerpt may be of no value; but no attempt was made to exclude any report and all reports are thus included. The reports are located in the T.E.C. Technical Records Library or the U.S.E.D. file. Appendix A is included in this report on page 90.

## Purpose

The purpose of this report is to provide an index of the corrosion data of tests that have been done in connection with this project. Appendices will follow each month in order to bring this report up to date.

## I. Hydrochloric Acid

| | Report No. | Page No. |
|---|---|---|
| A. 1% HCl | | |
| Antaciron | Chem S-331 | 16 |
| Durichlor | " | |
| Duriron | " | |
| Everdur | " | |

[redacted]

| | Report No. | Page No. |
|---|---|---|
| Hastelloy B & C | Chem S-331 | 16 |
| Illium G & R | " | |
| Inconel | " | |
| Monel | " | |
| Nickel | " | |
| Stainless Steel (type 304) | " | |
| 310 | " | |
| 316 | " | |
| Cb 316 | " | |
| 317 | " | |
| 329 | " | |
| 347 | " | |
| 446 | " | |
| Worthite | " | |

B. 5% HCl

| | | |
|---|---|---|
| Silicone Grease | CD-GS-29 | 23 |

C. 13.6% HCl (4 N)

| | | |
|---|---|---|
| Hastelloy B & C | Chem S-48 | 24 |
| Inconel | " | |
| Kovar | " | |
| Mallory 53 | " | |
| Nickel | " | |
| Ni-Resist | Chem S-183 | 29 |
| Stainless Steel | Chem S-48 | 24 |
| Tantalum | " | |

D. 30.0% HCl

| | | |
|---|---|---|
| Asplit | Chem S-31 | 30 |
| Duro | " | |
| Saran | " | |
| Tantalum | " | |

E. Concentrated HCl

| | | |
|---|---|---|
| Silicone Grease | CD-GS-29 | 23 |

F. 0.1% HCl, 2% $HNO_3$

| | | |
|---|---|---|
| Same as "A" | Chem S-331 | 16 |

G. ½% HCl, ½% $H_2O_2$

| | | |
|---|---|---|
| Ni-Resist | Chem S-183 | 29 |

| | Report No. | Page No. |
|---|---|---|
| H. 2% HCl, 2% $HNO_3$ | | |
| du Pont D-29 | CD-GS-20 | 30 |
| Koroseal | " | |
| Silastic-Dow | " | |
| Tygon TIJ-103 | " | |
| Tygon TU-2807 | " | |
| Tygon TU-3400 | " | |
| I. 2% HCl, ½% $H_2O_2$ | | |
| Copper | Chem S-138 | 32 |
| Nickel | " | |
| Ni-Resist | Chem S-183 | 29 |
| Stainless Steel (Type 302) | Chem S-138 | 32 |
| J. 2% HCl, 2% $H_2O_2$ | | |
| Same as "H" | CD-GS-20 | 30 |
| K. Concentrated HCl, 27% $H_2O_2$, Gunk (1:1:4) | | |
| Hastelloy C | X.L.4.9.802 | 32 |
| Lead | " | |
| Silver | " | |

## II. Hydrofluoric Acid

| | | |
|---|---|---|
| A. 6% HF | | |
| Silicone Grease | CD-GS-29 | 23 |

## III. Malonic Acid

| | | |
|---|---|---|
| A. 50% Malonic Acid | | |
| Copper | CDC-53 | 34 |
| Steel (cold rolled) | " | |
| Steel (hot rolled) | " | |
| Stainless Steel (Type 316) | " | |

[redacted]

## IV. Nitric Acid

| | Report No. | Page No. |
|---|---|---|
| A. 2% $HNO_3$ | | |
| Same as I-A | Chem S-331 | 16 |
| B. 2.09% $HNO_3$ (Beta Wash Solution) | | |
| Copper | Beta 52 | 35 |
| Silver | " | |
| C. 4.18% $HNO_3$ (Beta Wash Solution) | | |
| Same as B | Beta 52 | 35 |
| D. 5% $HNO_3$ | | |
| Same as B | Beta 52 | 35 |
| E. 10% $HNO_3$ | | |
| Silicone Grease | CD-GS-29 | 23 |
| F. 12% $HNO_3$ (2N) | | |
| Aluminum | Chem S-48 | 24 |
| Enamelled Iron | Chem S-89 | 37 |
| Gold | " | |
| Hastelloy B & C | Chem S-48 | 24 |
| Inconel | " | |
| Kovar | " | |
| Mallory 53 | " | |
| Manganese Steel | Chem S-92 | 38 |
| Nickel | Chem S-48 | 24 |
| Stainless Steel | " | |
| Stainless Steel (type 310) | Chem S-92 | 38 |
| 316 | " | |
| 317 | " | |
| 321 | " | |
| 329 | " | |
| 347 | " | |
| Tantalum | Chem S-48 | 24 |
| G. 70% $HNO_3$ | | |
| Silicone Grease | CD-GS-29 | 23 |

[redacted]

| | Report No. | Page No. |
|---|---|---|
| H. 2% $HNO_3$, 0.1% HCl | | |
| Same as I-A | Chem S-331 | 16 |
| I. 2% $HNO_3$, 2% HCl | | |
| Same as I-H | CD-GS-20 | 30 |
| J. 5% $HNO_3$, 0.1% $TCl_4$ | | |
| Stainless Steel (type 302) | Chem S-137 | 40 |
| K. 5% $HNO_3$, 1% $TCl_4$ | | |
| Stainless Steel (type 302) | Chem S-137 | 40 |
| L. 12.6% $HNO_3$ (2N), 0.076% $TCl_4$ (2M) | | |
| Aluminum | Chem S-48 | 24 |
| M. 67% $HNO_3$, 0.1% $TCl_4$ | | |
| Stainless Steel (type 302) | Chem S-137 | 40 |
| N. 67% $HNO_3$, 1% $TCl_4$ | | |
| Stainless Steel (type 302) | Chem S-137 | 40 |

## V. Oxalic Acid

| | | |
|---|---|---|
| A. 9% Oxalic Acid | | |
| Stainless Steel (type 308) 316 | XL 4.9.802 " | 32 |

## VI. Sulfuric Acid

| | | |
|---|---|---|
| A. 5% $H_2SO_4$ | | |
| Silicone Grease | CD-GS-29 | 23 |

[redacted]

| | Report No. | Page No. |
|---|---|---|
| B. Concentrated $H_2SO_4$ | | |
| Silicone Grease | CD-GS-29 | 23 |
| C. $H_2SO_4$ (Dil), $H_2O_2$ (Dil), water | | |
| Tuballoy Alloys | A-3000 | 41 |
| D. 10% $H_2SO_4$, 1% $TiCl_4$ | | |
| Stainless Steel (type 302) | Chem S-137 | 40 |

## VII. Bromides

| | Report No. | Page No. |
|---|---|---|
| A. Tuballoy Tetrabromide | | |
| Aluminum | Chem S-4 | 44 |
| Beryllium | " | |
| Copper | " | |
| Glass | " | |
| Gold | " | |
| Iron | " | |
| Molybdenum | " | |
| Monel | " | |
| Nichrome | " | |
| Nickel | " | |
| Platinum | " | |
| Silver | " | |
| Stainless Steel | " | |
| Tungsten | " | |

## VIII. Chlorine and Chlorine Compounds

| | Report No. | Page No. |
|---|---|---|
| A. Chlorine | | |
| Chrcmel "A" | Chem S-244 | 45 |
| Columbium | " | |
| Commercial 150, 180, 190, & 200 | " | |
| Discalloy | " | |
| Gold | " | |
| Hastelloy, B & C | " | |
| Inconel | " | |
| K-42-B | " | |
| Molybdenum | " | |

[redacted]

[redacted]

| | Report No. | Page No. |
|---|---|---|
| Monel | Chem S-244 | 45 |
| Nichrome | " | |
| Nickel | " | |
| Platinum | " | |
| Refractory (Porcelain) | " | |
| Stainless Steel (type 302) | " | |
| Tantalum | " | |
| B. 5% $Cl_2$, $TCl_5$, $RO_3$, $CCl_4$ | | |
| Stainless Steel (type 304) 316 | Chem S-527 | 46 |
| C. Chlorine and Steam | | |
| Aluminum | X L 4.9.802 | 32 |
| Brass | " | |
| Copper | " | |
| D-29 | " | |
| Duriron | " | |
| Hastelloy A, B, & C | " | |
| Haveg | " | |
| Inconel | " | |
| Lead | " | |
| Monel | " | |
| Nickel | " | |
| Saran | " | |
| Silver | " | |
| Steel (mild) | " | |
| Stainless Steel (type 302) | " | |
| Stainless Steel 18-8 | " | |
| Tantalum | " | |
| Tygon | " | |
| D. Chlorine, Steam and Gunk | | |
| Hastelloy C | X L 4.9.802 | 32 |
| Lead | " | |
| Silver | " | |
| E. $CaCl_2$, NaCl and $TCl_4$ | | |
| Chromel "A" | BT-11 | 47 |
| Stainless Steel 18-8 | " | |
| F. NaCl and $TCl_4$ | | |
| Stainless Steel 18-8 | BT-11 | 47 |
| G. NaCl, NaF, $TF_4$ | | |
| Stainless Steel 18-8 | BT-11 | 47 |

[redacted]

| | Report No. | Page No. |
|---|---|---|
| H. $S_2Cl_2$ | | |
| Chromel "A" | BT-11 | 47 |
| Nickel | " | |
| Stainless Steel 18-8 | " | |
| I. $TCl_4$ | | |
| Aluminum | Chem S-4 | 44 |
| | Chem S-48 | 24 |
| | Chem S-92 | 38 |
| Alundum | Chem S-4 | 44 |
| Beryllium | Chem S-48 | 24 |
| BeO | Chem S-4 | 44 |
| Chromel wire | Chem S-165 | 48 |
| Copper | Chem S-4 | 44 |
| | Chem S-144 | 49 |
| | Chem S-508 | 50 |
| | R.L.4.6.297 | 50 |
| Copper (plated) | Chem S-48 | 24 |
| | Chem S-90 | 29 |
| | Chem S-101 | 51 |
| | Chem S-122 | 52 |
| | Chem S-225 | 53 |
| Everdur | Chem S-92 | 38 |
| | Chem S-101 | 51 |
| Gold | Chem S-4 | 44 |
| | Chem S-89 | 37 |
| | Chem S-144 | 49 |
| Graphite | Chem S-4 | 44 |
| Hastelloy, B & C | Chem S-144 | 49 |
| Hastelloy C | CD-F-10 | 54 |
| | JRC-18 (ML 43) | 56 |
| Herculoy | Chem S-101 | 51 |
| Inconel | Chem S-144 | 49 |
| | R.L.4.6.289 | 57 |
| Iron | Chem S-4 | 44 |
| Iron (Enamelled) | Chem S-89 | 37 |
| Lead | Chem S-176 | 59 |
| Molybdenum | Chem S-4 | 44 |
| | Chem S-144 | 49 |
| Monel | Chem S-4 | 44 |
| | Chem S-508 | 50 |
| | R.L.4.6.297 | 50 |
| Monel "K" | R.L.4.6.289 | 57 |
| Nichrome | Chem S-4 | 44 |
| | R.L.4.6.289 | 57 |
| Nickel | Chem S-4 | 44 |
| | Chem S-144 | 49 |
| | Chem S-225 | 53 |
| | Chem S-508 | 50 |
| | R.L.4.6.289 | 57 |
| | A-3190 | 59 |

[redacted]



| | | Report No. | Page No. |
|---|---|---|---|
| Ni-Resistant | | Chem S-101 | 51 |
| | | Chem S-183 | 29 |
| Platinum | | Chem S-4 | 44 |
| Quartz | | Chem S-4 | 44 |
| Silver | | Chem S-4 | 44 |
| | | Chem S-144 | 49 |
| Steel (Manganese) | | Chem S-92 | 38 |
| Stainless Steel | | Chem S-4 | 44 |
| | | Chem S-225 | 53 |
| | | A-3190 | 59 |
| Stainless Steel (type 302) | | Chem S-101 | 51 |
| | | Chem S-144 | 49 |
| | | Chem S-165 | 48 |
| | | BT-11 | 47 |
| | 304 | Chem S-508 | 50 |
| | | RL 4.6.289 | 57 |
| | | RL 4.6.297 | 50 |
| | 309 | CD-F-10 | 54 |
| | | JRC-18 (ML 43) | 56 |
| | 310 | Chem S-92 | 38 |
| | | Chem S-165 | 48 |
| | 316 | CD-F-10 | 54 |
| | | Chem S-92 | 38 |
| | | Chem S-165 | 48 |
| | | Chem S-508 | 50 |
| | | JRC-18 (ML 43) | 56 |
| Stainless Steel (type 317) | | Chem S-92 | 38 |
| | | Chem S-101 | 51 |
| | | Chem S-165 | 48 |
| | 321 | CD-F-10 | 54 |
| | | JRC-18 (ML 43) | 56 |
| | | RL 4.6.297 | 50 |
| | | Chem S-92 | 38 |
| | | Chem S-165 | 48 |
| | 329 | Chem S-92 | 38 |
| | | Chem S-165 | 48 |
| | 347 | CD-F-10 | 54 |
| | | JRC-18 (ML 43) | 56 |
| | | Chem S-92 | 38 |
| | | Chem S-165 | 48 |
| Tantalum | | RL 28.5.25 | 60 |
| | | Chem S-144 | 49 |
| Thorium Oxide | | Chem S-4 | 44 |
| Tin | | Chem S-176 | 59 |
| Tungsten | | Chem S-4 | 44 |
| | | A-3191 | 61 |

J. $TCl_5$ to $TCl_4$

| | | |
|---|---|---|
| Cupro Nickel | Chem S-514 | 61 |
| Durichrome | " " " | |
| Glass | " " " | |
| Hastelloy A, B, C and D | Chem S-528 | 63 |
| Illium G | Chem S-514 | 61 |

[redacted]

| | Report No. | Page No. |
|---|---|---|
| Inconel | Chem S-514 | 61 |
| Nickel | Chem S-507 | 65 |
| Steel Rod | " | |
| Stainless Steel (type 304) | Chem S-514 | 61 |
| 310 | " | |
| 312 | " | |
| 316 | Chem S-507 | 65 |
| | Chem S-514 | 61 |
| 317 | " | |
| 325 | " | |
| 347 | " | |
| Tantalum | " | |

K. $TCl_4$, $HNO_3$

| | | |
|---|---|---|
| Aluminum | Chem S-48 | 24 |

## IX Fluorides

A. $TF_4$

| | | |
|---|---|---|
| Nickel | BT-11 | 47 |

B. $TF_4$ and fused salts

| | | |
|---|---|---|
| Chromel A | BT-11 | 47 |
| Stainless steel | " | |

C. $TF_6$

| | | |
|---|---|---|
| Aluminum | R.L. 16.6.72 | 65 |
| Brass | " | |
| Bronze | " | |
| Cadmium | " | |
| Copper | R.L. 4.6.296 | 66 |
| | R.L. 16.6.72 | 65 |
| Dowmetal | R.L. 16.6.72 | 65 |
| Gold | " | |
| Graphite | R.L. 28.5.24 | 67 |
| | R.L. 28.5.51 | 68 |
| Inconel | R.L. 4.6.296 | 66 |
| | R.L. 16.6.72 | 65 |
| | R.L. 28.5.51 | 68 |
| Kovar | R.L. 28.5.51 | 68 |
| Lead | R.L. 4.6.296 | 66 |
| Molybdenum | R.L. 16.6.72 | 65 |
| | R.L. 4.6.296 | 66 |
| Monel | R.L. 4.6.296 | 66 |
| | R.L. 16.6.72 | 65 |
| | R.L. 28.5.51 | 68 |
| | R.L. 28.5.24 | 67 |
| Nickel | R.L. 4.6.296 | 66 |

[redacted]

| | Report No. | Page No. |
|---|---|---|
| Nickel | RL 16.6.72 | 65 |
| | RL 28.5.24 | 67 |
| | RL 28.5.51 | 68 |
| Palladium | RL 16.6.72 | 65 |
| Platinum | RL 4.6.296 | 68 |
| | RL 16.6.72 | 65 |
| | RL 28.5.51 | 68 |
| Silver | RL 4.6.296 | 66 |
| | RL 16.6.72 | 65 |
| Steel | RL 16.6.72 | 65 |
| Stainless Steel | RL 4.6.296 | 66 |
| | RL 16.6.72 | 65 |
| | RL 28.5.24 | 67 |
| Stainless Steel (type 316) | RL 25.5.51 | 68 |
| Tantalum | RL 4.6.296 | 66 |
| | RL 4.6.904 | 68 |
| | RL 16.6.72 | 65 |
| | RL 28.5.51 | 68 |
| Tantalum K | RL 28.5.25 | 60 |
| Tin | RL 16.6.72 | 65 |
| Tungsten | RL 4.6.296 | 66 |
| | RL 4.6.904 | 68 |
| | RL 16.6.72 | 65 |
| | RL 28.5.24 | 67 |
| | RL 28.5.51 | 68 |
| Thoriated Tungsten | RL 4.6.904 | 68 |
| | RL 28.5.24 | 67 |

## X. Gunks

A. Alpha Gunk

| | | |
|---|---|---|
| Du Pont D-29 | CD-GS-20 | 30 |
| Koroseal | " | |
| Neoprene-Cork | " | |
| Silastic-Dow | " | |
| Tygon TLU-103 | " | |
| " TU - 2807 | " | |
| " TU - 3400 | " | |

B. Beta Gunk

| | | |
|---|---|---|
| Glass | CD-PPO-22 | 69 |
| Stainless Steel | " | |
| Tygon | " | |

C. Gunk, Chlorine, Steam

| | | |
|---|---|---|
| Hastelloy, C | XL 4.9.802 | 32 |
| Lead | " | |
| Silver | " | |

[redacted]

[redacted]

| | Report No. | Page No. |
|---|---|---|
| D. Gunk, Conc. HCl, 27% $H_2O_2$ (Same as C above) | XL 4.9.802 | 32 |
| E. Gunk Concentration (1/2 sat. with Fe $(NO_3)_3$ | | |
| Hastelloy, C | M-13 (Supplement 1) | 69 |
| Stainless Steel (Type 316) | " | |
| 317 | " | |
| F. Alkaline Gunk | | |
| Hastelloy C | M-13 (Supplement 1) | 69 |
| Stainless Steel (Type 302) | " | |
| 316 | " | |
| 317 | " | |
| 321 | " | |
| G. Oxidized Gunk | | |
| Hastelloy B | CD-522 CEL-a | 70 |
| Inconel | CD-519 CEL-a | 71 |
| | CD-522 CEL-a | 70 |
| Monel | CD-519 CEL-a | 71 |
| Nickel | " | |
| N 153 & 155 | CD-GS-24 | 72 |
| | CD-522 CEL-a | 70 |
| Stainless Steel (Type 302) | CD-GS-5 | 72 |
| | CD-519 CEL-a | 71 |
| | CD-522 CEL-a | 70 |
| 304 | CD-GS-5 | 72 |
| 316 | CD-GS-5 | 72 |
| | CD-519 CEL-a | 71 |
| | CD-522 CEL-a | 70 |
| 321 | CD-GS-5 | 72 |
| | CD-522 CEL-a | 70 |
| 330 | CD-519 CEL-a | 71 |
| | CD-522 CEL-a | 70 |
| 347 | CD-GS-5 | 72 |
| | CD-519 CEL-a | 71 |
| | CD-522 CEL-a | 70 |
| H. D-1 Gunk | | |
| Aluminum | Chem S-109 | 73 |
| Copper | Chem S-48 and 109 | 24 & 73 |
| Copper plated | " " | |
| Everdur | Chem S-109 | 73 |
| Hastelloy B, C | Chem S-48 and 109 | 24 & 73 |
| Inconel | " " | |
| Mallory 53 | " " | |
| Molybdenum | Chem S-109 | 73 |
| Nickel | Chem S-48 and 109 | 24 & 73 |
| Silver | " " | |
| Stainless Steel | " " | |
| Tantalum | " " | |

[redacted]

| | Report No. | Page No. |
|---|---|---|

## XI. Oxides

A. $TO_2 : CCl_4$

| | | |
|---|---|---|
| Inconel | Chem S-23 | 75 |
| Iron | " | |
| Molybdenum | " | |
| Monel | " | |
| Nichrome | " | |
| Nickel | " | |
| Stainless Steel (type 302) | " | |
| 317 | " | |

B. $TO_3, CCl_4$

| | | |
|---|---|---|
| Copper | Chem S-48 | 24 |
| | Chem S-509 | 75 |
| Copper (Plated) | Chem S-509 | 75 |
| Inconel | Chem S-48 | 24 |
| Mallory | " | |
| Nickel | " | |
| | Chem S-509 | 75 |
| Silver | " | |
| Steel | " | |
| Stainless Steel | Chem S-48 | 24 |
| | Chem S-509 | 75 |
| Stainless Steel (type 302) | A-1089 | 76 |
| 304 | Chem S-509 | 75 |
| | Chem S-527 | 46 |
| 309 | A-1089 | 76 |
| 310 | " | |
| 316 | Chem S-509 | 75 |
| | Chem S-527 | 46 |
| | A-1089 | 76 |
| 317 | A-1089 | 76 |
| 321 | " | |
| Tin | Chem S-509 | 75 |

C. $TO_4$ to $TO_3$

| | | |
|---|---|---|
| Hastelloy A, B, C & D | Chem S-528 | 63 |
| Nickel | Chem S-513 | 77 |
| Stainless Steel (type 304) | " | |
| 316 | " | |

D. $TO_4 : 5\% H_2O_2$

| | | |
|---|---|---|
| Hastelloy A, B, C, & D | Chem S-528 | 63 |

E. $TO_4 : 30\% H_2O_2$

| | | |
|---|---|---|
| Hastelloy A, B, C, & D | Chem S-528 | 63 |

[redacted]

[redacted]

| | Report No. | Page No. |
|---|---|---|
| F. $T_3O_8$, $CCl_4$ . | | |
| Low Carbon Steel | BT-11 | 47 |
| Stainless Steel (18-8) | " | |

## XII. Peroxide ($H_2O_2$)

| | | |
|---|---|---|
| A. Very Dilute $H_2O_2$ | | |
| Tuballoy, Alloys | A-3000 | 41 |
| B. 1/2% $H_2O_2$, 1/2% HCl | | |
| Ni-Resistant | Chem S-183 | [illegible] |
| C. 1/2% $H_2O_2$, 2% HCl | | |
| Copper | Chem S-138 | 32 |
| Nickel | " | |
| Ni-Resist | Chem S-183 | 29 |
| Stainless Steel | Chem S-138 | 32 |
| D. 2% $H_2O_2$, 2% HCl | | |
| Same as I, I | Chem S-138,183 | 29 & 32 |
| E. 27% $H_2O_2$, Conc. HCl, Gunk (1:1:4) | | |
| Hastelloy C | XI. 4.9.802 | 32 |
| Lead | " | |
| Silver | " | |
| F. 5% $H_2O_2$, $TO_4$ | | |
| Hastelloy A, B, C, and D | Chem S-528 | 63 |
| G. 30% $H_2O_2$, $TO_4$ | | |
| Hastelloy A, B, C, and D | Chem S-528 | 63 |
| H. Excess $H_2O_2$ ($TF_6$--Conversion-Process-Soln) | | |
| Stainless Steel (Type 316) | CD-GS-33 | 77 |
| 321 | " | |
| I. Excess $H_2O_2$, Alpha Gunk | | |
| N 153 | CD-GS-24 | 72 |
| N 155 | " | |

[redacted]

[redacted]



## XIII. Miscellaneous

| | Report No. | Page No. |
|---|---|---|
| A. Calcium Chloride | | |
| Copper | CD-GS-12 | 78 |
| Iron | " | |
| B. Calcium Nitrate | | |
| Same as A above | CD-GS-12 | 78 |
| C. Carbitol | | |
| Same as X, A | CD-GS-20 | 30 |
| D. Carbitol, Cellosolve, and Beta Gunk | | |
| Same as X, B | CD-PPO-22 | 69 |
| E. Carbon Tetrachloride | | |
| Silicone Grease | CD-GS-29 | 23 |
| F. CEC Solution | | |
| Hastelloy C | ML-59 | 85 |
| N-155 | " | |
| Stainless Steel (type 316) | " | |
| Ticonium III | " | |
| G. Cellosolve, Carbitol, Gunk | | |
| Same as D above | CD-PPO-22 | 69 |
| H. Dibutyl Carbitol | | |
| Same as C above | CD-GS-20 | 30 |
| I. Dibutyl Carbitol, Dibutyl Cellosolve and Beta Gunk | | |
| Same as D above | CD-PPO-22 | 69 |
| J. Tuballoy | | |
| TaC | RL 4.5.33 | 85 |
| | RL 4.6.914 | 86 |

[redacted]

[redacted]



EXCERPTED REPORTS

Chem S-331 File No. 3619

Corrosion Tests

W. M. Tucker - 5/7/43

Temperature: 70°C

Time: 96 hours (media changed and ran another 96 hours) with samples fully immersed.

