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~~Report 1673-COO-1319-12 (Q-3)~~

17 December 1963 - 16 March 1964

A STUDY OF THE MECHANISM OF STRESS CORROSION CRACKING
IN THE IRON-NICKEL-CHROMIUM ALLOY SYSTEM

F. H. Beck, M. G. Fontana, and J. P. Hirth
Department of Metallurgical Engineering

U. S. Atomic Energy Commission
Chicago Operations Office
Contract No. AT(11-1)-1319

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RF Project 1673

Report No. COO-1319-12
(Q-3)

QUARTERLY

REPORT

By
THE OHIO STATE UNIVERSITY
RESEARCH FOUNDATION

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COLUMBUS ~~12~~, OHIO
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To U. S. ATOMIC ENERGY COMMISSION
Chicago Operations Office
Argonne, Illinois
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On A STUDY OF THE MECHANISM OF STRESS CORROSION
CRACKING IN THE IRON-NICKEL-CHROMIUM ALLOY
SYSTEM

For the period 17 December 1963 - 16 March 1964

Submitted by F. H. Beck, M. G. Fontana, and J. P. Hirth
Department of Metallurgical Engineering

Date 31 March 1964

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I. INTRODUCTION

The aim of this program is to evaluate systematically the susceptibility of single-phase iron-chromium-nickel alloys to stress corrosion cracking in chloride and hydroxide environments. The general experimental program is divided broadly into studies of physical metallurgy, electrochemistry, and stress corrosion cracking susceptibility. A schematic description of the overall program is given in Fig. 1.

One of the significant aspects of this program is a strong emphasis on self-consistency. This is considered important if the data are to be subjected to meaningful analysis and interpretation. Self-consistency is being maintained in three important areas as follows:

1. Evaluation by Several Different Techniques

Over the course of the program each of the alloys will be evaluated according to the general plan described in Fig. 1. Trends observed in the stress corrosion cracking will be examined for possible correlations with observations in other areas such as anodic polarization experiments and studies of defect structure.

2. Simultaneous Evaluation of Iron, Chromium, Nickel, and Impurity Variations

The alloys to be evaluated are shown in Fig. 2. Approximately 100 ternary alloys, which have systematic variations in iron, chromium, and nickel, will be evaluated. In addition, about 100 alloys having a fourth component will be investigated. In this case the same level of a given fourth component (e.g., 0.1% carbon) will be added at five different ternary compositions. These compositions are widely separated and are noted by diamonds on Fig. 2. Of the five ternary alloy compositions, one of the alloys has been selected in the region of austenitic stainless steels and a second at the composition of Inconel-600. In addition, a number of commercial alloys, including stainless steels, the Inconels and Hastelloys will be studied. Approximately 240 specimens can be tested in one run of the recirculating autoclave system. For each alloy the time to cracking will be determined. Thus, in a given combination of environment temperature, dissolved gas, pH, and ionic composition the entire variability with respect to alloy composition can be evaluated.

3. Fabrication, Processing, Specimen Selection

One of the important aims of the program of fabrication and specimen preparation is to eliminate prior history as a variable. For most of the work, specimens for a given experiment will have the same size. For anodic polarization, specimens will be 0.250" in diameter; for tensile studies of single crystals, 0.125" diameter; and for time to cracking in stress

Figure 1

GENERAL PLAN FOR PROGRAM
OF RESEARCH ON STRESS CORROSION
MECHANISM OF IRON -
CHROMIUM - NICKEL ALLOYS

Figure 2

ALLOYS TO BE MELTED
(400° C ISOTHERM SHOWN)

corrosion experiments, 0.015" diameter. Important elements of self-consistent processing are as follows:

- a. All hot rod rolling will be performed at the same temperature for all alloys, and all alloys will receive the same rolling pass schedule.
- b. In cold reduction all alloys will be annealed at the same cold work levels and the same annealing treatment will be used for all materials. A possible exception may be made in the case of alloys in the region of martensitic stainless steels where temperatures may be lowered for intermediate anneals during wire drawing.
- c. Ingots will be melted from prehomogenized master alloy ingots. Prior melting of master ingots is aimed at "leveling out" the concentration of residual impurities and eliminating gaseous impurities.
- d. Specimens to be tested in the wire form will be vacuum annealed in straight lengths after the final wire drawing pass. Annealing in straight lengths should eliminate possible variability due to cold work resulting from testing in tension a wire which has been uncoiled from a round spool. For the early stages of the program all material will be evaluated in the dead annealed condition since the primary interest is the inherent susceptibility to stress corrosion cracking of a given chemical composition. Annealing in a vacuum is aimed at eliminating any hydrogen picked up during intermediate annealing and preventing surface contamination.
- e. All processing will be performed by the same group of people over a period of relatively few months.
- f. Specimens for a given experiment will always be taken from the same location within an ingot; e.g., specimens for anodic polarization would always come from the ingot top and the wire will always be taken from the bottom.

II. FABRICATION AND MATERIALS

A. PREPARATION OF INGOTS AND FABRICATION

Each of the various compositions described in Fig. 2 will be melted as approximately a one-pound ingot. The actual weight of material available for fabrication will be 0.8 - 0.9 pounds, with about 0.4 pounds in the hot top. Figure 3 shows a typical ingot melted in the initial fabrication study and Fig. 4 shows the disposition of each portion of the ingot.

Fig. 3. Typical ingot, weighing about 1.4 pounds, to be fabricated into specimens for studies in the physical metallurgy, electrochemistry, and corrosion aspects of stress corrosion cracking of iron-chromium-nickel alloys

Figure 4. Disposition of various portions of the one pound ingots

Prior to melting the one-pound ingots of specific compositions a number of binary master alloys are being prepared in 20-pound ingots by vacuum induction melting. This is expected to reduce the level of volatile impurities such as nitrogen, hydrogen, oxygen, and carbon (as CO) and to homogenize non-volatile impurities. Listed below are results of chemical analyses from the first five master alloys.

Table I. Chemical Analysis for Interstitial Impurities
in Five 20-Pound Master Ingots

(Results in ppm)

Alloy	Carbon	Oxygen	Hydrogen	Nitrogen
Fe-15Cr	120	15	0.4	10
Fe-15Cr	110	28	0.4	20
Fe-30Cr	50	100	0.3	30
Ni-5Cr	60	27	0.3	10
Ni-20Cr	60	19	0.5	10

It is expected that the carbon and oxygen will be further reduced during the vacuum induction melting of the one-pound ingots.

To demonstrate that the material from a one-pound ingot will be sufficient for the planned experiments, Fig. 5 shows the relation between ingot volume, specimen length, and specimen diameter. The usable volume of a one-pound ingot is approximately 3 cubic inches. This is equivalent to about 62 lineal inches of 0.250" diameter, or 250 inches of 0.125" diameter, or 1,250 feet of 0.015" diameter wire. At present the general plan is for about 5% of the material to be left at 0.250", 60% at 0.125", and the remainder in the form of 0.015" wire.

Based on results from a preliminary fabrication study, hot rod rolling to 0.250" will be done at 2000°F. The material will be subsequently cold swaged to 0.125" diameter. Wire drawing will be performed cold with intermediate anneals. For an 85% Ni - 15% Cr alloy the structure after hot rod rolling to 0.260" at 2000°F is shown in Fig. 6. The structure after cold swaging the alloy to 0.125" diameter is shown in Fig. 7. The structure of this alloy after annealing at 1800°F for 15 minutes is shown in Fig. 8. No difficulty was experienced in cold swaging this alloy from 0.250 to 0.125" (a reduction of 75%). A graph relating the per cent reduction of a cylindrical cross section to original diameter (D_0), and final diameter (D_f) after reduction is shown in Fig. 9.