Solutions: (1) 2% $HNO_3$; (2) 1% HCl; (3) 2% $HNO_3$ and 0.1% HCl

Ranking: (In order of preference)

Group I: Excellent because of (1) low penetration rate (2) small degree of contamination of attacking media.

Stainless Steel Type 316 (passivated and unpassivated)

Cb Stainless Steel Type 316

Stainless Steel Type 329

Stainless Steel Type 317

Group II: Usable because of penetration rates of a non-destructive nature, but not as desirable as Group I because of the greater amounts of metal dissolved into the media.

Duriron

Antaciron (Worthington Pump Co.)

Illium G

Illium R

Hastelloy C

Durichlor

Worthite

Stainless Steel Type 446

[redacted]

[redacted]



Group III: (Single purpose materials only)

1% HCl:

Hastelloy B

Nickel

Inconel

Monel

2% $HNO_3$:

Stainless Steel type 304

Stainless Steel type 310

Stainless Steel type 347

Conclusion: Group I would be the most usable, with 316 preferred. Certain cast vessels, pumps, etc., might be advantageously made of silicon ions. Type 446, although apparently usable, should probably be avoided because of danger of intergranular attack. The Illiums and Hastelloy C probably do not offer sufficient advantages to off-set their high cost. Everdur was tested -- unsatisfactory.

Experimental Results:

See Table I, pages 18, 19, 20, 21 and 22

[redacted]

TABLE I

Test Temperature 70°C - Samples Fully Immersed

| | Initial Loss 1st 48 hrs. Mdd | Initial Penetration Rate 1st 48 hrs. ipy | Loss 2nd 48 hrs. 2 da. Mdd | Penetration 2nd 48 hrs. 2 da. ipy | Av. Loss 48 + 144 hrs. 8 da. Mdd | Av. Penetration 48 + 144 hrs. 8 da. ipy | 96 hours exposure at 70°C in new Portions of Media: Ave Loss 96 hrs. Mdd | Av. Penetration 96 hrs. ipy | Appearance and Notes |
|---|---|---|---|---|---|---|---|---|---|
| **Antaciron (Si - 14.5%, rem. Fe)** | | | | | | | | | |
| (1). | 84 | 0.017 | 24 | 0.0049 | 19 | 0.0039 | 4 | 0.00082 | Etched brightly |
| (2). | 71 | 0.015 | 4 | 0.0008 | 3 | 0.0006 | 30 | 0.0062 | Etched finely & evenly |
| (3). | 71 | 0.015 | 5 | 0.0010 | 4 | 0.0008 | 3 | 0.00062 | Etched brightly & slightly pitted |
| **Duriron (Si - 14.5%, rem. Fe)** | | | | | | | | | |
| (2). | 8 | 0.002 | 52 | 0.0130 | 16 | 0.0033 | 11 | 0.0022 | Etched |
| (3). | 1 | 0.0003 | 7 | 0.0015 | 5 | 0.001 | 5 | 0.00103 | Very slightly et etched |
| **Durichlor (Si - 14.5%, Mo - 3.0%, rem. Fe)** | | | | | | | | | |
| (1). | 123 | 0.025 | 70 | 0.0143 | 60 | 0.012 | 59 | 0.012 | Etched brightly |
| (2). | 90 | 0.018 | 20 | 0.0041 | 13 | 0.0027 | 77 | 0.016 | Etched |
| (3). | 154 | 0.038 | 70 | 0.0143 | 60 | 0.012 | 36 | 0.011 | Etched brightly |
| **Hastelloy B (Ni - 65%, Mo - 30%)** | | | | | | | | | |
| (1). | 6015 | 0.930 | 133 | 0.0206 | 68 | 0.0105 | 3163 | 0.492 | Severely etched & pitted |
| (2). | 61 | 0.009 | 56 | 0.0087 | 83 | 0.013 | 65 | 0.010 | Stained & etched |
| (3). | 8490 | 1.320 | 520 | 0.081 | 276 | 0.043 | 3420 | 0.531 | Very badly etched & scored |
| **Hastelloy C (Ni - 58%, Cr - 14%, Mo - 17%, W - 5%)** | | | | | | | | | |
| (2). | 4 | 0.0006 | 4 | 0.0006 | 7 | 0.0011 | 16 | 0.0026 | Unchanged |
| (3). | 24 | 0.004 | 32 | 0.005 | 57 | 0.0092 | 93 | 0.015 | Unchanged |

1st Column numbers in parentheses signifies the solutions used. (1). 2% $HNO_3$, (2). 1% HCl, (3). 2% $HNO_3$, 0.1% HCl

Table I (continued)

| | Initial Loss 1st 48 hrs. Mdd | Initial Penetration Rate 1st 48 hrs. ipy | Loss 2nd 48 hrs. 2 da. Mdd | Penetration 2nd 48 hrs. 2 da. ipy | Av. Loss 48 & 144 hrs. 8 da. ipy | Av. Penetration 48 & 144 hrs. 8 da. ipy | 96 hours exposure at 70°C in new portions of Media Av. Loss 96 hrs. ipy | Av. Penetration 96 hrs. ipy | Appearance and Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | Illium G (Ni - 58%, CR - 22%, Cu - 6.5%, Mo - 4%, W - 2%) | | | | | | | |
| (1). | 2 | 0.0003 | 2 | 0.0003 | 1 | 0.00016 | 0.5 | 0.000082 | Unchanged |
| (2). | 73 | 0.010 | 68 | 0.010 | 51 | 0.0083 | 63 | 0.010 | Etched & sl.stained |
| (3). | 1 | 0.0002 | 3 | 0.005 | 1 | 0.00016 | 0.3 | 0.000048 | Unchanged |
| | | Illium R (Ni - 61%, Cr -31%, Cu - 4%, Mo - 6.5%) | | | | | | | |
| (1). | 3 | 0.0005 | 0.5 | 0.00008 | 0.2 | 0.00003 | 0.2 | 0.000033 | Unchanged |
| (2). | 96 | 0.020 | 69 | 0.0114 | 27 | 0.0045 | 70 | 0.012 | Etched & sl. pitted |
| (3). | 14 | 0.0023 | 0.5 | 0.00008 | 0.2 | 0.00003 | 0.1 | 0.000017 | Slightly etched |
| | | Everdur (Cu - 98.25%, Si - 1.5%) | | | | | | | |
| (1). | 3045 | 0.510 | 2906 | 0.488 | 782 | 0.131 | 1546 | 0.259 | Badly etched & scored |
| (2). | 556 | 0.093 | 514 | 0.086 | 343 | 0.058 | 226 | 0.038 | Badly etched |
| (3). | 378 | 0.064 | 2745 | 0.460 | 715 | 0.120 | 993 | 0.167 | Badly etched, scored and stained |
| | | Monel (Ni - 67%, Fe - 2.5%, rem. Cu) | | | | | | | |
| (1). | 20 | 0.004 | 124 | 0.0196 | 95 | 0.015 | 517 | 0.084 | Etched smoothly |
| (2). | 126 | 0.021 | 273 | 0.0445 | 172 | 0.028 | 101 | 0.016 | Etched semi-brightly |
| (3). | 413 | 0.067 | 2588 | 0.4220 | 633 | 0.103 | 1657 | 0.270 | Etched & stained |
| | | Nickel (Ni - 99% min., Fe - 0.5%, Cu - 0.25%) | | | | | | | |
| (1). | 2740 | 0.444 | 24 | 0.0039 | 10 | 0.0016 | 1434 | 0.232 | Very badly etched and perforated |
| (2). | 125 | 0.020 | 96 | 0.0156 | 86 | 0.014 | 137 | 0.022 | Etched |
| (3). | 1880 | 0.310 | 170 | 0.0275 | 182 | 0.029 | 134 | 0.022 | Etched |

1st Column numbers in parentheses signifies the solutions used. (1). 2% $HNO_3$. (2). 1% HCl. (3). 2% $HNO_3$ . 0.1% HCl

TABLE I (Continued)

| | Initial Loss 1 st 48 hrs. Mdd | Initial Penetration Rate 1st 48 hrs. ipy | Loss 2nd 48 hrs. 2 da. Mdd | Penetration 2nd 48 hrs. 2 da. ipy | Av Loss 48 & 144 hrs. 8 da. Mdd | Av Penetration 48 & 144 hrs. 8 da. ipy | 96 hours exposure at 70 C° in new portions of Media: Av. Loss 96 hrs. Mdd | Av. Penetration 96 hrs. ipy | Appearance and Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | Inconel ( Ni - 75% min., Cr 10% min, Fe - 8.0%, Cu 0.5%) | | | | | | | |
| (1). | 71 | 0.012 | 96 | 0.0169 | 217 | 0.037 | 162 | 0.027 | Etched semi-brightly |
| (2). | 147 | 0.025 | 107 | 0.0181 | 79 | 0.013 | 129 | 0.022 | Etched |
| (3). | 632 | 0.1070 | 2125 | 0.3590 | 533 | 0.090 | 1387 | 0.234 | Etched brightly |
| | | Stainless Steel 304 (Cr - 17% min., Ni - 7% min., C - .08%) | | | | | | | |
| (1). | 0.6 | 0.00011 | 0.7 | 0.00013 | 0.1 | 0.000018 | 0.1 | 0.000018 | Unchanged |
| (2). | 2123 | 0.385 | 21 | 0.0038 | 23 | 0.0042 | 1318 | 0.239 | Badly etched, pitted and perforated |
| (3). | 0.25 | 0.000047 | 0.6 | 0.00011 | 0.1 | 0.000018 | 0.3 | 0.000054 | Unchanged |
| | | Stainless Steel 304 Pickeled and Passivated | | | | | | | |
| (1). | 0 | 0.0 | 0.6 | 0.00011 | 0.1 | 0.00001 | 0.0 | 0.0 | Unchanged |
| (2). | 2122 | 0.385 | 21 | 0.0038 | 22 | 0.004 | 1151 | 0.209 | Badly etched, pitted and perforated |
| (3). | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0.3 | 0.000054 | Unchanged |
| | | Stainless Steel 347 (Cr - 17% min., Ni - 7% Min., C 0.8%, Cb - .08%) | | | | | | | |
| (1). | 1 | 0.00018 | 0.5 | 0.00009 | 0.1 | 0.000018 | 0.2 | 0.000036 | Unchanged |
| (2). | 925 | 0.178 | 915 | 0.165 | 399 | 0.072 | 896 | 0.163 | Badly etched & pitted |
| (3). | 1 | 0.00018 | 1 | 0.00018 | 0.2 | 0.000036 | 0.1 | 0.000018 | Unchanged |
| | | Stainless Steel 316 (Cr -16% Min., Ni - 14%, Mo - 2-4%, C - .08%) | | | | | | | |
| (1). | 0.8 | 0.00015 | 0.6 | 0.00011 | 0.2 | 0.000036 | 0.1 | 0.000018 | Unchanged |
| (2). | 5 | 0.0009 | 1 | 0.00019 | 0.7 | 0.00013 | 0.3 | 0.000054 | Unchanged |
| (3). | 4 | 0.0007 | 0.1 | 0.000019 | 0.1 | 0.000018 | 0.3 | 0.000054 | Unchanged |

1st Column numbers in parentheses signifies the solutions used. (1). 2% $HNO_3$; (2). 1% HCl, (3). 2% $HNO_3$, 0.1% HCl

TABLE I (Continued)

| | Initial Loss 1st 48 hrs. Mdd | Initial Penetration Rate 1st 48 hrs. ipy | Loss 2nd 48 hrs. 2 da. Mdd | Penetration 2nd 48 hrs. 2 da. ipy | Av. Loss 48 & 144 hr. 8 da. Mdd | Av. Penetration 48 & 144 hrs. 8 da. ipy | 96 hours exposure at 70°C in new portions of Media: Av. Loss 96 hrs. Mdd | Av. Penetration 96 hrs. ipy | Appearance and Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | Stainless Steel 316 Pickled and Passivated | | | | | | | |
| (1). | 0.1 | 0.000018 | 0.3 | 0.00006 | 0.1 | 0.000018 | 0.1 | 0.000018 | Unchanged |
| (2). | 0.7 | 0.0001 | 1 | 0.0002 | 0.6 | 0.00011 | 0.3 | 0.000054 | Unchanged |
| (3). | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0.3 | 0.000054 | Unchanged |
| | | Stainless Steel 316 Cb (Cr - 16%, Ni -14%, Mo 2-4%, Cb - 0.8%, C - .08%) | | | | | | | |
| (1). | 0.8 | 0.00014 | 0.5 | 0.0009 | 0.1 | 0.000018 | 0.0 | 0.0 | Unchanged |
| (2). | 0.8 | 0.00014 | 0.5 | 0.0009 | 0.2 | 0.000036 | 0.6 | 0.000109 | Unchanged |
| (3). | 0.8 | 0.00014 | 0.8 | 0.00014 | 0.2 | 0.000036 | 0.1 | 0.000018 | Unchanged |
| | | Stainless Steel 310 (Cr - 24% min., Ni - 19%, C - 0.15%) | | | | | | | |
| (1). | 0.5 | 0.00009 | 0.3 | 0.00006 | 0.1 | 0.000018 | 0.0 | 0.0 | Unchanged |
| (2). | 1030 | 0.19 | 13 | 0.0024 | 12.5 | 0.0023 | 938 | 0.170 | Badly etched & pitted |
| (3). | 8 | 0.001 | 1.4 | 0.00025 | 0.5 | 0.0009 | 0.3 | 0.000054 | Unchanged |
| | | Stainless Steel 317 (Cr - 16% min., Ni - 14%, Mo - 3-4%, C - 010%) | | | | | | | |
| (1). | 31.6 | 0.0057 | 19 | 0.0034 | 4.8 | 0.00087 | 0.0 | 0.0 | Etched brightly |
| (2). | 0.5 | 0.00009 | 0.6 | 0.00012 | 0.1 | 0.000018 | 0.4 | 0.000073 | Unchanged |
| (3). | 0.6 | 0.00012 | 0.4 | 0.00016 | 0.1 | 0.000018 | 0.2 | 0.000036 | Unchanged |
| | | Worthite (Fe - 50%, Ni - 24%, Cr - 20%, Mo -3%, C - .08%) | | | | | | | |
| (1). | 0.8 | 0.00014 | 0.8 | 0.00014 | 0.1 | 0.000018 | 0.8 | 0.000145 | Unchanged |
| (2). | 136 | 0.025 | 13 | 0.0023 | 10.0 | 0.0018 | 105 | 0.019 | Etched finely |
| (3). | 0 | 0.0 | 6 | 0.0011 | 1.4 | 0.00025 | 0.2 | 0.000018 | Unchanged |
| | | Stainless Steel 446 (Cr - 23-30%, C - 0.35%) | | | | | | | |
| (1). | 2 | 0.00038 | 0.4 | 0.00008 | 0.2 | 0.000038 | 0.2 | 0.000038 | Unchanged |
| (2). | 749 | 0.141 | 18 | 0.0034 | 19 | 0.0036 | 2.5 | 0.00047 | Etched, & sl. pitted |
| (3). | 1 | 0.00018 | 0.8 | 0.00015 | 0.2 | 0.000038 | 0.3 | 0.000057 | Unchanged |

1st Column numbers in parentheses signifies the solutions used. (1). 2% $HNO_3$, (2). 1% HCl, (3). 2% $HNO_3$ , 0.1% HCl

TABLE I (Continued)

| | Initial Loss 1st 48 hrs. Mdd | Initial Penetration Rate 1st 48 hrs. ipy | Loss 2nd 48 hrs. 2 da. Mdd | Penetration 2nd 48 hrs. 2 da. ipy | Av. Loss 48 & 144 hrs. 8 da. Mdd | Av. Penetration 48 & 144 hrs. 8 da. ipy | 96 hours exposure at 70°C in new portions of Media Av. Loss 96 hrs. Mdd | Av. Penetration 96 hrs. ipy | Appearance and Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | Stainless Steel 32° | | (Cr - 25-30%, Ni - 3%, Mo - 1.5%, C - 0.1%) | | | | | |
| (1). | 0.8 | 0.00015 | 0.5 | 0.00009 | 0.1 | 0.000019 | 0.3 | 0.000057 | Unchanged |
| (2). | 0.5 | 0.00009 | 1 | 0.00019 | 0.3 | 0.000057 | 0.3 | 0.000057 | Unchanged |
| (3). | 0.3 | 0.000057 | 0.1 | 0.000019 | 0.0 | 0.0 | 0.6 | 0.000113 | Unchanged |

Mdd - Mg. per sq. dm. per day
ipy - inches pentration per year

1st Column numbers in parentheses signifies the solutions used. (1). 2% $HNO_3$. (2). 1% HCl. (3) 2% $HNO_3$. 0.1%HCl

[redacted]



CD-GS-29

# THE EFFECT OF VARIOUS REAGENTS ON DOW-CORNING SILICONE STOPCOCK GREASE

E. M. Kelman, C. D. Susano - 3/15/45

Method: Small portions of Silicone grease were placed in test tubes and to each was added one of the reagents, allowed to stand for 12 hours at room temperature. The test specimens were examined at different time intervals and compared with an unused sample.

Results:

| Reagent | Effect of Reagent on Dow-Silicone at Room Temperature |
|---|---|
| HCl (1:20) | Slight swelling was observed within 3 hours. There was no apparent effect on the lubricating properties after 12 hours exposure. |
| HCl (concentrated) | Slight swelling occurred within 3 hours after exposure to the acid accompanied by a slight decrease in viscosity; no other change was observed during the next 9 hours. |
| $H_2SO_4$ (1:20) | No effect was observed other than a slight swelling which reached a maximum after 3 hours exposure. |
| $H_2SO_4$ (concentrated) | A clear viscous solution formed after 3 hours exposure. Dilution with water did not precipitate the silicone grease. |
| $HNO_3$ (1:10) | Swelling was slightly greater than it was in the case of 5% hydrochloric acid solution. The lubricating properties apparently remained unchanged, even up to 12 hours exposure. |
| $HNO_3$ (concentrated) | The silicone was decolorized and liquified within 1 hour. |
| HF (1:17) | The silicone broke up slowly into lumps, and finally liquified after 6 hours. |
| Carbon Tetrachloride | A colloidal suspension was formed within 3 hours which did not break down on continued exposure to $CCl_4$ for 12 hours. |

[redacted]

[redacted]



Conclusions: This sample of Dow-Corning silicone grease appears to be somewhat resistant to attack by weak acids, such as hydrochloric (1:20), sulfuric (1:20), and nitric (1:10).

This material will not withstand exposure to strong acids, namely, concentrated sulfuric, nitric, hydrochloric and dilute hydrofluoric (1:17); and the organic solvent, carbon tetrachloride.

Chem S-48

CORROSION TESTS

Ross Cummings - 3/19/43

ACID CORROSION TESTS

Temperature: Room temperature

Time: One hour

Solutions: 4 N HCl (13.6%) and 2 N $HNO_3$ (12%)

Samples: (see table) Submerged

Procedure: Various metals were submerged in 4 N HCl (equivalent to 1 N $TCl_4$ solution - about 30%) and 2 N $HNO_3$.

Results: Only Tantalum successfully withstands both acids, Hastelloy C is next choice.

| Metal | Loss in g/sq. in. | |
|---|---|---|
| | 4N HCl | 2N $HNO_3$ |
| Inconel | 0.00174 gassed | 0.0287 |
| | 0.00015 | 0.0281 |
| | 0.00222 | 0.0548 |
| Mallory 53 | 0.00128 | 0.0188 |
| Nickel | 0.00047 | 0.0132 |
| Stainless Steel | 0.00256 | 0.0000 |
| Tantalum | 0.00019 | 0.0001 |
| Hastelloy B | 0.00042 | 0.0095 |
| Hastelloy C | 0.00015 | 0.0015 |
| Kovar | 0.00259 | 0.9400 |

[redacted]

[redacted]



## CORROSION OF ALUMINUM

Temperature: (1) and (2) Room temperature (3) 70°C.

Time: (1) 130 minutes (2) 85 minutes (3) 75 minutes

Solution: (1) 0.47M $TCl_4$, (2) 2N $HNO_3$ and 0.2M $TCl_4$, (3) 2N $HNO_3$

Material: Sheet Aluminum (1) 1-5/16" x 4" (2) & (3) 2" x 4"

Results:

| Test | Loss in wt. $g/in^2/hr.$ | Penetration ipy |
|---|---|---|
| #1 | 0.0221 | 6.44 |
| #2 | 0.0154 | 3.03 |
| #3 | 0.0096 | 1.90 |

(1) and (2) had gas evolved and the aluminum was etched;

(3) was etched to a smooth matte finish.

## CORROSION EXPERIMENT - LIQUID PHASE REACTION

Time: 36 hours

Samples: Inconel, Mallory, Copper, Nickel and Stainless Steel.

Procedure: Wash two pieces of each metal in $CCl_4$. Weigh. For each pair of metals fix up a reaction tube containing 10 g. $TO_3$ and 100 ml. $CCl_4$. Place one piece in the boiler and suspend the other near the top so that it will be in the vapor. Boil for 36 hours. Remove, wash in water and scrub with a policeman. Wash in $CCl_4$. Weigh.

Results:

| Reaction in Liquid: | Inconel | Mallory | Copper | Nickel | Stainless Steel |
|---|---|---|---|---|---|
| Appearance after reaction: | green film | grey film on top of black film | very corroded, black and green | unchanged | partially greenish |
| Wt. after reaction and scrubbing: | 1.0836 | 0.4918 | 3.1828 | 2.0193 | 1.7003 |

[redacted]

Results (cont.)

| Reaction in Liquid: | Inconel | Mallory | Copper | Nickel | Stainless Steel |
|---|---|---|---|---|---|
| Wt. before reaction and scrubbing | 1.0833 | 0.5124 | 3.2630 | 2.0178 | 1.6994 |
| Change in Wt. grams | 0.0003 | -0.0206 | -0.0802 | 0.0015 | 0.0009 |
| Mg change/$cm^2$ | 0.18 | -13.7 | -16.2 | 0.41 | 0.22 |
| **Reaction in Vapor:** | | | | | |
| Appearance after reaction | green film | grey film | very corroded black and green | unchanged | greenish in spots |
| Wt. after reaction and scrubbing | 1.1169 | 0.4876 | 3.5264 | 2.2637 | 1.3706 |
| Wt. before reaction and scrubbing | 1.1168 | 0.5056 | 3.5741 | 2.2636 | 1.3727 |
| Change in Wt. grams | 0.0001 | -0.0189 | -0.0477 | 0.0001 | -0.0021 |
| Mg change/$cm^2$ | 0.06 | -12.6 | -9.35 | 0.023 | -0.42 |

In case of Inconel and Stainless Steel very little net change.

## RESISTANCE OF METALS TO CORROSION BY GUNK, III

Samples were attached to the D-1 "Gunk catcher" opposite the source. After one run they were removed, washed off with hot water and "loss of weight" determined. Confusing results did not tie in with such time factors as duration of run, length of time exposed to air, etc., also scouring the samples with abrasive cleaner to remove the deposits. This was changed to simply rub the pieces with cloth after washing and weighing. Gold and silver plate are best for corrosion resistance for assemblies that will be washed with hot water.

Results:

| Metal | Loss in wt. per exposure grams/sq.in.x$10^{-4}$ | Penetration per exposure inches x $10^{-7}$ | Comments |
|---|---|---|---|
| Copper | 27.0<br>90.0 | 180<br>610 | Considerable insoluble deposits, probably copper oxide, washing contaminated with Cu. |
| Silver | 61.7<br>7.3<br>9.1 | 355<br>42<br>52 | Forms a heavy insoluble deposit & contaminates washings. 1st result shown, the deposit was scoured off. |
| Mallory 53 | 66.0<br>8.1<br>2.7 | 447<br>55<br>18 | Acts very much like straight copper. In the last two tests insoluble not scoured off. |
| Stainless Steel | 13.6<br>10.6 | 105<br>82 | The metal washes clean. |
| Hastelloy B | 18.8<br>.5 gain | 124<br>15* | Sandblasted surface. In these, the exposed face was polished.* |
| Hastelloy C | 17.3<br>4.0<br>2.7 | 118<br>27*<br>18* | Sandblasted surface. |
| Inconel | 3.5<br>1.9 | 25<br>14 | |
| Tantalum | 5.5<br>10.8 | 20<br>40 | This metal accumulated a very adherent insoluble deposit. |
| Nickel | 7.2<br>9.3 | 49<br>64 | Washes very clean, but a thin, brown film forms while drying. |
| Nickel Plate | 2.7<br>2.4<br>1.7<br>0.9 | 18<br>16<br>12<br>6 | |
| Chrome plate on nickel plate | 5.4<br>2.5 | 48<br>22 | |
| Gold plate | 0.1<br>3.1 | 0.31<br>9.7 | This becomes slightly discolored. |

CORROSION OF UNPOLISHED NICKEL AND CHROMIUM-PLATED COPPER

Temperature: 450°C

Time: 1 hour (high vacuum)

Samples: Nickel and chromium-plated strips.

Medium: $TCl_4$ vapor

Procedure: Strips were cleaned with $CCl_4$, heated to 450°C for 1 hour in high vacuum. Many small blisters appeared under the plate. Average loss in weight 1/2 mg (Ni) and 1 mg (Cr). Same samples were placed in tube with a piece of $TCl_4$. Heated to 450°C, $TCl_4$ allowed to condense and later heated and vaporized off. Removed when cool, washed in water, dried, washed in $CCl_4$, dried, and weighed.

| Results: | Ni-plated | Cr-Plated |
|---|---|---|
| (1) | $6.1 \cdot 10^{-6}$ g/sq.in. | $2.8 \cdot 10^{-4}$ g/sq.in. |
| (2) | small gain | $2.8 \cdot 10^{-4}$ g/sq.in. |

CORROSION OF NICKEL AND GOLD-PLATED COPPER BY $TCl_4$ AT HIGH TEMPERATURE

Temperature: 450-500°C

Time: 1 hour (high vacuum)

Samples: Nickel and Gold-plated Copper strips 2" x 4".

Medium: $TCl_4$ vapor

Procedure: Same as above.

Results: A few very small blisters appeared on one side of the gold plate--loss in weight--0.00004 g/sq.in and the gold plate remained bright and in good condition. No evidence of blistering on the nickel plate--mean loss of weight--0.00004 g/sq. in.

Chem S-90

[redacted]



Chem S-90

## CORROSION OF NICKEL-PLATED COPPER

Ross Cummings, C. Hollingshead

Procedure: Same as above

Samples: 0.016" x 3" x 3"

Medium: $TCl_4$ vapor

Results: No blistering -- total gain in weight -- 0.0040 g or 0.00022 g/sq. in. The samples discolored buff to blue-gray. The surface film resists finger-nail scratching.

Chem S-183 File No. 652

## CORROSION OF NI-RESIST BY HYDROCHLORIC ACID - PEROXIDE SOLUTIONS

Ross Cummings - 5/21/43

Temperature: 20°C

Time: 6 1/2 hours

Sample: Cut from used Ni-Resist J-Casting and immersed in test solution.

Solution: 1/2% HCl, 1/2% $H_2O_2$; 2% HCl, 1/2% $H_2O_2$; 0.47M $TCl_4$; 4N HCl (13.6%)

Results:

| Corrosion rate in inches per year | |
|---|---|
| 1/2% HCl, 1/2% $H_2O_2$ | 1.10 |
| 2% HCl, 1/2% $H_2O_2$ | 1.30 |
| 0.47M $TCl_4$ | 0.08 |
| 4N HCl (13.6%) | 0.46 |

These rates are about twice the rate of copper, 3 times nickel, and 140 times Stainless Steel. The indication from the last rate in comparison with the above is that the peroxide is more important than the acidity.

[redacted]

## HCL CORROSION

H. R. McCombie - 1/13/43

These are some materials which are resistant to HCl and temperature.

| Concentration | Temp. | Material | Description | Behavior |
|---|---|---|---|---|
| 30% HCl | 60°C | Asplit | Acid-proof cement | Best |
| | | Duro | Non-porous bricks | Best |
| Cold HCl | | Saran | Plastic material (tube) | Excellent |
| 30% HCl, containing certain organics | 60°C | Saran | Plastic material | Satisfactory |
| Hot HCl | Above 80°C | Saran | Plastic material | Unsatisfactory |
| HCl | boiling | Tantalum | Sheet metal | Very good |

CD-GS-20

## SOLVENT RESISTIVITY OF SYNTHETIC GASKETS

M. E. Hall, C. D. Susano - 3/13/45

**Materials:**
(1) Neoprene-Cork Armstrong
(2) Silastic-Dow
(3) du Pont D-29
(4) Koroseal
(5) Tygon TU-3400
(6) Tygon TLU-2807
(7) Tygon TLU-103

**Solutions:**
A. Aqueous solution 2% $HNO_3$ - 2% HCl
B. Aqueous solution 2% $H_2O_2$ - 2% HCl
C. Alpha Gunk
D. Dibutyl Carbitol

Samples immersed completely in test solutions at the temperature and times listed immediately below.

| Exposure Time Interval | Temperature |
|---|---|
| 24 hours | Room temperature |
| 5 hours | 60°C |
| 5 hours | 95°C |

## Table I

### Effect of Certain Liquids on Gasket Materials

| Gasket Material | Time & Temp. | Test Solutions: 2% HCl-2% $HNO_3$ | 2% $H_2O_2$ | Alpha Gunk | Dibutyl Carbitol |
|---|---|---|---|---|---|
| | | Percent Thickness Change | | | |
| Neoprene-cork | 24 Hrs. - room temp. | 11 | 9 | 10 | 22 |
| Armstrong | 5 Hrs. - 60°C | 12 | 9 | 13 | 27 |
| | 5 hrs. - 95°C | | | | |
| Silastic, Dow | 24 | 3 | 0 | 0 | 25 |
| | 5 | 4 | 6 | 2 | 25 |
| | 5 | 4 | 6 | 5 | 31 |
| duPont D-29 | 24 | 0 | 0 | 0 | 0 |
| | 5 | 0 | 0 | 0 | 0 |
| | 5 | 3 | 0 | 0 | 0 |
| Koroseal | 24 | 1 | 1 | 2 | 7 |
| | 5 | 2 | 1 | 2 | 8 |
| | 5 | 2 | 1 | 2 | 10 |
| Tygon TU-3400 | 24 | 1 | 0 | 6 | 6 |
| | 5 | 1 | 0 | 9 | 11 |
| | 5 | 2 | 3 | 9 | 15 |
| Tygon TU-2807 | 24 | 2 | 0 | 0 | 0 |
| | 5 | 2 | 0 | 0 | 0 |
| | 5 | 3 | 2 | 2 | 0 |
| Tygon TLU-103 | 24 | 0 | 0 | 0 | 7 |
| | 5 | 1 | 0 | 0 | 7 |
| | 5 | 3 | 3 | 3 | 12 |

## Table II

### Order of Resistivity of Gasket Materials

| 2% $HNO_3$-2% HCl | 2% $H_2O_2$-2% HCl | Alpha Gunk | Dibutyl Carbitol |
|---|---|---|---|
| 1. duPont D-29 | duPont D-29 | duPont D-29 | duPont D-29 |
| 2. Tygon TLU-103 | TU-2807 | TU-2807 | TU-2807 |
| 3. TU-2807 | Tygon TLU-103 | Tygon TLU-103 | TLU-103 |
| 4. TU-3400 | TU-3400 | Silastic-Dow | TU-3400 |
| 5. Silastic-Dow | Silastic-Dow | TU-3400 | Neoprene-Cork |
| 6. Neoprene-Cork | Neoprene-Cork | Neoprene-Cork | Silastic-Dow |
| 7. Koroseal | Koroseal | Koroseal | Koroseal |
| | 24 hours | Room Temp. | |
| | 5 hours | 60°C | |
| | 5 hours | 95°C | |

## CORROSION BY HYDROCHLORIC ACID-PEROXIDE SOLUTION

Ross Cummings - 5/21/43

Time: 20 hours

Temperature: Room temperature

Solution: 2% HCl and 1/2% $H_2O_2$

Samples: Copper, nickel and stainless steel type 302 were immersed.

Results:

| Metals | Penetration |
|---|---|
| copper | 0.67 ipy |
| nickel | 0.43 ipy |
| Stainless steel (type 302) | 0.0072 ipy |

XI. 4.9.802

## SOME CORROSION STUDIES

Studhalter, McKinn, Kinderman, Dorough - 10/24/44

I. 1. Chlorine and steam were passed into a tube containing the test materials for four hours.

Results:

| Material | Gain (+) or Loss(-) mg/cm$^2$ | Notes |
|---|---|---|
| Nickel | -20 | Not discolored, surface slightly pitted |
| Inconel | -49 | Not discolored, surface slightly pitted |
| Monel | -145 | Surface etched |
| Tantalum | -4 | No etching, surface discolored |
| Hastelloy A | -128 | Very marked pitting and discoloring |
| Hastelloy B | -85 | Very marked pitting and discoloring |
| Hastelloy C | -32 | Some etching and discoloring |
| Duriron | -46 | Some etching and discoloring |
| Lead | -4.7 | Some discoloring |
| Stainless Steel, 18-8 | -205 | Very deep etching |
| Stainless Steel, 302 | -168 | Very deep etching |
| Coin Silver 10% copper | +0.4 | No etching, turned black |
| Haveg (Plastic) | +13 | Surface etching and colored, holes noted |

[redacted]

2. Same as #1 except $Cl_2$ was turned off for 5 minute intervals every 30 minutes. (5 hour test period)

Results:

| Material | Gain(+) or loss(-) mg/cm$^2$ | Notes |
|---|---|---|
| Stainless Steel-316 | -402 | Very deep etching |
| Havog | + 7.7 | Slightly etched |
| Nickel | -43 | Etched surface |
| Lead (Sample I) | -15 | Surface discolored |
| Lead (Sample II) | -9 | Surface discolored |
| Aluminum | -59 | Deep etching |
| Mild Steel | -256 | Very deep pitting |
| Copper | -173 | Very deep pitting |
| Brass | -213 | Very deep pitting |
| Tantalum | + 0.02 | Surface slightly discolored |
| Silver | + 1 | Surface blackened |
| Hastelloy C | -18.7 | Surface etched |
| Inconel | -126 | Surface etched |
| Saran | - 0.3 | Surface bleached |
| D-29 (plastic) | + 0.07 | Slight discoloration |
| Tygon (plastic) | + 21 | Surface blistered; elasticity gone |

3. The results of #2 suggested that D-29, silver, tantalum, lead, and hastelloy C were the best in that order. The D-29 and tantalum were not adaptable to our use. The others were retested with chlorine and steam in the presence of gunk solution. The samples were half immersed in the gunk sol. (boiling) through which a rapid stream of $Cl_2$ was bubbled for 4 hours. Thus, half the metal was in the gunk saturated with $Cl_2$ and half in an atmosphere of $Cl_2$ in steam.

Results:

| Material | Gain(+) or Loss(-) mg/cm$^2$ | Notes |
|---|---|---|
| Silver | + 2.4 | Surface blackened |
| Lead | -55.0 | Surface badly pitted |
| Hastelloy C | -1.7 | - - - - - - - - - - - |

The above piece of silver was retested in the same way to determine the stability of the AgCl coat. Two hour test shows loss 0.1 mg/cm$^2$, a satisfactory result. Note: Same Hastelloy C sample in all tests (passive characteristic to resist corrosion seems to develop).

II. $HCl-H_2O_2$ - Gunk Corrosion:

Temperature: 25°C

Time: 5 hours

Solution: Mixture of concentrated HCl, 27% $H_2O_2$ and Gunk (1:1:4)

Samples: Silver, lead and Hastelloy C were immersed.

Results:

| Material | Gain (+) or Loss (-) mg/cm$^2$ | Notes |
|---|---|---|
| Silver | +2.7 | Blackened |
| Lead | -23.0 | Pitted |
| Hastelloy C | -0.5 | - - - - - |

Hastelloy C was selected for wash tank construction.

III. Oxalic Acid corrosion: Two samples of stainless steel, types 308 and 316, were treated with a solution containing 90 grams of oxalic acid dihydrate per liter at 50-70°C for 3 1/2 hours and then at 25°C for another 17 hours. After the tests the solution had a very faint green tint. Both samples gain weight (small amt.) and were blackened in appearance; however, it is believed that immersion heaters made of stainless steel will withstand this corrosion sufficiently.

CDC-53

## CORROSION BY MALONIC ACID

B. M. Pitt -- 3/7/45

Metals: Copper, hot rolled steel, cold rolled steel and Stainless Steel type 316. (All polished sheet metal 1/16" stock)

Solution: 50% Malonic acid (50g/100 g of water) pH = 1.0

Temperature: Room temperature

Method: Samples were washed, weighed and put in the solution. Some were taken out at each specified weighing time, washed and weighed and put back, others remained in the solution for the full time period. Stainless steel #1 showed no further weight loss after 8 days, so no data is given beyond this time.

[redacted]

[redacted]



Results:

| Sample | Time Interval Days | Loss g/in$^2$/yr | Loss g/cm$^2$/yr | cm/yr Loss in depth |
|---|---|---|---|---|
| 316 SS-1 | 0-1 | 0.048 | 0.0079 | 0.001 |
| 316 SS-1 | 0-4 | 0.015 | 0.0024 | 0.0003 |
| 316 SS-2 | 0-4 | 0.015 | 0.0024 | 0.0003 |
| 316 SS-1 | 1-4 | none | none | none |
| 316 SS-1 | 0-8 | 0.011 | 0.0018 | 0.0002 |
| 316 SS-3 | 0-8 | 0.0075 | 0.0012 | 0.0001 |
| 316 SS-1 | 4-8 | 0.0075 | 0.0012 | 0.0001 |
| 316 SS-4 | 0-13 | 0.0108 | 0.0017 | 0.0002 |
| 316 SS-5 | 0-18 | 0.0080 | 0.0012 | 0.00015 |
| cold rolled-1 | 0-1 | 2.75 | 0.458 | 0.058 |
| cold rolled-1 | 0-4 | 1.85 | 0.308 | 0.039 |
| cold rolled 2 | 0-4 | 1.96 | 0.327 | 0.041 |
| cold rolled 1 | 1-4 | 1.56 | 0.260 | 0.032 |
| hot rolled 1 | 0-1 | 13.0 | 2.17 | 0.27 |
| hot rolled 1 | 0-4 | 5.42 | 0.903 | 0.11 |
| hot rolled 2 | 0-4 | 5.19 | 0.865 | 0.11 |
| hot rolled 1 | 1-4 | 2.83 | 0.[illegible] | 0.060 |
| Copper 1 | 0-1 | 1.06 | 0.177 | 0.016 |
| 1 | 0-4 | 0.911 | 0.152 | 0.014 |
| 2 | 0-4 | 1.16 | 0.193 | 0.017 |
| 1 | 1-4 | 1.18 | 0.197 | 0.018 |

Beta 52 (UCRL) File No. 2981

CORROSION OF COPPER AND SILVER IN NITRATE BETA WASH

M. D. Kamen -- 7/5/44

Temperature: 20, 70, and 100°C

Solution: 5% $HNO_3$, Beta wash (4.18 and 2.09% free nitric acid)

Samples: Silver (C.P. foil), copper (pure electrolytic and some from stock)

All samples were immersed.

Time: 1 hour, 20 hours, 68 hours

Procedure: Samples were washed with alcohol and dried at 100°C. Weights could be checked to 0.2 mgm. consistently and agreed to 0.1 mgm. Passivate copper (1) coated with fluroide by exposure to HF fumes. (2) coated with sulfide by exposure to $H_2S$ vapor from sodium sulfide solution. Pure silver can be considerably passivated to nitric by the formation of a chloride film. It is superior to copper for use in apparatus subjected to nitric-chloride corrosion. Characteristics of

[redacted]

ordinary grades of silver have not been investigated.

Whenever a protective film was present, it was washed and dried without removing the film, then weighed. After this, the film was removed with fine emory and weighed. In case of silver and some cases of copper, ammonia was used to completely remove the film. The coating was analyzed for Tuballoy in all cases.

Results:

Table I

Loss in mgms/decimeter$^2$

| | Temperature | 20°C | 70°C | 100°C |
|---|---|---|---|---|
| 5% $HNO_3$ 1 hour | Cu | 11.0 | 35 | >5000 |
| | Ag | <2.4 | 43 | >12000 |

In water (at all temperatures shown) no detectable corrosion ( 2.4 mgm/dm$^2$ per hour) resulted. Note little difference as regards corrosion rate in nitric.

Table II A

Wash solution containing 4.18% free nitric acid at 20°C

20 hrs. Cu 17 mgm/dm$^2$ loss (8.5 + 48 hrs. Cu 1460 mgm/dm$^2$ loss (30.4)

Ag 49 mgm/dm$^2$ gain(2.5) Ag 300 mgm/dm$^2$ loss (6.2.)

Rates per hour in parentheses.

Total corrosion (68 hours) 1000 mgm/dm$^2$ - Ag Cu 1600 mgm/dm$^2$

Table II B

Same experiment done in 2.09% Nitric Acid

20 hrs. Cu 5.55 mgm/dm$^2$ loss(2.7) + 48 hrs. Cu 150 mgm/dm$^2$ loss (3.1)

Ag 74.0 mgm/dm$^2$ gain(3.7) Ag 2 mgm/dm$^2$ gain(.04)

Film in the dilute acid was much more tenacious and homogeneous than more concentrated acid. When an attempt was made to clean the copper with ammonia, some dituballoy was precipitated on the copper, as a yellow dituballate. It had to be scraped off and gave strong qualitative test for T but no test for other metal was present. The [redacted] AgCl film formed on silver contained no T (<10 mgm/dm$^2$). The

experiments on possible passivation of copper with fluoride or sulfide are given in Table III.

Table III

Corrosion Rates (mgm/dm$^2$ per hr.)

| | | a. Cu coated with Fluoride | b. Cu coated with sulfide |
|---|---|---|---|
| 26-1/2 hr: | sample I | .075 | .054 |
| | sample II | .078 | .110 (coat flaked) |
| | control | .054 | .054 |
| 43 hr: | sample I | .160 | .031 |
| | sample II | .148 | ---- |
| | control | .056 | .056 |

Fluoride gave no protection in solutions containing beta wash and nitric-- corrosion rate increased. Attempts to coat the samples by a wet procedure failed to produce protective films. It is doubtful that the procedures described will be of use as it is considered necessary to clean copper between runs, which would mean removal of film with consequent apparent high corrosion loss.

Chem S-89

CORROSION TESTS ON GOLD ALLOY AND ENAMELLED IRON

Ross Cummings

1. Gold Alloys: Small pieces of rolled sheet:
No. 141 -- 14 K white gold
No. 142 -- 14 K yellow enamel
No. 143 -- 20 K gold

Test solutions: $TCl_4$ Sol:

Samples immersed in 0.47 M $TCl_4$ solution for 25.4 hours at room temperature. No loss in weight or change in appearance.

$HNO_3$: Samples immersed in 2N $HNO_3$ for 5 hrs. at 65-70°C. Loss in weight, no change in appearance.

| | Metal | ipy |
|---|---|---|
| $HNO_3$: | 143 | none |
| | 142 | 0.0005 |
| | 141 | 0.016 |
| $TCl_4$ Vapor | 143 | 0.0000005 |
| | 142 | 0.0000024 |
| | 141 | 0.0000010 |

[redacted]

in vacuum; The samples became discolored darker. 20 K Gold the least.

2. Enamelled Iron: Specimens were 3-3/8" x 2-1/16" Base 18 ga "enamelling iron" with cobalt ground coat and with at least 2 coats of white sign enamel all over.

Nitric Acid Specimen cleared in $CCl_4$, dried, weighed and immersed in 2N $HNO_3$ at 65-70°C for 5 hours. The enamel became opaque and chalky clear through to the base metal. It is soft enough to scratch with the finger nail. It flaked off the edges so that the metal is attacked. Loss in wt. 2.4 g or 0.16 g/sq. in.