Figure 5. Relationship among volume, length, and diameter of cylindrical geometries

Fig. 6. Structure of an 85% Ni - 15% Cr alloy after hot rolling from approximately 0.750" to 0.260" diameter at 2000°F. Etched electrolytically in oxalic acid. About 100 x as printed

Fig. 7. Material from Fig. 6 after cold swaging from 0.260" to 0.125" diameter. Same etch and magnification as Fig. 6

Fig. 8. Material from Fig. 7 after annealing at 1800°F for 15 minutes.
Same etch and magnification as Fig. 6

Figure 9. Relationship among percent reduction, initial diameter for cylindrical geometries

B. SINGLE CRYSTALS

It is planned to study the properties of single crystals of iron-chromium-nickel alloys in stress corrosion cracking and load-elongation experiments. Crystal-growing work is being performed on a vertical, electron-beam, zone-refining unit. Preliminary work has been performed using single upward passes of the electron-beam source. Using an 85% Ni - 15% Cr alloy and a speed of 35 microns per second (12.6 cm/hr) the structure shown in Fig. 10 was obtained. Note the pebble-grained appearance and the fact that some type of boundary appears to follow the grain structure. Several more pronounced grain boundaries appear near the perimeter. When the zone speed was slowed to 12.5 microns per second a much improved structure resulted. However, as shown in Fig. 11 several twins were produced and some boundary structure is associated with the twins. This work is continuing. The efficacy of various power settings, other speeds, multiple passes, and alloy composition will be evaluated.

III. STRESS CORROSION CRACKING EXPERIMENTS

The alloys described in Fig. 2, plus various commercial alloys, will be evaluated for susceptibility to stress corrosion cracking over a temperature range up to 700°F in single-phase aqueous solutions in a recirculating autoclave system. This system will have the capability of controlling temperature, dissolved gas concentration, and solution flow. In this system it will be possible to monitor time to cracking while the specimen is actually inside the autoclave so that time to cracking can be evaluated as a function of alloy, stress, pH, dissolved gas concentration, ionic composition, and temperature.

In addition to experiments in the large autoclave system, specimens will also be evaluated for time to cracking in the standard boiling magnesium chloride test. This is expected to provide a good correlation between the two techniques. A large cell is being constructed in which at least 20 specimens can be tested at one time. Again, in accord with the emphasis on self-consistency, a relatively large number of specimens will be tested at one time under one set of conditions.

The studies on stress corrosion cracking in the large system will be supplemented with studies in several smaller autoclaves. These experiments will be scoping in nature and will evaluate various environments and conditions so that the experiments in the large system can be chosen most effectively.

Fig. 10. Cross section of 0.125" diameter rod after a single pass in a vertical electron beam zone refining unit. Zone speed was 35 microns per second (12.6 cm/hr). Alloy was 85Ni-15Cr. Electrolytically etched in oxalic acid. Approximately 25x

Fig. 11. Same as in Fig. 9 but zone speed was 12.5 microns per second

A. SMALL AUTOCLAVES

Two small autoclaves have been purchased for the purpose of conducting scoping experiments. These autoclaves are constructed primarily of Inconel-600 and are capable of operating up to 900°F at pressures of 5000 psi. A special feature of these autoclaves is that electrical leads can be taken through the pressure boundary for monitoring the time to cracking. An overall photograph of the small autoclave is shown in Fig. 12. The projection out of the top with cooling fins is the fitting through which the electrical leads will pass.

Figure 13 shows the parts involved in the electrical leads fitting and Fig. 14 is a view of the bottom of the vessel head showing the insulator through which the leads will pass coming into the autoclave. A schematic of the arrangement of parts of the electrical lead fitting is shown in Fig. 15. Referring to Fig. 15, the cap is screwed down and makes contact with the gland follower. The gland follower compresses the Teflon. The Teflon flows and makes a seal around each wire. These seals are made for up to 16 electrical leads. Cooling fins have been added in the region around the Teflon seal to keep its temperature as low as possible. The concept of this fitting and many possible variations is due mainly to the Conax Corporation in Buffalo, New York. The same technique for bringing in electrical leads will be utilized in the large recirculating autoclave.

B. RECIRCULATING AUTOCLAVE SYSTEM

1. The General System

A layout of the recirculating autoclave system is shown in Fig. 16. In this system the solution is recirculated by a duplex action positive displacement capable of circulating 40 gallons per hour against a 5000 psi discharge head. The preheater is sized to heat the solution from RT to 700°F continuously.

All fittings, tubing, and components are sized so that a pressure of 5000 psi the stress on the surface in contact with solution will be less than 10,000 psi. In the case of the autoclave itself an Inconel-600 liner is being used and will be shrink-fitted so that at 700°F and 5000 psi the tensile stress on the inside surface will not exceed 1000 psi.