$TCl_4$ Solution: Immersed in 0.47M $TCl_4$ for 24 hours at room temperature. Stained pale green and the coating was crazed all over. It has been softened so it can be scratched off (fingernail), although not through the base coat except at the edges. Loss 1.4 g or 0.1g/sq.in.

$TCl_4$ Vapor: Vacuum -- regular procedure: The enamel is slightly yellowed and its surface has acquired an iridescent film. It seems to be hard and in good condition. Total loss in weight, 0.0068 g or 0.0005 g/sq. in.

Chem S-92 File No. 3146

CORROSION TESTS

Ross Cummings, C. Hollingshead - - 4/3/43

Method: Samples cleaned in $CCl_4$, dryed and weighed. In the nitric acid tests they were immersed in 2N nitric acid for a definite time (1-4 hours), Temperature 70°C. Washed in water, dried and weighed. In the TCl solution, the clean weighed samples were immersed in 0.47M $TCl_4$ at room temperature.

Material and Results: Penetration (ipy)

Everdur sheet from American Brass Company

$TCl_4$ test 0.109 color redder, surface etched.

The following samples from the Westinghouse E & M Company

P.D.S. 7610 Everdur plate, welded with Areway yellow shielded bronze weld; $TCl_4$ test plain 0.122 welded 0.118 color redder, surface etched. Black coating on weld.

P.D.S. 5071 Manganese Steel 7-8.5% Ni, 10.30-12.50% Mn, 0.25-0.40%C welded with 18-8 Cb rod.

$TCl_4$ test plain .090 welded 0.106
$HNO_3$ test plain 19.7 welded 20.5 non-magnetic

The following steels received from Westinghouse E & M. Co. manufactured by Crucible Steel Company, and welded with 18-8 Cb. rod.

K7 Type 310 Stainless Steel. Heat No. 925098

$TCl_4$ test plain 0.096 welded 0.105
$HNO_3$ test plain 0.80 welded 0.58 non-magnetic

KA2ST Type 321 Stainless Steel. Heat No. 621034

$TCl_4$ test plain 0.086 welded 0.104
$HNO_3$ test plain 0.0124 welded 0.055 non-magnetic

The welded specimen is more magnetic than the blank.

KA2CSB Type 347 Stainless Steel Heat No. 13455

$TCl_4$ test plain 0.080 welded 0.114
$HNO_3$ test plain 0.0088 welded 0.037 non-magnetic

Type 329 S.S. Heat No. 81704

$TCl_4$ test plain .0078 welded .0091
$HNO_3$ test plain .0081 welded .043

Type 316 S.S. Heat No. 95011

$TCl_4$ test plain .000113 welded .00266
$HNO_3$ test plain .0115 welded .041

Corrosion of Welded Molybdenum Stainless Steel

Material: Mo 18-8 Stainless Steel -- sandblasted specimens (0.2" x 1" x 4") included the weld seam were immersed.

Temperature: 65 - - 70°C ($HNO_3$), room temperature ($TCl_4$)

Time: Definite time (1-4 hours)

Solutions: 2N $HNO_3$, and 0.47M $TCl_4$

Procedure: The samples were cleaned in $CCl_4$, dried and weighed. Immersed in the solutions. Washed in water, dried, and weighed.

Results:

[redacted]



Results:

Exposure to 2N $HNO_3$ at 65° - 70°C

| | |
|---|---|
| Heat-treated weld | 0.20 ipy |
| Heat-treated blank | 0.79 |
| Weld not heat-treated | 0.024 |
| Blank | 0.0088 |

Exposure to 0.47M $TCl_4$ at room temperature

| | |
|---|---|
| Heat-treated weld | 0.100 |
| Heat-treated blank | 0.094 |
| Weld not heat-treated | 0.017 |
| Blank | 0.003 |

## CORROSION OF ANODIZED ALUMINUM

Material: 24.89 sq. in. piece of 2S rolled Aluminum with surface treatment, called Alumilite No. 204 (Immersed).

Temperature: Room Temperature

Time: 18.2 hours

Solution: $TCl_4$

Results:

| Time | Loss in wt. -- grams | Penetration -- ipy |
|---|---|---|
| 1st hour | 0.0080 | 0.00031 |
| 2nd hour | 0.0283 | 0.0011 |
| next 16.2 | 1.0035 | 0.25 |

Corrosion starts slowly but accelerates. This (18.2 hours) rate is approximately half the rate for pure Aluminum. At the end of the test, the plate was covered with a white coating with many dark specks.

Chem S-137 File No. 606

## CORROSION OF 18-8 STAINLESS STEEL

Ross Cummings - 5/20/43

Material: Stainless steel type 302, approximately 3" x 3" x 0.022" were completely immersed in closed glass jars.

Solutions: Made from distilled $TCl_4$, dissolved in tap water and C.P. acids (see table).

[redacted]

[redacted]



Time: 16.33 and 39.83 hours

Temperature: 20°C and 88°C

Procedure: Samples cleaned with $CCl_4$, and washed with hot water after exposure.

Table I

Results:

| Solution | Temperature °C | Time in Hours | Penetration - ipy |
|---|---|---|---|
| 5% $HNO_3$ 1% $TCl_4$ | 88 | 16.33 | 0.00057 |
| 5% $HNO_3$ 1% $TCl_4$ | 20 | 39.83 | 0.00013 |
| 5% $HNO_3$ 1/10% $TCl_4$ | 88 | 16.33 | 0.00042 |
| 5% $HNO_3$ 1/10% $TCl_4$ | 20 | 39.83 | 0.00014 |
| 67% $HNO_3$ 1% $TCl_4$ | 88 | 16.33 | 0.020 |
| 67% $HNO_3$ 1% $TCl_4$ | 20 | 39.83 | 0.00025 |
| 67% $HNO_3$ 1/10% $TCl_4$ | 88 | 16.33 | 0.013 |
| 67% $HNO_3$ 1/10% $TCl_4$ | 20 | 39.83 | 0.00023 |
| 10% $H_2SO_4$ 1% $TCl_4$ | 20 | 39.42 | 0.037 |

A-3000 File No. 2298

Corrosion Research - Tuballoy and Alloys

July 1, 1944

Metal: Tuballoy with smooth ground surface

Solution: Distilled water and $1 \times 10^{-5}$ $H_2O_2$

Temperature: 35, 50, 60, 70, 80 and 90°C

Time: 8 to 38 hours

[redacted]

[redacted]



Procedure: Tests were made in open 400 ml beakers, over coil-like hot plates with no stirring and addition to hold constant volume.

Results:

Table I

Corrosion Rate of Tuballoy in Water and in Dilute Hydrogen Peroxide, pH 6.0 - 6.5.

| Temp. °C | Weight loss, mg/cm$^2$/hr ** In distilled water | In $1 \times 10^{-5}$N $H_2O_2$ (Superoxol added to distilled water) |
|---|---|---|
| 90 | 0.7 (.4 - .8)* | 0.6 (.06 - 1.0) |
| 80 | 0.2 (.05 - .4) | 0.03 (.02 - .05) |
| 70 | 0.012 (.006 - .029) | 0.015 (.009 - .022) |
| 60 | 0.011 (.002 - .023) | 0.007 (.005 - .010) |
| 50 | 0.005 (.001 - .012) | 0.005 (.004 - .010) |
| Room temp. 35 - 38 | 0.0011 (.0005 - .0022) | 0.0020 (.0015 - .0025) |

* These values in parentheses give the range of experimental results.

** 1 mg/cm$^2$/hr is equivalent to a uniform surface loss of .015"/mo.

Varying results of the 9-18 tests, and errors due to change in the homogeneity of the metal gave proof that accurate results are difficult to ascertain.

Tuballoy Alloys

Metals: See Table II and Ni-T Alloy

Solution: $4 \times 10^{-5}$N $H_2O_2$ and $3 \times 10^{-5}$N $H_2O_2$, 2 ppm $Cl^-$ (pH = 6.0)

Temperature: 90°C

Time: 8-38 hours

Procedure: Same as above

Results: All results are given in Table II except for the nickel alloys. It was found that only these alloys showed any promising corrosion resistance. (See MUC - JED #28 (N 846), #1.9 (N 365) and #13 for these results)

[redacted]

CORROSION OF LOW PERCENTAGE ALLOYS OF TUBALLOY AT 90°C.

[redacted]

| Sample No. | Alloying Element and its atomic percent in alloy | Corrosion Rate, mg/cm²/hr. Loss in 4 x 10⁻⁵ N $H_2O_2$ pH = ca. 6.0 | Corrosion Rate, mg/cm²/hr. Loss in 3 x 10 10⁻⁵ N $H_2O_2$ 2 ppm Cl |
|---|---|---|---|
| 274 | Cu - 1/4 | 0.3 (.08-.57) | 0.58 (.48-.62) |
| 273 | 1/2 | .23 (.14-.30) | .3 (.08-.44) |
| 215 | 1 | .4 (.11-.65) | .9 (.3-1.5 ) |
| 218 | 5 | .2 (.10-.40) | .4 (.13-.62) |
| 220 | 10 | .22 (.06-.29) | .42 (.26-.56) |
| 227 | 95 | Sample swelled with wt. gain, then broke up. | Sample swelled & broke up. |
| 219 | 99 | .077(.004-.012) | .007(.002-.017) |
| 265 | Sn - 1/4 | 0.2 (.07-.29) | 0.46 (.32 -.67) |
| 262 | 1/2 | .9 (.3-1.3 ) | 1.4 (.8 -2.2 ) |
| 260 | 1 | Sample broke up | Sample broke up |
| 264 | 5 | Sample broke up | Sample broke up |
| 260 | 10 | Disintegrated rapidly | Disintegrated rapidl |
| 270 | Cr - 1/4 | 0.6 (.16-.85) | 0.8 (.2-1.4 ) |
| 269 | 1/2 | .3 (.11-.43) | .4 (.18-.52) |
| 211 | 1 | .7 (.55-.78) | .6 1 det. |
| 214 | 5 | .31 2 det. | .36 2 det. |
| 210 | 10 | .08 (.03-.13) | .5 2 det. |
| 209 | 15 | .06 (.04-.08) | .22 2 det. |
| 228 | 20 | .02 (.01-.03) | .22 2 det. |
| 268 | 50 | .03 (.02-.05) | .04 (.03-.06) |
| 293 | Si - 1/4 | 0.24 (.18-.36) | 0.51 (.46-.56) |
| 292 | 1/2 | .8 (.59-.87) | .9 (.6-1.3 ) |
| 277 | 1 | .7 (.45-.93) | .8 (.5-1.4 ) |
| 276 | 5 | .57 (.53-.60) | .3 2 det. |
| 273 | 10 | .34 2 det. | ------ |
| 242 | Al - 1/8 | .42 (.38-.51) | 0.4 (.18-.73) |
| 243 | 1/4 | .2 (.07-.48) | ------ |
| 241 | 1 | .48 (.40-.54) | ------ |
| 239 | 5 | Broke up-intergranular attack | Broke up-intergranular attack |
| 232 | Be -1/4 | 0.91 (.82-1.0) | 0.5 2 det. |
| 231 | 1/2 | .3 (.09-.55) | .8 (.4-1.2) |
| 229 | 5 | .50 (.41-.55) | .5 2 det. |
| 230 | 10 | .80 (.66-.89) | .56 2 det. |
| 297 | Sb - 10 | 1.5 (1.4-1.6) | 2.0 (0.4-3.6) |
| 244 | Pb - 1. | Lose wt. rapidly, went to pieces | |
| 246 | 5 | Ditto. | |

[redacted]

[redacted]



Chem S-4 File No. 3101

## Corrosion Studies

Chemical Group - September 1942

**Material:** See Table

**Temperature:** 450°C

**Time:** 140 hours

**Media:** Tuballoy Chloride and Bromide vapor

**Method:** Each sample sealed off in a pyrex tube with the sample suspended above the medium by means of a constriction. Tubes heated in an oven and after opening the metals were washed with water and weighed.

**Results:** The first column of the bromide results are from the first run with this material, using the Bureau of Standards product without preliminary sublimation. In spite of the rather thorough heating before sealing off, a considerable pressure (HBr?) was built up during the run, so some of the tubes exploded violently upon opening. All the other tests were sublimed which gave almost no gas.

Table I

| Material | Chloride | mg/cm$^2$ | Bromide | | |
|---|---|---|---|---|---|
| Pyrex | | | 0.1 | | |
| Pt | 0.1 | | 0.3 | 0.0 | |
| Au | 0.6 | | 0.6 | 0.1 | |
| Mo | 0.1 | 0.1 | 1.7 | | |
| W | | 0.5 | 1.3 | | |
| Ni | 0.4 | 0.3 | 2.5 | 1.1 | 0.9 |
| Nichrome | 3.9 | | 2.1 | 1.4 | |
| Monel | | 0.6 | 9.1 | | |
| Al | 1.7 | | 11.5 | | |
| Stainless Steel | | 3.6 | 2.5 | 5.8 | |
| Fe | 5.5 | 4.7 | 8.4 | 9.5 | |
| Ag | 3.4 | | 18.0 | | |
| Cu | 5.9 | | 7.1 | | |
| Be | | 16.2 | 16.0 | | |

[redacted]

[redacted]



Other tubes with the metal directly in contact with the solid were made. These gave, in general, greater losses, but in about the same order.

The corrosion was small for Pt, Au, Mo (except possibly in the bromides), pyrex, W, Ni, nichrome. (Boiling in liquid chlorides we found that $ThO_2$ and alundum were badly attacked, whereas BeO, graphite and quartz were not.)

Chem S-244 (UCRL) File No. 3180

CORROSION TEST IN CHLORINE ATMOSPHERE AT 500°C

Nelson Garden - 1/28/44

Temperature: 500°C

Pressure: 1 mm (approximately)

Time: 17 hours

Procedure: Passed in $CO_2$ for 1/2 hour (heating up period), then passed in $Cl_2$ for 17 hours.

Results:

| Sample | Approximate Analysis | Disappeared | Poor | Fair | Worth Further Treating |
|---|---|---|---|---|---|
| Pt | 10% Ir. | | | | X |
| Gold | 20 K | | | X | |
| Cb | | X | | | |
| Ta | | X | | | |
| Mo | | X | | | |
| Monel | Cu Ni | | X | | |
| Stainless | 18% Ni, 8% Cr | | | X | |
| Nichrome | 80% Ni, 20% Cr | | | X | |
| K-42-B | 45% Ni, 23% Co, 20% Cr 2% Ti | | | X | |
| Inconel | Ni 78.4%, Cr 13.1%, Fe 7.2% | | | | X |
| Nickel | | | | | X |
| Hastelloy B | | | X | | |
| Hastelloy C | | | X | | |
| Chromel A | | | | | X |
| Refractalloy | | | | X | |
| Discalloy | | | | X | |

| Commercial | Cr | Ni | Si | Ti | Mn | Mo | | | |
|---|---|---|---|---|---|---|---|---|---|
| 150 | 23.9 | 20.9 | 2.06 | 1.79 | — | — | X | | |
| 180 | 24.4 | 2.9 | .47 | — | 1.17 | — | X | | |
| 190 | 17.6 | 13.2 | .55 | — | 1.69 | 2.25 | | X | |
| 200 | — | 8 | — | — | 11.00 | — | X | | |

[redacted]

[redacted]



Stainless stood up under pure $Cl_2$ but failed under other metallic chlorides mixed with $Cl_2$ atmosphere (followed by Cu bearing alloy failed)

Further Tests:

| Sample | Original wt. | After 17 hrs. | Loss |
|---|---|---|---|
| Ni | 2.5282 | 2.5226 | .0056 |
| Ni | 2.8611 | 2.8556 | .0055 |
| Inconel | 2.3149 | 2.3091 | .0058 |
| Inconel | 2.3319 | 2.3249 | .0070 |

Washed (methyl Alcohol) and machined before and after $Cl_2$ coating removed.

Chem S-527 (ROCH) File No. 731

## CORROSION IN THE LIQUID PHASE REACTION

George DeCroes - 8/12/43

**Metals:** Stainless steel type 304 and 316, 2" x 5/16" x 1/16" (A size too small to give accurate or precise results. The actual rates should be lower) Weld bead, polished smoother and dressed. Two test strips were annealed for 15 minutes (304 at 1850-1900°F and 316 at 1900-1950°F). Pickeled 5 minutes (too long as they appeared pitted) passivated at 25°C for 30 minutes in 30 vol., % $HNO_3$.

**Temperature:** 130°C

**Time:** 4 hours

**Medium:** 5 g of $RO_3$, 2 g $TCl_5$, and 50 cc of $CCl_4$. Other tests with 5% solution $Cl_2$ in $CCl_4$ as a solvent.

**Method:** Samples sealed in pressure tubes containing the media.

**Results:**

Reaction in $CCl_4$ without $Cl_2$

| Sample | Rate (Mg loss dec 2/24 hrs) |
|---|---|
| 304 | 66 |
| 304 annealed | 162 |
| 316 | 27 |
| 316 annealed | 40 |

Reaction in $CCl_4$ with $Cl_2$

| Sample | Rate |
|---|---|
| 304 | 30 |
| 304 annealed | 36 |
| 316 | 20 |
| 316 annealed | 13 |

[redacted]

[redacted]



BT-11 File No. 2854

CORROSION OF METALS BY VARIOUS MATERIALS

Progress Report - 11/2/42

Summary: Stainless steel is sufficiently resistant for many purposes, but in many instances chromel A exhibits a greater resistance at high temperatures.

A. Stainless steel 18-8 resistance to fused mixtures of: (1) NaF and $TF_4$ (2) NaCl and $TCl_4$ (3) NaCl, $CaCl_2$, and $TCl_4$, and (4) NaF, NaCl and $TF_4$. When the mole ratio of NaF to $TF_4$ (1) was 1.5:1 or greater, the corrosion of stainless steel was neglibible; with a ratio 1:1 corrosion was excessive. All the mixtures containing $TCl_4$ corroded stainless steel.

A Results:

Table I

Data on the corrosion of Stainless Steel (18-8) by $TF_4$ and $TCl_4$ - Salt Mixtures

| Test No | Composition Mole-Ratio | Highest Temp Reached | Length of Time the Sample was Above 600°C | Weight of Sample Grams | Loss in Weight Mg | Rate of Loss $Mg/cm^2/hr$ |
|---|---|---|---|---|---|---|
| 2 | 1 NaF: 1 $TF_4$ | 1075°C (30 Min) | 6 1/2 hrs | 8.35 | 481 | 10.0 |
| 7 | 1.1 NaF: 1 $TF_4$ | 1100°C (30 Min) | 6 hrs | 6.12 | 350 | 8.0 |
| 5 | 1.5 NaF: 1 $TF_4$ | 1100°C (50 Min) | 8 hrs | 3.82 | 25 | 0.6 |
| 3 | 2 NaF:1 $TF_4$ | 1100°C (40 Min) | 8 hrs | 12.93 | 31 | 0.3 |
| 4 | 2.1 NaCl: 1 $TCl_4$ | 1000°C (60 Min) | 7 hrs | 7.35 | 1000 | 17.3 |
| 6 | 2.1 NaCl: 2.1 $CaCl_2$: 1 $TCl_4$ | 1000°C (10 Min) | 4 hrs | 5.27 | 601 | 23.2 |
| 8 | 1.1 NaF: 1.1 NaCl: 1 $TF_4$ | 1100°C (10 Min) | 4 3/4 hrs | 5.90 | 45 | 2.0 |

B. Corrosion of Stainless Steel, Low Carbon Steel, Pure Nickel and Chromel A in Various Media.

Stainless Steel satisfactory for containers for conversion of $T_3O_8$ to $TCl_5$ by means of $CCl_4$. Chromel A for $TCl_4$ (fused salt mixtures at higher temperature).

[redacted]

B. Results:

Table II

Corrosion of Metals by Various Materials

| Test No | Metal | Corroding Media | Max Temp | Wt Sample Grams | Loss $mg/cm^2/hr$ | Remarks |
|---|---|---|---|---|---|---|
| 1 | Stainless Steel 18-8 | $S_2Cl_2$ at B.P. | 138°C | 2.96 | 0.00 | No corrosion |
| 2 | Stainless Steel 18-8 | Reaction Mixture $T_3O_8$ and $CCl_4$ | 147°C | 6.395 | 0.15 | Mixture contained $TCl_4$, $TCl_5$, $CCl_4$, $COCl_2$, $Cl_2$, $FeCl_3$, $C_2Cl_6$, etc |
| 3 | Same as 2 | Same as 2 | 128°C | 5.23 | 0.14 | Mixture contained: $TCl_5$, $CCl_4$, $COCl_2$ |
| 4 | Same as 2 | Pure $TCl_4$ | 500°C | 1.63 | 7.6 | Corrosion was excessive |
| 5 | Low carbon drawn steel | Same as 2 | 128°C | 8.65 | 1.25 | Same as No. 3 |
| 6 | Pure Nickel | $S_2Cl_2$ Vapor | 500°C | 2.6 | 6.8 | Badly corroded |
| 7 | Pure Nickel | Fused $TF_4$ | 1050°C | | | Tube ruined |
| 8 | Chromel A | $S_2Cl_2$ Vapor | 500°C | 32.0 | 1.22 | Attacked only mildly |
| 9 | Chromel A | Fused salt mixtures in table 1 runs 5, 6, 7, 8 | 1100°C | | (1.1) | Greatest loss in run (7) in most cases corrosion negligible |

Chem S-165 File No. 634

Corrosion of Metals in Contact With Hot $TCl_4$

Ross Cummings - 6/25/43

Time: 70 hours

Temperature: 450°C under vacuum

Medium: Solid $TCl_4$

Metals: (See Table) Chromel wire, No. 22 gauge x 4'; the steel sheets were 3" x 1/4" by various gauges. All samples were buried in the $TCl_4$.

[redacted]

[redacted]



Procedure: Samples recovered after run, washed in cold water, dried and weighed.

Results:

| Metal | Penetration in inches per run |
|---|---|
| Chromel wire | 0.000094 |
| Stainless Steel: | |
| 18-8 from Westinghouse | 0.000112 |
| Type 302 | 0.000127 |
| Type 310* | 0.000158 |
| Type 316* | 0.000082 |
| Type 316° | 0.000113 |
| Type 317° | 0.000111 |
| Type 321* | 0.000114 |
| Type 329* | 0.00018 |
| Type 347* | 0.000069 |
| Type 347° | 0.000099 |

* Made by Crucible Steel Company
° Maker unknown

Chem S-144 File No. 613

## Corrosion of Metals In Contact With $TCl_4$

Ross Cummings - 5/25/43

Method: Samples were placed in crude $TCl_4$ in the large still. At the end of this run they were recovered, washed with hot water and weighed.