Since it is not clear what problems might arise with regard to contamination from corrosion of the system itself and the specimens, the system has been designed so that solution can either be recirculated continuously, or be flushed following one pass through the autoclave. The recirculating paths may be arranged so that the solution can stay at pressure and temperature or pass through a low-pressure, low-temperature region. This latter alternative is necessary in order to inject dissolved gas continuously in concentrations greater than about 50 ppm.

Fig. 12. Small autoclave for conducting scoping experiments. Fitting with fins at top is for bringing electrical leads through pressure boundary. Overall height is 36 inches. Usable inside length is 16" and inside diameter is 2". Vessel material is Inconel-600

Fig. 13. Parts involved in fitting for bringing electrical leads through pressure boundary. A schematic diagram showing these parts is given in Fig. 14

Fig. 14. Bottom of pressure vessel head showing location where electrical leads come into autoclave. Screw and washer keep insulators from falling into autoclave. Four symmetrically arranged holes are for bolts for attaching experiments. Hole next to washer is opening to pressure gauge and vent

Figure 15. Schematic arrangement of parts in electrical lead fillings

Fig. 16. Schematic arrangement of recirculating autoclave system

Maintaining a constant level of dissolved gas will be accomplished by injecting a measured amount of gas at each stroke of the positive displacement pump. This measured amount of gas will be trapped between two solenoid operated valves. When one of the pistons of the pump is taking suction, the downstream solenoid valve will be opened by a mechanically actuated electrical switch on the pump and the gas will be drawn in. As the downstream valve closes, the upstream solenoid will open, allowing gas to fill the measured volume. The downstream solenoid valve will again open and the trapped gas will enter the suction of the opposed piston. The process will continue. By knowing the volume of the trapped gas, the upstream pressure (maintained by a pressure regulating valve), and the downstream pressure, the quantities V and ΔP will give the number of moles of gas injected per stroke. The actual amount of gas in solution will be analyzed periodically by taking samples of solution.

2. Electrical Power

A schematic design of electrical power circuits for the recirculating system is shown in Fig. 17. Heaters on the autoclave have sufficient capacity that a static autoclave full of solution and specimens can be heated to 700°F in less than one hour. It is expected that the recirculating system can bring specimens to 700°F in less than 15 minutes. Rapid heating of the autoclave coupled with sensitive control will be accomplished by having two-thirds of the heaters on manual control. These heaters will be turned off when the outside autoclave wall reaches test temperature. One-third of the heaters will be controlled by a saturable core reactor which can receive temperature signals from either, or both, the thermocouples on the outside surface or those inside the autoclave.

3. The Preheater

The preheater unit will heat the solution by self resistance of the tubing. The selection of tubing length and voltage is based on the graph in Fig. 18 which relates the total length of tubing, power required, and the voltage. Since a 50-kw unit is required, it has been decided to use approximately 140 feet of tubing and 24 volts.

An important consideration in selecting the power density of the preheater is the thermal stress. This has additional importance in the preheater since the inside surface is in tension. While the Inconel-600 is expected to be generally resistant to corrosion in the temperature range and solution compositions planned, the presence of appreciable stresses is not desirable. At 5000 psi the resulting inside surface will not exceed 10,000 psi. This is based on the relationship for stress in thick annular sections which is given by

$$\sigma = P_i \frac{w^2 + 1}{w^2 - 1} \quad , \quad (1)$$

Fig. 17. Schematic arrangement of electrical power circuitry for recirculating autoclave system

Figure 18. Relationship among voltage, power, and tubing length in preheater

where

σ = stress in psi,

P_1 = inside pressure in psi, and

$w = b/a$, where b is the outside wall radius and
 a is the inside wall radius.