Results: All metals show evidence of corrosion either as discoloration, formation of coating or etching. From loss in weight was calculated the penetration in inches in this run.

| Metal | Penetration Inches |
|---|---|
| Stainless Steel Resistal KA2 (Type 302) | 0.00045 |
| Nickel | 0.00063 |
| Hastelloy B | 0.00042 |
| Hastelloy C | 0.00041 |
| Inconel | 0.00063 |
| Ta | 0.00044 |
| Mo | 0.00037 |
| Silver | 0.0032 |
| Cu | 0.0014 |
| Gold Alloys | |
| Yellow Enamel | 0.0030 |
| 14K White | 0.00074 |
| 20K | 0.000037 |

[redacted]

[redacted]

Chem S-508 (ROCH) File No. 717

Corrosion Tests of Metals in the Presence of $TCl_4$ at 350-450°C

J. W. Gates, Jr - 6/11/43

Procedure: Corrosion strips were weighed and then buried in approximately 70g of $TCl_4$ and heated 24 hours at 350-450°C in a slow stream of nitrogen. The strips were removed and weighed.

Results:

| Sample | % Loss | Remarks |
|---|---|---|
| Monel | Too bad to measure | |
| Nickel | Too bad to measure | |
| Copper | Disappeared completely | |
| Stainless Steel type 304 | 1.97 | |
| First repeat | 1.83 | |
| Stainless Steel type 316 | .05 | |
| First repeat | .4 | better sample |

RL 4.6.297 File No. 2163

Corrosion of Metals By $TCl_4$ Vapor

P. H. Davidson - 12/11/42

Material: Disks 2.125 inches diameter were cut from sheets of copper, monel, type 304 and 321 stainless steel. Thickness, 0.029 - .061 in.

Procedure: Rubbed with abrasive cloth, washed with acetone, water and placed in 1/2% $H_2O_2$-2% HCl solution for 5 minutes. Washed in water, dried and weighed. Placed in pyrex tube about 1 inch apart, and $TCl_4$ covered the sample and filled the space between them. System was under vacuum--$10^{-4}$ to $5 \times 10^{-5}$ mm of Hg. When $10^{-3}$ was reached, heaters were turned on. Total exposure time was recorded from temperature 490°C until the heaters were turned off. When the apparatus was cold, dry air was admitted and samples removed, washed in separate portions of distilled $H_2O$ followed by a 2-minute washing in boiling distilled water. Dried, cooled, and weighed. Initial Alpha count was made. Each sample was placed

[redacted]

[redacted]



in 50 cc 1/2% $H_2O_2$-2% HCl solution long enough to dissolve a desired layer. Washed, dried, weighed. Time was 12, 24 and 72 hours.

Results: The stainless steel showed a significant increase in penetration between 12 and 72 hours exposure. Copper is the only one that showed a significant increase with increased exposure.

Taken from Table 5.

The Amount of Tuballoy in A Metallic Surface

| Metal | Tuballoy contained in: 1st 1/10 Mil Micrograms /in$^2$ | 1st 2/10 Mil Micrograms /in$^2$ | Entire Sample Micrograms/in$^2$ | Vapor Corrosion |
|---|---|---|---|---|
| Copper | 126 | 142 | 153 | 68.80 |
| Type 304 | 52 | 55 | 55 | 3.05 |
| Type 321 | 23 | 25 | 25 | 3.78 |
| Monel | 6 | 7 | 7 | 3.08 |

Chem S-101 File No. 582

Corrosion of Various Materials By Tetrachloride at High Temperatures

P. H. Davidson - 4/12/43

Metals: Chromium plate directly on copper

Molybdenum 18-8 stainless steel

Plain 18-8 stainless steel from 184" metal stock

Cast Herculoy (silicon-manganese-copper)

Cast Everdur (Silicon-copper)

Ni-Resistant (copper-free grade of high Ni cast iron)

Procedure: (1) Cleaned samples with $CCl_4$, dried, cooled and weighed. Heated in vacuo to 450°C for 1 hour. Repeat (1). In the vacuum furnace $TCl_4$ was vaporized and allowed to condense on the specimens in the cold zone. Then the $TCl_4$ was evaporated from the surface of the metals. Total time 1 hour. Temperature 450°C. Cooled, washed in $H_2O$, Rubbed with cotton gauze, washed in $CCl_4$, dried and weighed.

[redacted]

[redacted]



Results:

| | Remarks | Loss in wt. $gr/in^2/hr$ |
|---|---|---|
| Chromium Plate: | No change in appearance, no blisterings | 0.000405 |
| Molybdenum 18-8 Stainless Steel | | 0.000284 |
| Plain 18-8 Stainless Steel | | 0.000213 |
| Cast Herculoy: | Discolored by heating in vacuo. In the $TCl_4$ treatment a non-adherent black coat was formed. | 0.00239 |
| Cast Everdur: | Discolored by heating in vacuo. In $TCl_4$ same as cast Herculoy | 0.00128 |
| Ni-Resist: | Dark marks like an oxide appeared on this specimen when heated in vacuo. These persisted through the $TCl_4$ treatment. | 0.00022 |

Chem S-122 File No. 593

## Corrosion Tests On Palladium Plate

Ross Cummings - 5/3/43

A. In $TCl_4$ Vapor

Metal: The basis metal is sheet copper plated with 0.002" to 0.003" nickel, followed by 0.0005" gold and finally 0.0005" palladium. The specimens had four degrees of surface finish grading from quite dull and rough to the touch, to a high polish.

Procedure: Specimens were washed with $CCl_4$, dried, weighed, ($W_1$). They were heated in vacuum, to 450°C (840°F) washed in $CCl_4$, dried and weighed ($W_2$). Put in vacuum apparatus and $TCl_4$ vapor condensed on surface and distilled off again at 450°C. Following this treatment (required 1 hour) washed in water, $CCl_4$, dried and weighed ($W_3$). Specimens have a surface area of about 4.5 sq. in.

Results:

| Surface | $W_1$ | $W_2$ | $W_3$ |
|---|---|---|---|
| Rough | 10.7532 grams | 10.7505 grams | 10.7518 grams |
| Med. rough | 9.5498 | 9.5489 | 9.5494 |
| Med. smoother | 11.3803 | 11.3770 | 11.3782 |
| Polished | 9.6916 | 9.6881 | 9.6898 |

These changes in weight are much greater than was observed with nickel plate. All samples were discolored a little yellow. The polished piece was dulled considerably. Small blisters appeared on the roughest specimen.

[redacted]

B. In $TCl_4$ Solution: [redacted]

Four specimens with surface areas 18.75 square in. were submerged in 0.47 molal $TCl_4$ solution, 41 hours at room temperature. All lost weight, from .03 grams to 1.3 grams. All were discolored. The two rougher samples acquired blisters. The polished suffered extensive peeling, the gold plate having broken away from the nickel. No bare copper was visible.

Results: In general all were unsatisfactory against $TCl_4$ vapor or solution.

Chem S-225 (UCRL) File No. 3165

THE CORROSION OF STAINLESS STEEL, NICKEL AND NICKEL-PLATED COPPER BY MOLTEN $TCl_4$

P. H. Davidson - 10/30/43

Procedure: Sample bottles were made and filled with approximately the same amount of $TCl_4$ and subjected to high temperature in an inert atmosphere to duplicate those used to prepare the melted charge for the polatron. Non-volatile residues were determined on those same samples by subjecting them to a temperature of 638°C for 14 hours under a pressure of $1 \times 10^{-4}$ mm of mercury.

Results:

| Container | Penetration (mm) | Non-Volatile Residue |
|---|---|---|
| Stainless Steel | $5.02 \times 10^{-2}$ | 20.4% |
| Stainless Steel | $4.52 \times 10^{-2}$ | 19.1% |
| Glass | $0.02 \times 10^{-2}$ | 3.3% |
| Glass | $0.02 \times 10^{-2}$ | 3.6% |
| Nickel | $0.66 \times 10^{-2}$ | 3.1% |
| Nickel | $0.58 \times 10^{-2}$ | 8.3% |

These data show conclusively that nickel is superior to stainless steel. Nickel-plated copper bottles were tried without success. The nickel plate lifts, exposing the copper surface, which is rapidly attacked by molten $TCl_4$. The thin layer of nickel itself remains partially intact, a qualitative indication of its resistance to corrosion.

I.C.T. gives the Curie point of nickel as 363°C, well below the operating

[redacted]

conditions. It seems improbable that nickel's magnetic properties will cause any difficulty in the operation of the polatron.

CD-F-10 File No. 3055

## Corrosive Action of Tuballoy Tetrachloride on Certain Ferrous Alloys

J. M. Folk, C. D. Susano - 4/12/45

Materials:

| AISI No. | Description |
|---|---|
| 309S | Columbium-stabalized 25% Cr-12% Ni steel |
| 316 | Molybdenum 18% Cr-8% Ni steel |
| 316S | Columbium-stabilized Mo 18%-Cr-8% Ni steel |
| 321 | Titanium-stabilized 18% Cr-8% Ni steel |
| 347 | Columbium-stabilized 18% Cr-8% Ni Steel |
| | Hastelloy C |

Tuballoy tetrachloride was standard Alpha charge material furnished by Dr. Alan Bell.

Procedure: Test specimens, approximately 3 1/2 square inches in area, were cleaned with acetone to remove oil film and scrubbed with a brush using "Calgonite". The specimens were rinsed with water, alcohol and ether, finally dried and weighed. The specimens were placed in a Hastelloy boat as follows:

(1) One inch of charge material
(2) Glass rods
(3) Sample marked #1
(4) One inch of charge material
(5) Glass rods
(6) Samples marked #2
(7) Fill the boat completely with charge material
(8) Glass rods
(9) Samples marked #3 and #4

This system is then placed in the tube furnace. Heated to 500°C and evacuated from 30 to 3 microns, at the end of the run (150 hours).

Results: Most resistant listed first

| Solid $TCl_4$ | Vapor $TCl_4$ |
|---|---|
| 1. Hastelloy C | Hastelloy C |
| 2. 316 | 321 |
| 3. 316S | 347 |
| 4. 321 | 316 |
| 5. 347 | 316S |
| 6. 309S | 309S |

TABLE I

Loss in Weight of Some Ferrous Alloys, Resulting From Their Exposure to $TCl_4$ and Vapor, at a Temperature of 500°C and Low Pressure for 150 Hours

| Specimen | Phase | Area Sq. Cms. | Loss in Wt. Gm/Sq.Cm. |
|---|---|---|---|
| 309S (1) | Solid | 9.074 | 0.03099 |
| (2) | Solid | 9.022 | 0.05205 |
| (3) | Vapor | 9.096 | 0.02146 |
| (4) | Vapor | 9.022 | 0.02026 |
| 316 (1) | Solid | 8.433 | 0.01435 |
| (2) | Solid | 8.331 | 0.01757 |
| (3) | Vapor | 8.308 | 0.02779 |
| (4) | Vapor | 8.278 | 0.02834 |
| 316S (1) | Solid | 9.343 | 0.01994 |
| (2) | Solid | 9.343 | 0.02106 |
| (3) | Vapor | 9.343 | 0.02376 |
| (4) | Vapor | 9.343 | 0.03531 |
| 321 (1) | Solid | 10.315 | 0.02455 |
| (2) | Solid | 10.467 | 0.02516 |
| (3) | Vapor | 10.599 | 0.02028 |
| (4) | Vapor | 10.599 | 0.01898 |
| 347 (1) | Solid | 8.775 | 0.03113 |
| (2) | Solid | 8.733 | 0.03380 |
| (3) | Vapor | 8.882 | 0.01966 |
| (4) | Vapor | 8.882 | 0.02248 |
| H (1) | Solid | 8.372 | 0.00895 |
| (2) | Solid | 8.423 | 0.00966 |
| (3) | Vapor | 8.372 | 0.00768 |
| (4) | Vapor | 8.423 | 0.01212 |

[redacted]



JRC-18 (ML-43)

## PROGRESS REPORT ON CORROSION TESTS IN $TCl_4$

Pvt. Donald R. Mash - 5/26/45

Test run 150 hours at 500°C in both solid and vapor. All samples were annealed. Also tests were run in the Alpha still at 700°C for 12 hours.

### Exposed To $TCl_4$ and $TCl_4$ Vapor for 150 Hours at 500°C

| Specimen | Phase | Penetration (ipy) |
|---|---|---|
| 309S | Solid | .0900 - .1515 |
| | Vapor | .0625 - .0590 |
| 316 | Solid | 0.0418 - 0.0511 |
| | Vapor | 0.0810 - 0.0826 |
| 316 Cb | Solid | 0.0592 - 0.0614 |
| | Vapor | 0.0691 - 0.1025 |
| 321 | Solid | 0.0715 - 0.1732 |
| | Vapor | 0.0590 - 0.0552 |
| 347 | Solid | 0.0905 - 0.0982 |
| | Vapor | 0.0573 - 0.0656 |
| Hastelloy C | Solid | 0.0229 - 0.247 |
| | Vapor | 0.0196 - 0.0310 |

### Penetration of Alloys In Alpha Still For 12 Hours At 700°C

| | | |
|---|---|---|
| Hastelloy C | Solid | 2.39 - 1.73 |
| | Vapor | 0.895 - 0.776 |
| 316 | Solid | 8.87 - 9.44 |
| | Vapor | 2.47 - 3.06 |
| 347 | Solid | 9.14 -10.46 |
| | Vapor | 2.72 - 2.85 |
| 316S | Solid | 6.27 - 5.53 |
| | Vapor | 2.46 - 2.66 |

[redacted]

[redacted]



RL 4.6.289 File No. 3278

THE CORROSION RESISTANCE OF NICKEL ALLOYS TO $TCl_4$ VAPOR

P. H. Davidson, I. Streeter - 9/5/44

Pressure: Between $2 \times 10^{-4}$ and $5 \times 10^{-5}$ mm Hg.

Sample: Analysis:

| | Thickness | % Cr | % Ni | % Fe | Other Constituents |
|---|---|---|---|---|---|
| 304 Stainless Steel | 0.050 in | 17.8 | 11.7 | 67.6 | |
| Inconel | 0.010 | 13.1 | 78.0 | 6.9 | |
| Nichrome | 0.020 | 17.0 | 57.5 | 24.1 | |
| Monel K | 0.063 | — | 64.3 | 2.0 | 32.4% Cu 0.1% Al |
| Nickel | 0.005 | — | 97.93 | — | |

Size 3" x 1/4" and thickness stated above. Acetone and water wash, samples were then subjected to 350°C for two hours under high vacuum. Considerable loss in weight occured. Washed in concentrated HCl for five minutes, then several times in distilled water. Dried at 125°C for 1/2 hour. Individual weights accurate to 0.1 mg. Weight loss accurate to 0.2 mg.

The charge material used was material normally used to load charge bottles. Three samples were run at the same time.

Results: See table on page 58.

[redacted]

## Corrosion Rates (Gram per in.$^2$/hr x $10^5$)

| Run | Charge Temp | Sample Temp. | Expos. Time Hours | Charge Material | Metal Sample From | Type 304 Stainless Steel | Inconel | Ni-Chrome | Monel K | Nickel |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 440 | 447 | 16.2 | Bakeout | - | 6.2±2.4 | 4.1±1.6 | 6.2±2.7 | 5.4±1.5 | 3.3±1.2 |
| 2 | 434 | 450 | 14.0 | " | - | 2.4±2.0 | 0.0±0.9 | 0.0±1.6 | 1.2±0.9 | 0.2±1.0 |
| 3 | 437 | 481 | 18.8 | " | - | 8.0±1.5 | -0.9±0.9 | -0.8±1.5 | 1.2±1.5 | 0.2±0.9 |
| 4 | 441 | 518 | 16.5 | " | - | 13.5±0.7 | -1.6±0.8 | -0.7±1.3 | 0.0±0.8 | -1.0±1.2 |
| 5 | 478 | 519 | 19.4 | " | - | 16.3±2.9 | -1.0±1.0 | -2.3±1.7 | 3.2±1.6 | -1.7±1.4 |
| 6 | 516 | 523 | 19.2 | " | - | 24.5±6.7 | 0.7±1.0 | 0.3±2.1 | 21.4±2.9 | -0.2±0.8 |
| 7 | 476 | 483 | 14.2 | " | - | 16.0±2.0 | -1.2±1.2 | -1.2±2.0 | 2.6±1.8 | -0.7±1.2 |
| 8 | 481 | 484 | 16.5 | " | Run 7 | 0.7±1.0 | 1.4±1.0 | 1.0±1.7 | 1.9±1.1 | 0.0±1.2 |
| 9 | 476 | 484 | 15.1 | " | 3 | 0.0±0.7 | 1.8±1.3 | 1.1±1.9 | 2.1±1.2 | -0.4±0.9 |
| 10 | 477 | 484 | 15.0 | " | 9 | 0.7±0.7 | 0.4±0.9 | 1.1±1.9 | 0.6±1.0 | 0.9±0.9 |
| 11 | 476 | 485 | 19.8 | " | 10 | 0.6±0.7 | 0.3±0.7 | 0.0±1.1 | 0.6±1.0 | 0.0±0.7 |
| 12 | 446 | 449 | 16.5 | Direct from Sublimer | - | 24.0±1.7 | 19.0±3.2 | 19.0±4.1 | 21.0±3.0 | 16.2±1.6 |
| 13 | 443 | 443 | 15.2 | Contaiminated with $H_2O$ | - | 1.8±1.5 | 1.1±1.1 | 1.1±1.8 | 2.3±1.0 | 0.7±1.1 |

Conclusions: (1) The initial corrosion rate of the nickel alloys studied decrease with time because of the formation of a protective film of pure nickel.

(2) It is probable that the speed with which this film forms is roughly proportional to the nickel content of the alloy.

(3) Inconel, nickel, and nichrome show negligible corrosion at all temperatures between 440°C and 520°C. Type 304 Stainless Steel and monel K show significant corrosion, that of 304 being higher than monel K at all temperatures less than 520°C.

(4) Type 304 Stainless Steel compares very unfavorably with the others studied.

Chem S - 176 File No. 645

CORROSION OF LEAD AND TIN BY $T_4$ VAPOR

Ross Cummings - 7/27/43

Time: 1 hour heating (1 hour cooling)

Temperature: 480°C in vacuum

Results: Washed black coating fairly clean with water. Tin (same button form) loss 0.64% weight, lead (foil crumbled a round edge and became rough and pitted) loss 9.60% weight.

A-3190 File No. 2194

CORROSION OF STAINLESS STEEL AND NICKEL BY $TuCl_4$ VAPORS

F. H. Spedding - 11/25/44

Sample: Stainless steel and nickel of the following dimensions, respectively:

| Weight | Area | Weight | Area |
|---|---|---|---|
| (1) 5.07g. | 8.25 $cm^2$ | (1) 4.75g. | 8.55 $cm^2$ |
| (2) 2.54g. | 4.40 " | (2) 4.31g. | 7.56 $cm^2$ |
| (3) 2.59g. | 4.40 " | | |
| (4) 3.09g. | 5.06 " | | |

Medium: $TCl_4$ Vapor

Temperature: 500°C in vacuum

Results:

Table I

| Sample | Experiment I 28 hours | II 72 hours | III 40 hours | IV 16 hours | V 22 hours | VI 39 hours |
|---|---|---|---|---|---|---|
| Stainless Steel | | | Loss in weight - $g/cm^2$ | | | |
| (1) | - | 0.029 | 0.0084 | 0.0075 | 0.0023 | 0.011 |
| (2) | 0.100 | 0.027 | - | - | - | - |
| (3) | 0.075 | 0.030 | 0.0077 | 0.0068 | 0.0025 | 0.008 |
| (4) | - | - | - | 0.0071 | 0.0028 | 0.0138 |
| Nickel | | | | | | |
| (1) | - | - | 0.0068 | 0.0007 | 0.0002 | 0.0043 |
| (2) | - | - | 0.0067 | - | - | - |

Table II
Loss in weight per hour ($g/cm^2/hr$)

| Sample | Experiment I | II | III | IV | V | VI |
|---|---|---|---|---|---|---|
| Stainless Steel | | | | | | |
| (1) | - | .0024 | .00021 | .00047 | .0001 | .00028 |
| (2) | .0036 | .0022 | - | - | - | - |
| (3) | .002 | .0025 | .00019 | .00042 | .00011 | .0002 |
| (4) | - | - | - | .00044 | .00013 | .00035 |
| Nickel | | | | | | |
| (1) | - | - | .00017 | gain | - | .00012 |
| (2) | - | - | .00017 | - | - | - |

Cooled, dry air allowed to enter - washed strips with water, lightly scoured and dried before weighing. Black scale flaked off of stainless easily. More adherent to nickel.

RL 28.5.25 File No. 1879

SUMMARY OF RESEARCH PROGRESS MEETING

R. Gundelfinger - 10/14/44

Tantalum K life is probably much shorter with $TF_6$ than with $TCl_4$.

A-3191 File No. 2195

PROGRESS REPORT

F. H. Spedding, H. A. Wilhelm, A. H. Daane - 11/25/44

Medium: $TCl_4$ Vapor

Material: Tungsten

Results: #1 Drain fin - very little corrosion.

Drain plates - uncorroded.

Chem S-514 (ROCH) File No. 723

CORROSION IN THE DECOMPOSITION OF $TX_5$

J. W. Gates, Jr - 6/24/43

Time: 4 hours

Temperature: 350°-400°C

Medium: 70 grams of $TX_5$

Materials: See table for the samples that were buried in medium.

Method: Samples were cleaned, weighed and immersed in $TX_5$ in a slow stream of nitrogen.

Results: The best materials as to the corrosion are Pfaudler glass, stainless steel numbers 329, 347, 317, 316, Illium G and Durichrome. The remainder are not satisfactory material for lining the decomposer in the preparation of $TX_4$ from $TX_5$. (See table on page 62)

| Sample | Composition | (Mg/dec$^2$/hrs) Rate | Remarks |
|---|---|---|---|
| Pfaudler Glass | | S 65* | |
| Stainless Steel Type No. 329 | 25-30 Cr<br>3-5 Ni<br>1-1 1/2 Mo | S 504 | No Stain |
| Stainless Steel Type No. 347 | 18 Cr<br>8 Ni<br>0.8-1 Nb (Columbium) | S 524 | No Stain |
| Stainless Steel Type No. 317 | 18 Cr<br>8 Ni<br>3 Mo | S 553 | No Stain |
| Durichrome | 14 Si<br>3 Mo<br>3-5 C<br>Remainder Fe | S 725 | Appeared Pitted |
| Stainless Steel Type No. 316 | 18 Cr<br>8 Ni<br>2-2 1/2 Mo | S 754 | Stained |
| Illium G | 54 Ni<br>24 Cr<br>8 Cu<br>4 Mo + others | S 770 | Slight Stain |
| Stainless Steel Type No. 310 | 25 Cr<br>20 Ni | 926 | Appears Corroded |
| Stainless Steel Type No. 325 | 7-10 Cr<br>19-23 Ni<br>1-1 1/2 Cu | 1000 | |
| Stainless Steel Type No. 304 | 18 Cr<br>8 Ni<br>.08 C | 1390 | Appears Pitted |
| E.K. 630 Inconel | 80 Ni<br>14 Cr<br>6 Fe | 1561 | Corroded |
| Stainless Steel Type No. 312 | 30 Cr<br>9 Ni | 1973 | Pitted |
| Nuriron | 14 Si<br>3 C | 2063 | Pitted |
| Tantalum | Pure | 8658<br>9312 | Badly Corroded<br>Badly Corroded |
| No. 3-7 Cupro Nickel | 20-30 Ni<br>70-80 Cu | 16320 | Badly Corroded |

* "S" Signifies satisfactory rate.

Chem S-528 (ROCH) File No. 731

## CORROSION RESISTING PROPERTIES OF HASTELLOYS A, B, C AND D

George DeCroes - 8/12/43

**Time:** 4 and 24 hours

**Temperature:** 350°- 400°C, 350° - 450°C, 60° - 70°C

**Metals:** Hastelloy A - 58 Ni, 20 Mo, 20 Fe, 2 Mn
B - 62 Ni, 30 Mo, 5 Fe
C - 58 Ni, 14 Cr, 17 Mo, 5 W, 6 Fe
D - 85 Ni, 8 Cu, 2 Al, 10 Si

**Media:** $TCl_5$, $TO_4 \cdot 2H_2O$ and $H_2O_2$

**Method:** The samples were polished, washed, dried and weighed before used in the different experiments, on reruns of the same experiment they were not polished. The same batches of $TO_4 \cdot 2H_2O$ (dried at 100°C) and $TCl_5$ (Kraus) were used throughout. (1)70 grams $TCl_5$ containing buried samples in a porcelain dish were heated in the furnace with a slow stream of nitrogen (4 hours at 350-400°C - 2 tests) (24 hours at 350-450°C - 1 test). (2) 30 grams $TO_4 \cdot 2H_2O$ - heated 4 hours at 350-400°C - slow stream of nitrogen (dry). (3) 30 grams $TO_4 \cdot 2H_2O$ and 25 cc of 5% $H_2O_2$. (4) 30 volume $H_2O_2$ at 60-70°C for 4 hours.

**Results:** See page 64.

[redacted]



(1) a. Decomposition of $TCl_5$ to $TCl_4$ at 350-400°C for 4 hours:

| | Test I | | Test 2 | |
|---|---|---|---|---|
| | Rate | | Rate | |
| Sample | mg/dec$^2$/24 hours | Remarks | mg/dec$^2$/24 hours | Remarks |
| A | 281 | Slight stain | 64 | Slight stain |
| B | 95.5 | Slight stain | 55.6 | Slight stain |
| C | -274 | Stain (gained wt.) | 180 | Stain (based on 8 hr) |
| D | 285 | Stain | 174 | Stain |

b. Decomposition of $TCl_5$ to $TCl_4$ at 350-450°C for 24 hours:

| | | |
|---|---|---|
| A | 1515 | Stained |
| B | 1150 | Stained |
| C | 194 | Stained |
| D | 133 | Stained |

(2) Reduction of $TO_4 \cdot 2H_2O$ to $TO_3$

| | Test 1 | | Test 2 | |
|---|---|---|---|---|
| A | 17.5 | Slight stain | -19.8 | Slight stain (wt.gain) |
| B | 15.5 | Slight stain | -17.8 | Slight stain (wt.gain) |
| C | 35.9 | No stain | 24.8 | No stain |
| D | -15.9 | Stain (wt. gain) | - 9.0 | Stain (wt. gain) |

(3) Drying and decomposition of $TO_4, H_2O_2$ mixture.

| | | |
|---|---|---|
| A | 2 | Slight stain |
| B | 82 | Slight stain |
| C | 34 | No stain |
| D | 11 | Stain |

(4) Oxidizing action of $H_2O_2$:

| | Test 1 | | Test 2 | |
|---|---|---|---|---|
| A | -53 | Slight stain (wt gain) | -19 | Slight stain (wt. gain) |
| B | 1302 | Pitted | 800 | Pitted |
| C | 152 | Slight stain | 83 | Slight stain |
| D | 137 | No stain | 122 | No stain |

Conclusions: (1) a. Hastelloy B - Best, others show relatively low rates.
b. Hastelloy C and D - Little corrosion, others show very high rates.
(2) Corrosion of all very small.
(3) All very resistant to corrosion.
(4) Hastelloy B acted upon quite vigorously, others had low rates of corrosion.

[redacted]

[redacted]

Chem S-507 (ROCH) File No. 716

## CORROSION TESTS IN THE DECOMPOSITION OF $TCl_5$ TO $TCl_4$ AT 300-350°C

J. W. Gates, Jr - 6/11/43

Temperature: 300-350°C

Time: 4 hours

Medium: 70 grams $TCl_5$ in a slow stream of $CO_2$

Samples: Stainless steel and nickel were buried in medium

Results:

| Sample | | % Loss | Remarks |
|---|---|---|---|
| Stainless steel | | | |
| Type 316 (welded) | | .051 | |
| 1st Repeat | | .032 | |
| 2nd Repeat | | .023 | |
| Steel Rod | | .031 | |
| 1st Repeat | | .114 | |
| Ni Plate | gain of | .035 | Nickel chloride present |
| 1st Repeat | loss of | .204 | |
| | net | .169 | |
| Pure Ni | gain of | .027 | |
| 1st Repeat | loss of | .159 | |
| 2nd Repeat | loss of | .013 | |
| | Net | .145 | |

RL 16.6.72 File No. 2513

## $TF_6$ AS A CHARGE MATERIAL

E. J. Lofgren - 11/25/44

Time: 24 hours

Temperature: 250°C

Medium: $TF_6$ vapor

Metals: (See table) Samples were approximately 2 square centimeters.

Method: Samples were exposed in the J slits under vacuum and were weighed and brushed when removed.

[redacted]

Results:

| Metals | Weight Loss | Remarks |
|---|---|---|
| Nickel | +1.06 mg/cm$^2$ xx xx | - Increase in wt. could be due to corrosion film that resisted washing, or to diffusion of T into the nickel. |
| Monel | +0.40 " | |
| Inconel | -0.82 | |
| 18-8 Stainless Steel | 4.78* | |
| Copper | 8.36 | |
| Platinum | 8.52 | .. - Probably experimental error |
| Tantalum | 9.14 | |
| Molybdenum | 24.50 | * - Wt. loss is probably not a good criterion, because of intergranular attack. |
| Tungsten | 43.18 | |
| Silver | 68.34 | |

References: List of Metals in decreasing order of corrosion resistance is given by H. S. Brown (Chicago, CC-408, Jan. 1943).

| | | |
|---|---|---|
| Nickel | Platinum | very bad, useless |
| Inconel | Palladium | |
| Monel | Gold | |
| Copper | Silver | |
| Brass | Tin | |
| Bronze | Steel | |
| Aluminum | Stainless steel | |
| Dowmetal | Cadmium | |
| | Lead | |

Corrosion rates vary from about 0 to 1 milligram per square decimeter per day at 160°C, for those in the left column. $TF_6$ does not react with fluorocarbons, butyl rubber, and dry glass. It does react with hydrocarbons, buna rubber, graphite, and wet glass.

RL 4.6.296 File No. 3283

## CORROSION OF SOME METALS WITH $TF_6$ VAPOR

D. Altman - 10/27/44

Time: Time during a regular run

Temperature: Not given

Medium: $TF_6$ vapor

Metals: (see table) Samples were 1 cm$^2$ in area and approximately .015 inch thick. They were placed on their sides in the J chamber and this caused one side to be more corroded than

the other. Nickel and platinum were found pasted together and the pasted sides were perfectly clean. Therefore, the effective areas are 50-100% of the values given in the table.

Method: Samples were washed in distilled water and ammonium oxalate, scraped and final weighing made.

Results: The actual weight losses are:

| Metal | Loss ($mg/cm^2$) |
|---|---|
| Cu | -4.18 |
| Inconel | -0.41 |
| Monel | +0.20 gain |
| Molybdenum | -12.25 |
| Ni | +1.06 gain |
| Pt | -8.52 |
| Ag | -34.17 |
| Stainless steel | -2.39 |
| Ta | -4.57 |
| W | -21.59 |

Conclusions: The behavior can be placed in four classes:

A. Metal essentially unchanged: Inconel and Monel

B. Metal builds up $TF_4$ coat, but reacts very little itself: Nickel

C. Metal builds up $TF_4$ coat and a non-volatile fluoride coat: Copper, Silver, Stainless steel

D. Metal forms a volatile fluoride coat: Molybdenum, Platinum, Tantalum, Tungsten

RL 28.5.24 File No. 1869

SUMMARY OF RESEARCH PROGRESS MEETING

R. Gundelfinger - 10/7/44

The fluoride charge reacts with materials normally used more rapidly than chloride; thus graphite has been found impracticable for window frames, J slits, and J baffles. Tungsten collimating plates have developed large growths which sometimes clog up the slits. A Thoria coated K has been used on R-1 and operated all right, except a nickel collimating plate was used

and melted at the ends and the tungsten of the K at the edges of the thoria layer were worn. Monel was used for the J baffle and stood up satisfactorily. A graphite J chamber was used without too much wear and a V-shaped copper J slit 1/8 inch thick was used without too much wear. A whitish material was deposited in the J chamber, probably copper fluoride. The stainless steel liner of the vapor manifold was badly eaten away.

RL 28.5.51 File No. 3311

## CORROSION OF METALS PLACED IN J CHAMBER OF 8 J-UNIT

R. Gundelfinger - 4/15/45

Time: 55 hours

Medium: $TF_6$ vapor

Metals: See table

Method: One block of each metal was placed in the inter-J space subject only to corrosion.

Results:

| Metal | Corrosion Volume cc/in$^2$ | Sputtering Volume cc/in$^2$ | Total Depth of wear mils. |
|---|---|---|---|
| Graphite | +0.0008 | 0.005 | 2.0 |
| Platinum | +0.0001 | 0.015 | 5.0 |
| Tungsten | -0.00193 | 0.0238 | 5.0 |
| Tantalum | -0.0233 | 0.083 | 16.0 |
| Stainless steel 316 | -0.0305 | 0.0975 | 22.0 |
| Monel | -0.0344 | 0.077 | 12.5 |
| Kovar | -0.040 | 0.074 | 13.5 |
| Inconel | -0.0444 | 0.051 | 9.0 |
| Nickel | -0.069 | --- | 20.0+ |

RL 4.6.904 File No. 2405

## K CORROSION

J. A. Holmes, F. L. Reynolds - 12/30/44

Abstract: Tungsten and tantalum filaments operating at 2500°K were subjected to the action of $TF_6$ at a calculated pressure of $3.6 \times 10^{-5}$ mm. Hg. Cold resistance measurements were used to follow the rate of chemical attack, and a theoretical mechanism of the corrosion is proposed.

[redacted]



Conclusions: 1. The corrosion of tungsten and thoriated tungsten at 2500°K is caused primarily by the direct reaction of the decomposition products of $TF_6$. $WF_6$ is unstable at 2500°K, redepositing tungsten at this temperature.

2. The mechanism probably involves the following reaction:

$$3TF_6 + W \rightleftharpoons 3TF_4 + WF_6$$

$$WF_6 \xrightleftharpoons{2500^\circ K} W + 3F_2$$

$$3F_2 + W \rightleftharpoons WF_6$$

$$TF_6 \xrightleftharpoons{2500^\circ K} TF_4 + F_2$$

3. The corrosion of tantalum is similar except that the compound $TaF_5$ has a much slower decomposition rate, most of the $TaF_5$ formed does not redeposit metal on the hotter filament area. Corrosion seems to be at the grain boundaries, with subsequent disintegration of the filament.

CD-PPO-22 (Series A)

## THE EXTRACTION OF BETA GUNK IN PACKED COLUMNS WITH DIBUTYL CELLOSOLVE AND DIBUTYL CARBITOL

M. W. Bredekamp - 6/4/45

Miscellaneous facts were noted, such as:

1. Dibutyl cellosolve does not wet ceramic packing.
2. All lines and fittings must be stainless steel or glass.
3. Tygon was found to be one of the few gasket materials suitable to withstand the solvent and chemical action involved.

M-13 Supplement 1

## CORROSION OF METALS BY VARIOUS SOLUTIONS

C. A. Kraus - 7/6/44

Time: 4 hours

Temperature: (1) Near boiling and (2) 80°C

Media: (1) Gunk solution 1/2 saturated with $Fe(NO_3)_3$ and (2) alkaline gunk solution $(NH_4)_2CO_3$)

[redacted]

[redacted]



Metals: Stainless steels and Hastelloy C were immersed in the media.

Method: Samples were immersed in the solutions. (1) Weighed when half volume had been concentrated and again when 4/5 of original volume was evaporated. (2) Fe was removed by $(NH_4)_2CO_3$ and small amounts were added at intervals to keep the solution slightly alkaline.

Results: (1) Fe $(NO_3)_3$-Gunk Solution

| Experiment No. | Metal | Weight Loss $mg/cm^2/hr.$ |
|---|---|---|
| #1 (Sol. evaporated to 1/2 original vol.) | Hastelloy C | 1.28. |
| | St. St. 316 | 0.022 |
| | St. St. 317 | 0.016 |
| #2 (Sol. evaporated to 4/5 original vol.) | Hastelloy C (oxide not removed) | 0.938 |
| | Hastelloy C (polished) | 0.178 |
| | St. St. 316 | 0.003 |
| | St. St. 317 | 0.006 |

(2) Alkaline Gunk Solution - $(NH_4)_2CO_3$

| | |
|---|---|
| Hastelloy C | 0.060 |
| St. St. 302 | -0.001* |
| St. St. 316 | -0.013 |
| St. St. 317 | -0.015 |
| St. St. 321 | -0.004 |

*Negative sign indicates that sample gained weight. Hastelloy C shows slight corrosion. The others formed a very thin film which looked like oxide.

CD-522 CEL-a

## CORROSION STUDIES

C. R. Estee, C. E. Larson - 1/10/45

Temperature: 25°C

Time: 15 days

Medium: Alpha Gunk oxidized with excess $H_2O_2$ (pH: 1.5-1.7)

[redacted]

[redacted]

Metals: See table below. Samples were immersed and rotated constantly.

Method: Samples were washed in acetone, dried and weighed. Placed on a rotating spindle and immersed in the medium. Excess peroxide concentration maintained throughout the test.

Results:

| Metal | Loss mg/sq. in. | Penetration (ipy) |
|---|---|---|
| N-153 | 0.00 | 0.000000 |
| N-153 | 0.00 | 0.000000 |
| 321 heat-treated | 0.18 | 0.000033 |
| 302 | 0.19 | 0.000036 |
| 347 | 0.19 | 0.000036 |
| 316 | 0.23 | 0.000045 |
| 302 heat-treated | 0.35 | 0.000064 |
| 321 stress sample | 0.50 | 0.000093 |
| Inconel | 0.65 | 0.000112 |
| 330 | 4.01 | 0.000732 |
| Hastelloy B | 1116.40 | 0.205993 |

N-153 and 155 seem well suited. Hastelloy B was badly pitted, and seemed to have lost some material by flaking while 330 was eaten through in several spots.

CD-519 CEL-a

## CORROSION STUDIES

C. R. Estee, C. E. Larson - 1/10/45

Temperature: 4.5°C

Time: 13 days

Medium: Alpha Gunk oxidized with excess $H_2O_2$

Metals: See table. Samples were immersed and rotated constantly.

Method: Samples were washed in acetone, dried, weighed and immersed in the medium and rotated.

Results:

| Metal | Loss mg/sq. in. | Penetration (ipy) |
|---|---|---|
| 316 | 0.23 | 0.000049 |
| 347 | 0.23 | 0.000049 |
| Inconel | 0.81 | 0.000163 |
| 330 | 1.10 | 0.000349 |
| Nickel | 1570.30 | 0.303650 |
| Monel | 2014.90 | 0.392320 |
| Spindle | 0.44 | 0.000100 |
| 302 | gain 0.40 | 0.000085 gain |

[redacted]

Conclusion: Apparently high nickel-copper alloys are not suited for use with such solutions. Despite the gain in weight, sample 302 showed definite pitting on the surfaces. Probably surface oxide was formed. The monel was badly corroded and crumbling on removal may have contributed to the high weight loss.

CD-GS-24

EFFECT OF OXIDIZED ALPHA GUNK SOLUTION AND PEROXIDE-PRECIPITATED GUNK SLURRY ON THE NEW FERROUS ALLOYS, N153 AND N155

J. M. Folk, C. D. Susano - 3/13/45

Time: 210 hours

Temperature: 35-40°C

Media: Oxidized Alpha gunk solution and peroxide-precipitated gunk slurry.

Metals: N153 and N155 were immersed in the media.

Method: Agitation and aeration were accomplished by passing a slow stream of air through the liquids. The specimens were immersed and removed after 18 hours, washed with calgonite, rinsed in water, alcohol and ether, dried and reweighed; then again every 24 hours until a total of 210 hours had elapsed.

Results: There was no loss in weight during the 210-hour test period.

CD-GS-5

CORROSION OF STAINLESS STEEL

C. D. Susano, H. A. Young - 8/1/44

Medium: Oxidized gunk

Reference: Reported facts show that equipment requiring welding should be heat-treated to prevent corroding in the use of type 302, 304 and 316 stainless steel. Type 347 which contains columbium is the

best and does not need the heat-treatment, but should be welded with same type 347 rod. Type 321 is satisfactory if welded with 347 rod.

Chem S-109

## CORROSION OF VARIOUS METALS BY GUNK IN D-1

Ross Cummings - 4/21/43

Method: Specimens were attached to the gunk catcher of D-1 opposite the arc. At the end of one run they were washed in hot water, dried and weighed.

Discussion of Results:

Copper and Copper Alloys: Visibly attacked by $TCl_4$ solution, resulting in contamination of the wash water and formation of a film on the metal surface. (Can be removed by light scouring, but serves as protection to metal if left on.) Everdur does not build as resistant film as copper or Mallory 53 (beryllium-copper).

Silver: Behaves much like copper. Corroded silver converted to $AgCl_2$ and appeared as heavy percipitate in the solution. Forms a protective coat as copper.

Aluminum: Heavily attacked but corrosion products being adherent.

Tantalum: Very little corroded, but does not clean readily.

Molybdenum: Shows excellent resistance.

Stainless steel: Has a moderate loss, does not seem to form a protective film.

Gold Plate: Shows good to excellent corrosion resistance.

Hastelloy B, C, and Inconel: Have fairly low corrosion rates. The Hastelloys had higher rate when first tried due to type of surface (sandblasted). When polished the rate was reduced.

Chrome Plate: Decidedly not satisfactory. Chrome on nickel (visual inspection) showed plate gone in places after one exposure. Chrome on Cu -- loss is high and much copper visible after one run.

Nickel and Nickel Plate: Fairly good resistance to corrosion especially after building surface film. After exposure the surface is brownish-gray. It appears to be characteristic of nickel that it is easily washed and no tendency for tuballoy compounds to adhere to it.

EXPERIMENTAL DATA:

| Metal | Duration of run hours | Duration of exposure to air before washing hours | Penetration inches x $10^{-6}$ |
|---|---|---|---|
| Copper | 29.5 | 2.0 | 15 |
| | 30.67 | 4.0 | 62 |
| | 36.08 | 2.8 | 6.1 |
| | 18.7 | 3.0 | 4.7 |
| Mallory 53 (Beryllium-copper) | 12.5 | 6.0 | 45.0 |
| | 5.0 | 1.8 | 5.5 |
| | 37.25 | 1.2 | 1.9 |
| Everdur (Silicon-copper) | 45.0 | — | 22.0 |
| | | — | 42.0 |
| Silver | 12.5 | 6.0 | 36.0 |
| | 5.0 | 1.8 | 4.2 |
| | 37.25 | 1.2 | 5.3 |
| Aluminum | 36.08 | 2.8 | 3.7 |
| | 18.7 | 3.0 | gain |
| Tantalum | 30.67 | 4.0 | 4.0 |
| | 29.50 | 2.0 | 2.0 |
| Molybdenum | 36.08 | 2.8 | .16 |
| | 18.7 | 3.0 | .12 |
| Stainless steel | 29.5 | 2.0 | 10.3 |
| | 30.67 | 4.0 | 8.1 |
| Hastelloy B | 28 | 1.5 | 12 |
| | 5 | 1.8 | 0 |
| | 37.25 | 1.2 | 1.6 |
| Hastelloy C | 28 | 1.5 | 12 |
| | 5 | 1.8 | 2.7 |
| | 37.25 | 1.2 | 1.8 |
| Inconel | 5 | 1.8 | 2.5 |
| | 37.25 | 1.2 | 1.4 |
| Chrome plate over nickel plate | 5 | 1.8 | 4.8 |
| | 37.25 | 1.2 | 2.1 |
| Chrome plate on copper direct | 36.08 | 2.8 | 10.4 |
| | 18.7 | 3.0 | 120 |
| Cold plate on copper | 5 | 1.8 | .02 |
| | 37.25 | 1.2 | .98 |
| | 36.08 | 2.8 | 1.04 |
| | 18.7 | 3.0 | .27 |
| Nickel | 30.67 | 4.0 | 6.4 |
| | 29.5 | 2.0 | 5.0 |
| Nickel plate Haw's plating Works | 5 | 1.8 | 1.9 |
| | 5 | 1.8 | 1.7 |
| | 37.25 | 1.2 | 1.2 |
| | 37.25 | 1.2 | .6 |
| | 36.08 | 2.8 | 1.2 |
| | 18.7 | 3.0 | .2 |
| Nickel plate E.K. Co. | 45.0 | — | 25.0* |
| | — | — | 15.0* |

* See discussion

[redacted]

Chem S-23 File No. 3111

CORROSION TESTS OF VARIOUS METALS IN A GLASS

REACTOR WITH $TO_2$ AND IN THE USUAL MANNER USING $CCl_4$ VAPOR

H. R. McCombie - 2/20/43

Results:

| Metal | Reaction Temperature - °C | Corrosion Penetration - Cm/Yr. |
|---|---|---|
| Cast Iron | 415 | 39. |
| Wrought Iron | 415 | 14. |
| Monel | 435 | 20. |
| Stainless 18-8 | 435 | 1.7 |
| Stainless 18-8Mo | 415 | 1.7 |
| Molybdenum | 435 | 1.6 |
| Nichrome | 400 | 0.18 |
| Inconel | 435 | 0.24 |
| Nickel | 435 | 0.15 |

Corrosion is usually influenced largely by temperature as well as by corrosive products which result from the change in temperature. In this particular reaction an increase in temperature gives an increase in $Cl_2$ formation. Also hydrogen-containing materials in the $CCl_4$ such as $CHCl_3$ increase corrosion because of HCl formed.

| | | |
|---|---|---|
| Stainless 18-8 | 415 | 0.28 |
| | 435 | 1.7 |
| | 470 | 3.5 |
| Nickel | 400 | 0.18 |
| | 415 | 0.16 |
| | 435 | 0.15 |
| | 470 | 0.13 |

Nickel is particularly suitable because of the small influence of temperature on corrosion as shown above.

Chem S-509 (ROCH) File No. 718

METAL CORROSION TESTS IN THE FORMATION OF $TCl_5$ FROM $TO_3$ AND $CCl_4$

J. W. Gates, Jr - 6/11/43

Time: 4 hours

Temperature: 160°C

[redacted]

[redacted]

Medium: 5 grams $TO_3$ and 50 cc of $CCl_4$

Metals: See table

Method: The sample strips were weighed and placed in a sealed tube with the medium.

Results:

| Sample | Penetration $112 \times 10^{-6}$/hr | Crystals | Remarks |
|---|---|---|---|
| Ni (?) rod | 0.023 | o.k. | |
| Ni-sheet (CP. Lab) | 0.250 | o.k. | |
| Ni-sheet " " Dupl. | 0.100 | o.k. | |
| Ni (Pure-Tucker) | 0.554 | o.k. | Stood overnight before opening |
| Ni (plated) | 0.625 | o.k. | |
| No. 304 St.St. (welded) | 0.293 | o.k. | Stood overnight |
| No. 316 St.St. (welded) | 0.064 | o.k. | |
| No. 316 St.St. (repeat) | 0.517 | o.k. | Stood overnight |
| Unknown St.St. (not welded) | 0.838 | o.k. | |
| Chromium Plate | 0.682 | o.k. | Stood overnight |
| Gold Plate | 2.7 | bad | Severe corrosion |
| Tin Rod | 7.9 | bad | |
| Silver Sheet | Too bad to measure | bad | AgCl noted |
| Copper Sheet | Too bad to measure | bad | Cuprous chloride |
| Steel Rod | 1.7 | bad | Local reduction |

A-1089 File No. 3008

## CORROSION OF STAINLESS STEEL DURING THE LIQUID PHASE CHLORINATION OF $RO_3$ BY $CCl_4$

C. A. Kraus - 11/1/43

Temperature: 120-160°C

Time: See table

Medium: $RO_3$ and $CCl_4$

Results:

| Specimens | Total Hours Exposed | Weight loss in $Mg/cm^2/hr.$ |
|---|---|---|
| 302 | 35.8 | 0.043 |
| 316 | 24.2 | 0.004 |
| 317 | 24.7 | 0.003 |
| 321T | 15.8 | 0.009 |
| 309 | 19.6 | 0.017 |
| 310 | 11.0 | 0.010 |

The above time includes the exposure during heating and cooling the reactor.

[redacted]

[redacted]

Chem S-513 (ROCH) File No. 722

CORROSION IN THE PEROXIDE DECOMPOSITION

J. W. Gates, Jr - 6/24/43

Procedure: The weighed, cleaned corrosion strips were immersed in peroxide ($TO_4 \cdot 2H_2O$) to be decomposed and dried for six, four-hour drying. The rates are expressed as mgs. loss/dec$^2$/24 hrs.

Results:

| Sample | Rate | |
|---|---|---|
| Nickel | 15.6 | are suitable |
| No. 316 St. St. | 33.2 | |
| No. 304 St. St. | 450.0 | |

CD-GS-33 File No. 2873

THE CORROSION RESISTANCE OF CERTAIN STAINLESS STEELS TO HEXAFLUORIDE-CONVERSION-PROCESS SOLUTIONS

J. M. Folk, C. D. Susano - 3/24/45

Materials: Stainless steel type 316 and 321. The 316 was welded with 316 electrodes. The 321 was welded with 347 electrodes. One sample of 316 was heat-treated.

Test Solutions:
(1) 724--Filtrate from Tuballoy precipitation; peroxide filtrate
(2) 824--Filtrate from Tuballoy precipitation; (S-50) peroxide filtrate
(3) 727--Ammonia decantrate from dituballate precipitation
(4) 828-- " " (S-50) " "
(5) 705--Hydrogen peroxide effluent

Procedure: The specimens were washed with water, then alcohol, finally ether, dried, and weighed. Immersed in test solution. The solutions were agitated by means of a stirrer for one day. Specimens removed, washed, dried and weighed as above, then returned to respective test solutions and examined in accordance with the following schedule:

a. Twenty-five days, alternating every day, between "peroxide filtrate" at room temperature, "ammonia

[redacted]

decantrate" at 70°C, and "peroxide effluent" at room temperature.

b. Twelve days, alternating every day, between "Peroxide filtrate" at room temperature and "ammonium decantrate" at 70°C.

c. Fifty days immersion in "peroxide filtrate" at room temperature. After 22 days, 5 ml of 3% hydrogen peroxide was added to the solution every day to replace the $H_2O_2$ lost by evaporation and decomposition.

Results:

| Days | Solutions | Heat-treated 316 | Untreated 316 | Titanium Stabilized 321 |
|---|---|---|---|---|
| 25 | 724<br>728<br>705 | 0.00072 | 0.00019 | 0.00056 |
| 12 | 824<br>827 | 0.00065 | 0.00007 | 0.00013 |
| 50 | 824 | 0.00003 | 0.00003 | 0.00002 |

CD-GS-12 File No. 2347

CORROSIVE ACTION OF CALCIUM NITRATE AND CALCIUM CHLORIDE BRINES ON METALS

J. M. Folk, C. D. Susano - 1/26/45

Solutions: Calcium Chloride — 2.5 M
Calcium Nitrate — 3.5 M

Materials: Cast iron, brass, copper couple, copper-base alloy

Temperature: 14°F and room temperature

Time: 275 hours (Supplement 475 hours)

Procedure: Clean test metal specimens were 4 sq. in. in area, clean, polished with emery cloth, washed with 5% citric acid, water and alcohol, dried with ether in a stream of air, weighed. Placed in the solutions and at approximately 70 hour intervals removed, cleaned, dried and weighed as above. Same procedure used in supplement, but time was extended. Specimens were placed in the solutions in contact with each other, the ferrous metal contacts the copper-base alloy in turn contacts the copper.

Test system and the conditions of each test are found in table I, Page 79.

Results: Tables II, II supplement, IV, V and VI on following pages 80, 81, 82, 83 and 84 respectively.

TABLE I

CAST IRON, BRASS, COPPER COUPLE

| Test No. | Salt | Moles | CaO Added Percent | $K_2Cr_2O_7$ Added Percent | PH | Temp °F |
|---|---|---|---|---|---|---|
| 1 | $Ca(NO_3)_2$ | 3.5 | ——— | ——— | 3.7 | 14 |
| 2 | $Ca(NO_3)_2$ | 3.5 | 0.0005 | ——— | 7.0 | 14 |
| 3 | $Ca(NO_3)_2$ | 3.5 | 0.001 | ——— | 8.5 | 14 |
| 4 | $Ca(NO_3)_2$ | 3.5 | 0.0012 | 0.15 | 7.0 | 14 |
| 5 | $Ca(NO_3)_2$ | 3.5 | *See Note | 0.39 | 10.9 | 14 |
| 5a** | $Ca(NO_3)_2$ | 3.5 | 0.002 | 0.39 | 4.0 | 14 |
| 6 | $CaCl_2$ | 2.5 | ——— | ——— | 6.2 | 14 |
| 7 | $CaCl_2$ | 2.5 | 0.0005 | ——— | 7.0 | 14 |
| 8 | $CaCl_2$ | 2.5 | 0.001 | ——— | 8.5 | 14 |
| 9 | $CaCl_2$ | 2.5 | 0.012 | 0.18 | 7.0 | 14 |
| 10 | $CaCl_2$ | 2.5 | 0.002 | 0.45 | ***4.2 | 14 |
| | | | CAST IRON, ADMIRALTY METAL, COPPER COUPLE | | | |
| 4a | $Ca(NO_3)_2$ | 3.5 | 0.012 | 0.15 | 7.2 | 14 |
| 4b | $Ca(NO_3)_2$ | 3.5 | 0.012 | 0.15 | 7.4 | 77 |

* Solid CaO was added until pH of 10.9 was obtained.
** Contains a small amount of free $HNO_3$.
*** The pH of solution 10 was changed to 10.4 after 200 hours by the addition of solid CaO.

Hereafter in this report all test systems will be referred to by the test numbers shown above.

The compositions of the metal test specimens are shown in Table IV.

[redacted]

[redacted]



TABLE II

| Test No. | Cast Iron Wt. Loss Mg/sq/cm. | Cast Iron Ave. Penet. Inches/year | Copper-base Alloy Wt. Loss Mg/sq/cm. | Copper-base Alloy Ave. Penet. Inches/year | Copper Wt. Loss Mg/sq/cm | Copper Ave. Penet. Inches/year |
|---|---|---|---|---|---|---|
| 1 | 1.21 | 0.00192 | 0.135 | 0.00021 | 0.141 | 0.00021 |
| 2 | 1.42 | 0.00226 | 0.161 | 0.00025 | 0.100 | 0.00015 |
| 3 | 1.14 | 0.00181 | 0.178 | 0.00031 | 0.080 | 0.00012 |
| 4 | 1.50 | 0.00239 | 0.125 | 0.00019 | 0.065 | 0.00010 |
| 4a | 0.89 | 0.00173 | 0.047 | 0.00007 | 0.020 | 0.00003 |
| 4b* | 4.04 | 0.00620 | 0.051 | 0.00008 | 0.030 | 0.00004 |
| 5 | 2.74 | 0.00435 | 0.213 | 0.00033 | 0.086 | 0.00013 |
| 6 | 3.36 | 0.00535 | 0.178 | 0.00028 | 0.144 | 0.00021 |
| 7 | 1.82 | 0.00290 | 0.116 | 0.00018 | 0.107 | 0.00016 |
| 8 | 2.20 | 0.00350 | 0.154 | 0.00024 | 0.246 | 0.00037 |
| 9 | 1.15 | 0.00199 | 0.129 | 0.00020 | 0.130 | 0.00019 |
| 10 | 1.42 | 0.00224 | 0.087 | 0.00013 | 0.110 | 0.00016 |
| **5a | 289.00 | 1.770 | 271.00 | 1.626 | 242.00 | 1.415 |

*4b at 77°F

**Duration of test--70 hours

Weight loss per sq. cm for a period of 275 hours and average penetration per year, calculated on basis of 275 hours, for metals exposed to calcium nitrate and calcium chloride solutions at 14°F.

[redacted]

[redacted]



TABLE II (Supplement)

Average Penetration in Inches Per Year for Metals Exposed to Calcium Nitrate and Calcium Chloride Brines at a Temperature of 14°F.
Based on Loss in Weight for 475 Hours

| Test No | Cast Iron | Copper Base Alloy | Copper | Average: Copper Base Alloys Plus Copper | Stainless Steel |
|---|---|---|---|---|---|
| 1 | 0.00200 | 0.00014 | 0.00014 | 0.00014 | |
| 1C | 0.00382 | | | 0.00020 | |
| 1D | 0.00317 | | | 0.00023 | 0.00004 |
| 2 | 0.00233 | 0.00016 | 0.00011 | 0.00014 | |
| 3 | 0.00204 | 0.00021 | 0.00010 | 0.00016 | |
| 4 | 0.00229 | 0.00015 | 0.00008 | 0.00012 | |
| 4A | 0.00143 | 0.00009 | 0.00005 | 0.00007 | |
| 4C | 0.00255 | | | 0.00028 | |
| 4D | 0.00208 | | | 0.00022 | 0.00002 |
| *$4A_b$ | 0.00697 | 0.00008 | 0.00005 | 0.00007 | |
| *$4C_b$ | 0.00700 | | | 0.00014 | |
| *$4D_b$ | 0.00396 | | | 0.00019 | 0.00002 |
| 5 | 0.00458 | 0.00031 | 0.00013 | 0.00022 | |
| 5C | 0.00344 | | | 0.00025 | |
| 5D | 0.00207 | | | 0.00025 | 0.00001 |
| 6 | 0.00478 | 0.00024 | 0.00017 | 0.00021 | |
| 6C | 0.00377 | | | 0.00020 | |
| 6D | 0.00338 | | | 0.00040 | 0.00003 |
| 7 | 0.00314 | 0.00014 | 0.00014 | 0.00014 | |
| 8 | 0.00354 | 0.00019 | 0.00027 | 0.00023 | |
| 9 | 0.00190 | 0.00016 | 0.00015 | 0.00016 | |
| 9C | 0.00352 | | | 0.00063 | |
| 9D | 0.00232 | | | 0.00030 | 0.00004 |
| 10 | 0.00228 | 0.00010 | 0.00014 | 0.00012 | |
| 10C | 0.00314 | | | 0.00011 | |
| 10D | 0.00191 | | | 0.00020 | 0.00002 |
| 5a** | 1.770 | 1.626 | 1.415 | 1.521 | |
| $1C_x$ | 0.00575 | | | 0.00021 | |
| $1D_x$ | 0.00272 | | | 0.00024 | 0.00001 |

*b temperature of 77°F.

** duration of test 70 hours

[redacted]

[redacted]



TABLE IV

COMPOSITION OF METAL SPECIMENS

| | | |
|---|---|---|
| Copper Tubing | | 99.98 percent copper |
| Copper Plate | | 99.94 perdent copper |
| Brass | | Percent |
| | Copper | 60.3 |
| | Zinc | 36.5 |
| | Lead | 3.0 |
| | Tin | 0.11 |
| | Aluminum | 0.03 |
| | Iron | 0.09 |
| Admiralty Metal | | |
| | Copper | 71.4 |
| | Zinc | 27.3 |
| | Tin | 1.2 |
| Cast Iron | Total carbon | 3.5 |
| | Graphitic carbon | 2.7 |
| | Manganese | 0.44 |
| | Phosphorus | 0.97 |
| | Sulfur | 0.11 |
| | Silicon | 1.6 |
| Silver Solder | | |
| | Silver | 49.9 |
| | Cadmium | 18.3 |
| | Zinc | 15.8 |
| | Copper | 15.7 |

[redacted]

## TABLE V

Weight Loss in mg/sq.cm for a period of 48 hours and Average Penetration in Inches per year for Metals Exposed to Calcium Nitrate and Calcium Chloride Brines at a Temperature of 14°F

| | | pH | Cast Iron | | Admiralty Metal & Copper Brazed with Silver Solder | |
|---|---|---|---|---|---|---|
| | | | Loss in Weight mg/sq/cm 48 hrs | Penetration Inches/year | Loss in Weight mg/sq/cm 48 hrs | Penetration Inches/year |
| 1C | $3\frac{1}{2}$M $Ca(NO_3)_2$ | 3.2 | 0.47 | 0.00420 | 0.034 | 0.00029 |
| 4C | " " + CaO + .15% $K_2Cr_2O_7$ | 7.2 | 0.17 | 0.00150 | 0.045 | 0.00029 |
| *$4C_b$ | " " " " " | 9.2 | 0.54 | 0.00490 | 0.034 | 0.00029 |
| 5C | " " " .39% " | 7.2 | 0.33 | 0.00310 | 0.047 | 0.00041 |
| 6C | $2\frac{1}{2}$M $CaCl_2$ | 7.3 | 0.54 | 0.00490 | 0.118 | 0.00103 |
| 9C | " " + CaO + .18% $K_2Cr_2O_7$ | 8.9 | 0.38 | 0.00340 | 0.204 | 0.00181 |
| 10C | " " " .45% " | 7.2 | 0.32 | 0.00290 | 0.005 | 0.00005 |
| $1C_x$ | $3\frac{1}{2}$M $Ca(NO_3)_2$ + ($HNO_3$) | 3.0 | 2.13 | 0.1920 | 0.062 | 0.00054 |

*$4C_b$ - Room Temperature

## TABLE VI

A Comparison of Different Combinations of Metal Couples in Alkaline 3½ Molal Solution of Calcium Nitrate + .15% Potassium Bichromate

| | | Temp. F | pH | Penetration Inches Per Year: Cast Iron | Copper-base Alloy | Copper | Copper-base Alloy |
|---|---|---|---|---|---|---|---|
| 4 | 3½M $Ca(NO_3)_2$+CaO+.15% $K_2Cr_2O_7$ | 14° | 7.0 | 0.00239 | 0.00019 | 0.00010 | 0.00029 |
| 4A | " " " " " | 14° | 7.0 | 0.00173 | 0.00007 | 0.00003 | 0.00010 |
| 4C | " " " " " | 14° | 7.2 | 0.00150 | | | 0.00029 |
| $4A_b$ | " " " " " | 77° | 9.2 | 0.00620 | 0.00008 | 0.00008 | 0.00016 |
| $4C_b$ | " " " " " | 77° | 9.2 | 0.00490 | | | 0.00029 |

4- Cast Iron, Brass, Copper

4A-Cast Iron, Admiralty Metal, Copper

4C-Cast Iron, admiralty metal brazed to copper

[redacted]



ML-59

## CORROSION TEST IN CEC SOLUTION

Pvt. Donald R. Mash - 6/27/45

Temperature: 90°C

Time: 14 days

Medium: CEC solution

Metals: N-155, Hastelloy C, sensitized stainless steel type 316, Ticonium III, Stainless steel type 316 (not sensitized).

Results:

| Materials | Penetration (ipy) |
|---|---|
| N-155 | 0.000894 |
| Hastelloy C | 0.0274 |
| Type 316 s.s. (sensitized) | 0.0433 |
| Ticonium | 0.0001044 |
| Type 316 s.s. | 0.0001216 |

Conclusions: 1. On the basis of penetration, Ticonium proved to be the best, stainless steel type 316 was next.

2. Microscopic examination showed Hastelloy C, N-155, Ticonium and type 316 stainless steel to have no form of intergranular penetration in evidence. As was to be expected, 316 sensitized showed definite intergranular precipitation.

3. After a bend test, Ticonium and 316 both bent flat with no cracks. 316 sensitized cracked readily at a bend of about 90°. N-155 cracked along the edges on bending flat. Hastelloy C bent 90° before cracking.

RL 4.5.33 File No. 3898

## CHEMICAL GROUP PROGRESS REPORT

C. H. Prescott, Jr. - May 1945

Resistance of TaC to T corrosion is far higher than that of tantalum metal.

[redacted]

RL 4.6.914 File No. 3694

"K" RESEARCH

THE ACTION OF TUBALLOY METAL ON CARBIDES OF TANTALUM

F. L. Reynolds, J. A. Holmes, E. R. Parker - 5/12/45

Experiment 1

Time: 15 minutes

Temperature: 2000°C in a vacuum of $1 \times 10^{-3}$ mm Hg.

Material: TaC

Medium: Tuballoy wire

Method: A sintered TaC block was slit by a carborundum saw into a small rectangular piece about 1/4 inch x 1/2 inch x 1 inch. Then a hole 1/16 inch in diameter was drilled into the center of the end of the block for about 3/4 inch. Into this was placed a clean piece of tuballoy wire.

This tiny TaC crucible with its T-metal contents was placed in a tantalum tube (Dia. = 3/4 inch, length 4 inches) which had been pressed closed at one end to form a crucible itself. Finally, this was placed in a large quartz crucible (4 inches long, diameter 1-1/2 inch). The space between the tantalum and the quartz crucible was loosely packed with small pieces of electrically fused thorium oxide.

The whole nest of crucibles was placed in a water-cooled vacuum chamber of the induction furnace. A vacuum of $1 \times 10^{-3}$ mm. Hg. was established by holding at 1000°C for one hour. Then by intermittently flashing to 2000°C for short periods of time, the TaC crucible and the T-metal wire were brought up to 2000°C for 15 minutes. Finally, the furnace

was turned off and allowed to slowly cool in vacuum over night.

Results: T-metal interspersed in the TaC grain boundaries. In sectioning, it became more difficult as the center was approached, and only with extreme persistance was a section made. Polishing was attained only with diamond dust and oil on a paper lap.

Conclusions: 1. Tuballoy in the liquid state at 2000°C attacks the carbides of tantalum by three methods: (a) By entering the grain boundaries; (b) by dissolving the carbides of tantalum forming liquid solutions; (c) by dislodging whole grains from TaC structure when the tuballoy content is in excess.

2. Complex carbides formed may offer possibilities as K and/or J slit material. (Not much superior to tantalum in life expectancy insofar as solution is concerned, however, the great hardness of TaC might reasonably be expected to reduce the filament loss due to sputtering).

3. Hardness tests indicate that the complex carbides of Ta and T are greater than Boron carbide and fall between this and diamond.

Experiment 2

Time: 0-30 minutes

Temperature: Room - 2200°C in a vacuum $1 \times 10^{-6}$mm. Hg.

Medium: T

Material: TaC filament

Method: A thread of metalic tuballoy was looped over the TaC filament. Vacuum established and the filament brought slowly up to temperature.

Results: See table on page 88

[redacted]

TABLE 2.

Reaction of T on Hot TaC Filament.

| Time in Min. | Temp. of Filament °C | Temp. of Bead °C | Discription of Filament Action |
|---|---|---|---|
| 0 | Room | | T-metal rider placed on TaC filament. |
| | 1650 | | T-melting around TaC filament. |
| | 1740 | | T-bead begins to grow to left edge of T-rider. |
| | 1740 | | T-bead also begins to grow to right of T-rider. |
| | 1740 | | The oxide of T still hangs over the tantalum filament. |
| | 1740 | | T-bead to right approximately twice diameter of filament. |
| | 2200 | 1580 | T-beads enlarging. |
| | 2200 | 1740 | T-seems to be drawn up from inside of the legs of the T-metal rider, shown by collapse of T-oxide coating. |
| 20 | 2200 | 1740 | In the regions where the two beads meet their respective outer hot portion of the filament, the filament diameter seems to be decreasing. |
| 25 | | 1850 | One leg of T-rider falls off. |
| | | 1850 | The two T-beads separate each going toward its respective hot zone on the filament. |
| | | 1850 | The two beads about 1/4" apart. |
| 30 | 2200 | 1850 | The TaC filament broke just to the left of the left hand bead. |

[redacted]

Conclusion: 1. The Tac sheath of the filament has to some extent gone into solution in the molten T.

2. On solidification this dissolved TaC recrystallized out as dendrites.

3. It is obvious that whole grains of TaC have been dislodged and floated to the surface of the tuballoy bead.

4. Filaments that were completely carbonized are very fragile and subject to breakage.

## APPENDIX A

### INTRODUCTION

Due to the extensiveness of this report, and in order to include future reports, it is necessary to record these reports as an appendix. The appendices will follow each month and will include the table of contents for the material and a complete index up to the date of each new appendix. The first appendix is APPENDIX A which is included with this report in the following pages. The next appendix will be APPENDIX B, and the page reference shown in the index hereafter accompanying appendices will be shown by the appendix letter as 1-B, 2-B, or 1-C, 2-C.

### TABLE OF CONTENTS

I. CITRIC ACID

| | Report No. | Page No. |
|---|---|---|
| A. 10% Citric acid | | |
| Iron, sheet | CD-GS-42 | 92 |

II. HYDROCHLORIC ACID

| | Report No. | Page No. |
|---|---|---|
| A. 10% Hydrochloric acid, 0.5% Ammonium Acetate | | |
| Iron, sheet | CD-GS-42 | 92 |
| B. 10% Hydrochloric acid, 2% Aniline | | |
| Iron, sheet | CD-GS-42 | 92 |

III. OXALIC ACID

| | Report No. | Page No. |
|---|---|---|
| A. 10% Oxalic Acid | | |
| Iron, sheet | CD-GS-42 | 92 |

[redacted]



## IV. TARTARIC ACID

| | Report No. | Page No. |
|---|---|---|
| 10% Tartaric acid, 2% Aniline | | |
| Iron, sheet | CD-GS-42 | 92 |

## V. CHLORINE AND CHLORINE COMPOUNDS

| | Report No. | Page No. |
|---|---|---|
| A. Chlorine | | |
| Hastelloy C | C-3. DO.18 | 94 |
| B. 10% Ammonium Chloride | | |
| Iron, sheet | CD-GS-42 | 92 |
| C. 10% Ammonium Chloride, 10% Ammonium Acetate | | |
| Iron, sheet | CD-GS-42 | 92 |
| D. $TCl_4$ | | |
| Inconel | J.R.C. 33 | 95 |
| Stainless Steel | " | |
| E. $TCl_5$ to $TCl_4$ | | |
| Hastelloy C | J.R.C. 27 | 100 |
| Inconel | " | |
| Nickel | " | |
| Stainless steel Type 309 Cb | " | |
| 316 | " | |
| 316 Cb | " | |
| 316 Ti | " | |
| 321 | " | |
| 347 | " | |
| 446 | " | |

## VI. MISCELLANEOUS

| | Report No. | Page No. |
|---|---|---|
| A. 10% Ammonium Acetate | | |
| Iron, sheet | CD-GS-42 | 92 |
| B. 0.5% Ammonium Acetate, 10% Hydrochloric Acid | | |
| Iron, sheet | CD-GS-42 | 92 |

[redacted]

[redacted]

| | Report No. | Page No. |
|---|---|---|
| C. 2-1/2% Ammonium Acetate, 7-1/2% Ammonium Citrate | | |
| Iron, sheet | CD-GS-42 | 92 |
| D. 10% Ammonium Acetate, 10% Ammonium Chloride | | |
| Iron, sheet | CD-GS-42 | 92 |
| E. 10% Ammonium Citrate | | |
| Iron, sheet | CD-GS-42 | 92 |
| F. 7-1/2% Ammonium Citrate, 2-1/2% Ammonium Acetate | | |
| Iron, sheet | CD-GS-42 | 92 |
| G. 2% Aniline, 10% Hydrochloric Acid | | |
| Iron, sheet | CD-GS-42 | 92 |
| H. 2% Aniline, 10% Tartaric Acid | | |
| Iron, sheet | CD-GS-42 | 92 |

## ABSTRACTS

CD-GS-42 (Series A)

### REMOVAL OF SLUDGE DEPOSITS FROM BLACK IRON PIPES

J. G. Newman, C. D. Susano - 6/29/45

Temperature: 80°C

Time: 17 to 135 hours

Metal: Sheet iron of the following composition:

| Component | Percent |
|---|---|
| Carbon, C | 0.12 |
| Sulfur, S | 0.055 |
| Silicon, Si | 0.02 |
| Manganese, Mn | 0.022 |
| Phosphorus, P | 0.021 |

[redacted]

[redacted]



Media: Ten solutions, namely:

1. 10% Ammonium Chloride
2. 10% Ammonium Acetate
3. 10% Oxalic Acid
4. 10% Ammonium Acetate, 10% Ammonium Chloride
5. 7-1/2% Ammonium Citrate, 2-1/2% Ammonium Acetate
6. 10% Ammonium Citrate
7. 10% Hydrochloric Acid, 0.5% Ammonium Acetate
8. 10% Hydrochloric Acid, 2% Aniline
9. 10% Tartaric Acid, 2% Aniline
10. 10% Citric Acid

Procedure: Specimens were cleaned with No. 11 emery paper, washed with water, rinsed in ethyl alcohol, dried and weighed. The specimens were then suspended by means of glass hooks and immersed in 500 ml of the various test solutions. Temperature of 80°C was maintained, and test periods ranged from 17 to 135 hours. Air was bubbled intermittently through the solution. The samples were removed for observation at suitable intervals. Each was brushed clean with a hand brush, washed in water, rinsed with alcohol followed by ether, inspected, reweighed, and then returned to the test solution. The amount and extent of pitting was recorded.

Results:

TABLE I

| Solution Identifying No. | Time Immersed Hours | mg/sq. dm./hr. | Penetration ipy | Observations |
|---|---|---|---|---|
| 1 | 112 | 3.57 | 0.0274 | No pitting |
| 2 | 112 | 3.72 | 0.0278 | No pitting |
| 3 | 17 | 7.01 | 0.0539 | No pitting |
| 4 | 93 | 14.8 | 0.0829 | Slight pitting |
| 5 | 64 | 20.2 | 0.155 | No pitting |
| 6 | 135 | 36.1 | 0.277 | Slight pitting |
| 7 | 117 | 70.1 | 0.538 | Slight pitting |
| 8 | 67 | 100.2 | 0.769 | Severely pitted |
| 9 | 17 | 110.0 | 0.845 | No pitting |
| 10 | 17 | 686.0 | 3.66 | Severely pitted |

[redacted]

[redacted]



Conclusions: On the basis of their corrosive action, the solutions may be grouped as follows:

Negligible Corrosion

1. 10% Ammonium Chloride
2. 10% Ammonium Acetate
3. 10% Oxalic Acid
4. 10% Ammonium Acetate, 10% Ammonium Chloride

Very Slightly Corrosive

5. 7-1/2% Ammonium Citrate, 2-1/2% Ammonium Acetate
6. 10% Ammonium Citrate
7. 10% Hydrochloric Acid, 0.5% Ammonium Acetate

Severe Corrosion

8. 10% Hydrochloric Acid, 2% Aniline
9. 10% Tartaric Acid, 2% Aniline
10. 10% Citric Acid

The observations indicate that of the ten solutions tested, only numbers 8, 9 and 10 will corrode black iron to more than a negligible extent within a two hour period. In fact, it appears probable that even the more corrosive solutions could be used for occasional flushings without serious damage to the pipe lines.

C-3.100.18 (Series A)

D. RECOVERY OF TUBALLOY FROM TANTALUM

E. L. Wagner - 7/14/45

Temperature: 500-525°C

Time: Period of two chlorinations (6 hours each)

[redacted]

[redacted]

Medium: Chlorine

Metal: Hastelloy C

Method: A boat, made of Hastelloy C, was filled with the K filament charge. This was exposed for a period of two chlorinations.

Results: Approximately 50% corrosion shown by decrease in the weight of the boat from 150 grams to 80 grams.

J.R.C. 33 File No. 4294

REPORT ON NATIONAL BUREAU OF STANDARDS CERALIC COATINGS ON INCONEL AND STAINLESS STEEL

R. E. Tate - 7/2/45

A. Alpha Sublimation Still

Time: 12 hours

Temperature: Approaches 760°C (1400°F) (vacuum)

Materials: 1-1/2" x 2-1/4" specimens of Inconel and Stainless steel coated with ceramic coatings identified as A, D and E.

Method: Weighed samples were immersed in the solid material in a charge boat of an alpha sublimation still; after the run the samples were water washed and weighed.

[redacted]

[redacted]



Results:

| Sample | Coating | Base | Wt. Loss in Grams |
|---|---|---|---|
| 8A4 | A | Inconel | 0.3851 |
| 8D2 | D | " | 0.2090 |
| 13D7 | D | St. St. | 1.2094 |
| 8E2 | E | Inconel | 0.5499 |

These weight losses show that the attack is quite severe. The combination $TCl_4$, side reaction products and high temperature cause most of the enamel to be removed and the base metal to be exposed in spots.

B. Beta M Unit

Time: Duration of run

Temperature: Not given (melting point of Inconel 1393°C)

Material: Same type as used in A.

Method: Weighed specimens were placed in two parts of the M unit, a group subject to ion bombardment and a group on the floor of the housing beneath the JCC slit system. The investigation was carried out by the following steps:

1. Microscopic examination of coating.
2. Weigh.
3. Run in Beta M unit.
4. First Wash - 30 sec. in boili[illegible] water, cooled, brushed with nylon brush for 1 [illegible]n., and then given 3 rinses in boiling water.
5. Weigh.
6. Count with a Geiger Mueller counter.
7. Microscopic examination of coating.
8. Second wash - scrub 1 minute in pH 1.5 $HNO_3$ at room temperature with a stainless steel tooth brush. Rinse once in distilled water.
9. Weigh.
10. Count with a Geiger Meuller counter.
11. Microscopic examination of coating.
12. Third wash - 30 sec. dip in MPD solution. (Dissolve 36.3 grams of Cu in 455 ml concentrated $HNO_3$ and add 272 grams $H_2O$) followed by a thorough water rinse.
13. Weigh.
14. Count with a Geiger Meuller count.
15. Microscopic examination.

[redacted]

[redacted]

Experimental Results:

TABLE I

Run 4 First Wash

| Coating | Exposure | Base | Sample | Wt. Loss | Wt. Loss Gm/meter | MgT Front | MgT Back |
|---|---|---|---|---|---|---|---|
| A | Blank | Inconel | 8A5 | +0.0003 | gain | - | - |
| A | Housing | Inconel | 8A6 | +0.0011 | gain | 1.0 | 7.2 |
| A | Beam | Inconel | 8A10 | 3.1103 | melted | 12.0 | 6.6 |
| D | Blank | Inconel | 8D9 | 0.0023 | .501 | - | - |
| D | Housing | Inconel | 8D3 | +0.0043 | gain | 1.8 | 2.2 |
| D | Beam | Inconel | 8D1 | 1.1906 | 260. | 7.6 | 5.0 |
| D | Blank | S.S. | 13D9 | 0.0016 | .349 | - | - |
| D | Housing | S.S. | 13D4 | +0.0001 | gain | 6.3 | 0.8 |
| E | Blank | Inconel | 8E9 | 0.0000 | 0.0000 | - | - |
| E | Housing | Inconel | 8E4 | 1.0295 | 225. | 0.6 | 1.4 |
| E | Beam | Inconel | 8E5 | 0.0895 | 19.5 | 3.2 | 3.0 |

First Wash -- 30 sec. in boiling water, cooled, brushed with Nylon brush for 60 sec., and then 3 rinses in boiling water.

[redacted]

[redacted]

## Second Wash

| Coating | Exposure | Base | Sample | Wt. Loss | Wt. Loss Gm/meter2 | *MgT Front | MgT Back |
|---|---|---|---|---|---|---|---|
| A | Blank | Inconel | 8A5 | .0007 | .153 | - | - |
| A | Housing | Inconel | 8A6 | .0027 | .588 | 0.2 | 0.6 |
| A | Beam | Inconel | 8A10 | .0309 | 6.73 | 6.5 | 37. |
| D | Blank | Inconel | 8D9 | .0001 | .022 | - | - |
| D | Housing | Inconel | 8D3 | .0042 | .915 | 1.6 | 1.1 |
| D | Beam | Inconel | 8D1 | .0063 | 1.37 | 3.0 | 4.6 |
| D | Blank | S.S. | 13D9 | .0000 | .000 | - | - |
| D | Housing | S.S. | 13D4 | .0026 | .567 | 4.8 | 0.0 |
| E | Blank | Inconel | 8E9 | .0006 | .131 | - | - |
| E | Housing | Inconel | 8E4 | .1393 | 30.2 | 0.4 | 0 |
| E | Beam | Inconel | 8E5 | .0294 | 6.40 | 3.0 | 2.0 |

Second Wash - Scrub 60 sec. in pH 1.5 $HNO_3$ at room temperature.

[redacted]

[redacted]



Third Wash

| Coating | Exposure | Base | Sample | Wt. Loss gm. | Gm/meter$^2$ | *MgT Front | MgT Back |
|---|---|---|---|---|---|---|---|
| A | Blank | Inconel | 8A5 | .0001 | .022 | - | - |
| A | Housing | Inconel | 8A6 | .0004 | .087 | neg. | neg.** |
| A | Beam | Inconel | 8A10 | .0199 | 4.34 | 6.4 | 13. |
| D | Blank | Inconel | 8D9 | .0001 | .022 | - | - |
| D | Housing | Inconel | 8D3 | .0021 | .458 | 0.5 | 0.6 |
| D | Beam | Inconel | 8D1 | .0078 | 1.70 | 1.7 | 1.3 |
| D | Blank | S.S. | 13D9 | .0002 | 0.044 | - | - |
| D | Housing | S.S. | 13D4 | .0034 | .740 | 1.0 | 0.5 |
| E | Blank | Inconel | 8E9 | .0000 | .000 | - | - |
| E | Housing | Inconel | 8E4 | .0048 | 1.05 | neg. | neg. |
| E | Beam | Inconel | 8E5 | .0044 | .960 | 2.2 | 2.4 |

Third Wash - 30 sec. dip in MPD solution followed by a thorough water rinse.

** neg. signifies negligible

Results: Samples exposed to the beam show: Coating D was eroded to the base metal, Coating E was badly blistered, and the Inconel base of Coating A was melted. Samples exposed to the $TCl_4$ condensing vapors show: Coating E badly attacked, Coating A had a slight deposit of Cu, Coating D (both) had a light deposit of grey material.

The weight losses and estimated amounts of tuballoy on each

[redacted]

[redacted]



sample after each treatment are shown in Table I.

Conclusion: Comparison with the blank samples show that the media used in washing attack the various coatings only slightly. It is shown that coating D is most difficult to clean as it has a comparatively rough surface. (Coating D was not cleaned to a point where the T hold-up was negligible as measured by a Beta counter.)

Microscopic examination shows coating A and E are smooth, translucent and contain many bubbles, some of which are broken in service and become focal points for corrosion and hold-up. Coating D shows a relative rough surface which seems quite difficult to clean.

J.R.C. 27 File No. 4251

PROGRESS REPORT ON CORROSION STUDIES

Donald R. Mash - 6/14/45

TESTS IN THE DECOMPOSER

Temperature: 550°C

Time: 2 hours (three tests)

Metals: See list under results

Medium: $TCl_5$ decomposing to $TCl_4$

Method: The samples were tested in the Decomposer.

[redacted]

**Results:** The following are average results of the test runs:

| Type | Weight Loss ($mg./cm^2/Run$) | Remarks |
|---|---|---|
| 316 Cb | 0.371 | All non-magnetic |
| 309 Cb | 0.422 | |
| 446 | 1.07 | except nickel |
| 347 | 0.388 | |
| 316 | 0.751 | |
| Inconel | 0.178 | |
| 316 Ti | 0.618 | |
| 321 | 0.856 | |
| Hastelloy C | 0.224 | |
| Ni | 0.812 | |

**Conclusions:** To be able to choose the best material for decomposition charge bottles, the behavior must be ascertained under three distinct phases:

1. During the decomposition of $TCl_5$, in which nascent $Cl_2$ would be the corrosive agent.
2. During the runs, $TCl_4$ solid and vapor.
3. During the wash in which an aqueous solution of $HNO_3$ and $TCl_4$ acts as the corrosive agent.

Also, since the test runs at about 550°C (within the sensitizing range for the stainless steels) the St. St. samples no doubt would show an increased corrosion rate over a larger test run due to increased carbide precipitation.

[redacted]

The page number indicates the beginning of the report which covers the material listed.

## INDEX


| Materials | Page No. |
|---|---|
| Admiralty Metal | 78 |
| Aluminum | 24, 32, 38, 44, 65, 73 |
| Alundum | 44 |
| Antaciron | 16 |
| Asplit | 30 |
| Beryllium | 44 |
| BeO | 44 |
| Brass | 32, 65, 78 |
| Bronze | 65 |
| Cadmium | 65 |
| Cast Iron | 75, 78 |
| Chromel "A" | 45, 47 |
| Chromel wire | 48 |
| Columbium | 45 |
| Commercial 150, 180, 190, 200 | 45 |
| Copper | 24, 32, 34, 35, 44, 49, 50, 65, 66, 73, 75, 78 |
| Copper (plated) | 24, 29, 51, 52, 53, 65, 73, 75 |
| Cupro Nickel | 61 |
| Discalloy | 45 |
| Downmetal | 65 |
| Durichlor | 16 |
| Durichrome | 61 |
| Duriron | 16, 32 |


[redacted]

[redacted]


| Materials | Page No. |
|---|---|
| Duro | 30 |
| du Pont D-29 | 30, 32 |
| Enamelled Iron | 37 |
| Everdur | 16, 38, 51, 73 |
| Glass | 44, 53, 61, 69 |
| Gold | 37, 44, 45, 49, 65 |
| Graphite | 44, 67, 68 |
| Hastelloy, A | 32, 63 |
| Hastelloy, B | 16, 24, 32, 45, 49, 63, 70, 73 |
| Hastelloy, C | 16, 24, 32, 45, 49, 54, 56, 63, 69, 73, 85, 94, 100 |
| Hastelloy, D | 63 |
| Haveg | 32 |
| Herculoy | 51 |
| Illium, G | 16, 61 |
| Illium, R | 16 |
| Inconel | 16, 24, 32, 45, 49, 57, 61, 65, 66, 68, 70, 71, 73, 75, 95, 100 |
| Iron | 44, 75, 78, 92 |
| Iron, Enamelled | 37 |
| K-42-B | 45 |
| Koroseal | 30 |
| Kovar | 24, 68 |
| Lead | 32, 59, 65 |
| Low Carbon Steel | 47 |
| Mallory | 24, 63 |
| Manganese Steel | 38 |


[redacted]

[redacted]


| Materials | Page No. |
|---|---|
| Mild steel | 32 |
| Molybdenum | 44, 45, 49, 65, 66, 73, 75 |
| Monel | 16, 32, 44, 45, 50, 65, 66, 67, 68, 71, 75 |
| Monel, K | 57 |
| N 153 | 70, 72 |
| N 155 | 70, 72, 85 |
| Neoprene-Cork | 30 |
| Nichrome | 44, 45, 57, 75 |
| Nickel | 16, 24, 32, 44, 45, 47, 49, 50, 53, 57, 59, 65, 66, 67, 68, 71, 73, 75, 77, 100 |
| Ni-Resist | 29, 51 |
| Nuriron | 61 |
| Palladium | 65 |
| Platinum | 44, 45, 65, 66, 68 |
| Porcelain (Refractory) | 45 |
| Pyrex | 44 |
| Quartz | 44 |
| Refractory | 45 |
| Saran | 30, 32 |
| Silastic-Dow | 30 |
| Silicone Grease | 23 |
| Silver | 24, 32, 35, 44, 49, 65, 66, 73, 75 |
| Silver Solder | 78 |
| Steel | 32, 34, 47, 65, 75 |
| Steel ( Manganese) | 38 |


[redacted]

| Materials [redacted] | Page No. |
|---|---|
| Stainless Steel | 24, 32, 44, 45, 47, 53, 59, 65, 66, 67, 69, 73, 75, 95 |
| Stainless Steel - Type 302 | 32, 40, 45, 47, 48, 49, 51, 69, 70, 71, 72, 75, 76 |
| Type 304 | 16, 46, 50, 57, 61, 72, 75, 77 |
| Type 308 | 32 |
| Type 309 | 54, 56, 76 |
| Cb Type 309 | 100 |
| Type 310 | 16, 38, 48, 61, 76 |
| Type 312 | 61 |
| Type 316 | 16, 32, 34, 38, 46, 48, 50, 54, 56, 61, 65, 68, 69, 70, 71, 72, 75, 76, 77, 85, 100 |
| Cb Type 316 | 16, 56, 100 |
| Ti Type 316 | 100 |
| Type 317 | 16, 38, 48, 61, 69, 75, 76 |
| Type 321 | 38, 48, 50, 54, 56, 69, 70, 75, 76, 77, 100 |
| Type 325 | 61 |
| Type 329 | 16, 38, 48, 61 |
| Type 330 | 70, 71 |
| Type 347 | 16, 38, 48, 54, 56, 61, 70, 71, 72, 100 |
| Type 446 | 16, 100 |
| Tantalum | 24, 30, 32, 45, 49, 60, 61, 65, 66, 68, 73 |
| Tantalum Carbide | 85, 86 |
| Tantalum, K | 60 |
| Thorium Oxide | 44 |
| Ticonium | 85 |


[redacted]

| Materials | Page No. |
|---|---|
| Tin | 59, 65, 75 |
| Tuballoy (and alloys) | 41 |
| Tungsten | 44, 61, 65, 66, 67, 68 |
| Tungsten (Thoriated) | 67, 68 |
| Tygon | 69 |
| Tygon TLU 103 | 30, 32 |
| Tygon TU 2807 | 30, 32 |
| Tygon TU 3400 | 30, 32 |
| Worthite | 16 |

L. F. Little

L. F. Little

C. D. Susano

C. D. Susano

CDS:mpt
Date submitted: 8/10/45
Attachments: None

Distribution: See page 107

SECRET

Distribution:

cc. 1-2. Lt. Col. J. R. Ruhoff
3-4. U. C. R. L.
5-16. Dr. Wensel
17-18. T.R.I.O.
19. Dr. F. R. Conklin
20. Dr. J. G. McNally
21. Mr. D. C. Hull
22. Dr. H. L. Hull
23. Mr. L. G. Warren
24. Mr. W. R. Chambers
25. Dr. C. E. Larson
26. Mr. J. L. Patterson
27. ~~Mr. A. E. Ballard~~
28. Mr. A. D. Caley
29. Mr. John H. Rogers
30. Mr. M. L. Piker
31. Mr. R. J. Schmidt
32. Mr. C. B. Graham
33. Mr. J. A. Kyger
34. Mr. G. H. Clewett
35. Dr. G. A. Akin
36. Dr. Alan Bell
37. Mr. H. R. Brigham
38. Dr. D. W. Stewart
39. Mr. E. D. Kane
40. Dr. J. W. Gates, Jr
41. Mr. C. M. Sheridan
42. Mr. J. E. Reeves
43. Mr. M. F. Quinn
44. Mr. D. Z. Elliot
45. Mr. J. B. Allen
46. Dr. R. J. Schrader
47. Mr. E. Howe
48. Dr. R. Wilder
49. ~~Dr. L. E. West~~
50. Mr. C. D. Susano
51. Mr. V. T. Waugh
52. Mr. M. M. Fiedler
53. Mr. C. R. Sanford
54. Dr. Wm. Feldman
55. Mr. R. A. Stipp
56. Mr. W. H. Jenners
57. Mr. W. B. England
58. Mr. M. A. Richtmyer
59. Mr. T. F. Taylor
60. Mr. J. S. Hood
61. Mr. R. W. Peters
62. Mr. W. L. McKusick
63. Mr. S. N. Smith
64. Mr. C. P. Wright
65. Mr. E. V. Martin
66. Mr. T. L. Brown
67. Mr. T. G. Veal
68. Mr. W. L. Bradshaw
69. Mr. G. W. Mitchell
70. Mr. J. L. Bray
71. Mr. W. D. Lavers
72. Mr. R. L. Murray
73. Mr. F. R. O'Brien
74. Mr. C. G. Plomasen
75. Mr. R. S. Livingston
76. Mr. R. L. Fellers
77. Mr. H. G. Lines
78. Mr. R. M. Batch
79. Mr. Wm. Nixon
80. Mr. L. F. Little
81. File

SECRET