In the case of the 9/16" x 5/16" tubing to be used in the pre-heater, $w^2 = 3.24$ and $(w^2 + 1)/(w^2 - 1) = 1.89$. At $P_1 = 5000$ psi, $\sigma = 9450$ psi. It is desirable that the thermal contribution to stress not alter the situation appreciably. The temperature distribution in an annular cylinder is given by

$$T = T_a + \frac{\dot{q}}{2k} \left[b^2 \ln \frac{r}{a} + \frac{1}{2} (a^2 - r^2) \right], \quad (2)$$

where

T = temperature ($^{\circ}\text{F}$);

T_a = temperature at inside radius, a ($^{\circ}\text{F}$);

$\dot{q}$ = internal heat generation rate (BTU/hr-ft³);

k = thermal conductivity (BTU/hr-ft- $^{\circ}\text{F}$);

a, b = inside and outside radius, respectively (ft);

r = radius at T (ft);

and the mean temperature in the metal wall is given by

$$T_M = \frac{1}{b-a} \int_a^b \left\{ T_a + \frac{\dot{q}}{2k} \left[b^2 \ln \frac{r}{a} + \frac{1}{2} (a^2 - r^2) \right] \right\} dr. \quad (3)$$

The thermal stress is given by

$$\sigma_T = E \alpha_T (T_M - T_a), \quad (4)$$

where

σ_T = thermal stress (psi),

E = Young's modulus (psi), and

α_T = coefficient of thermal expansion ($^{\circ}\text{F}$) $^{-1}$.

Internal heat generation is related to power level and tubing length by

$$\dot{q} = \frac{PK}{L\pi (b^2 - a^2)}, \quad (5)$$

where

P = power in kw,

K = conversion constant to BTU/hr, and

L = length of tube (ft).

Therefore, for Inconel-600 tubing with 9/16" OD and 5/16" ID the thermal stress on the inside surface is given approximately by

$$\sigma_T = 3330 \frac{P}{L}, \quad (6)$$

where

P = power in kw,

L = tube length (ft), and

σ_T = thermal stress (psi).

Thus for 50 kw and 140 feet of tubing the thermal stress contribution is about 1200 psi.

The preheater will be electrically grounded at both ends, as noted in Fig. 17. In addition, the preheater will be electrically isolated from the system by the use of a special high-pressure fitting designed by the autoclave vendor, Pressure Products Industries. This fitting is shown in Fig. 19.

Figure 19. Electrical isolation filling for preheater

4. Time-to-Cracking Circuitry

To monitor time to cracking, standard event recorders will be utilized. An event recorder consists of a series of pens held in position by energized relays. When the circuit is deenergized (the specimen cracks in the case of our experiments), the pen shifts position and an exact record is obtained of the moment the circuit was deenergized. Figure 20 shows a typical event recorder and a typical trace. The circuit diagram for monitoring time to cracking is shown in Fig. 21.

In monitoring time to cracking inside the autoclave, special consideration has been given to minimizing interference with the corrosion process, thereby assuring reliability of the monitoring system. To meet this objective the following features are being incorporated:

- a. the monitoring circuit will utilize alternating current and the voltage drop across the specimen will be on the order of 0.005 volts;
- b. the monitoring circuit will not be monitored continuously but will be energized for about one second out of every minute;
- c. since simultaneous cracking of the several specimens at one time would be very unlikely and to assure that a circuit break exists due to specimen cracking, each pen circuit on the event recorder will actually monitor a number of specimens;
- d. current required to activate the pen in the event recorder will be maintained as low as possible to minimize heating transients in the specimen.

In considering the importance of item (d) (heating transients), consideration must be given to the contribution of resistance heating to both (1) thermal stresses inside the specimen and (2) a rise in surface temperature which would alter the surface reaction rate. The maximum central temperature in a resistively heated cylinder is given by

$$T_c = T_o + \frac{\dot{q}r_o^2}{4k}, \quad (7)$$

where

r_o = outer radius

T_c = temperature of wire axis

T_o = temperature at r_o

k = thermal conductivity of metal

$\dot{q}$ = internal heat generation rate

Fig. 20. Event recorder showing a typical trace for 20 channels being monitored simultaneously. In the case of monitoring time to cracking, blips would occur each time the circuit for a given specimen is energized. When the specimen breaks, the blips will no longer occur

Fig. 21. Circuit diagram for monitoring time to cracking by the use of an event recorder

The surface temperature is related to the bulk solution temperature by

$$T_o = T_B + \frac{q''}{hA} \quad , \quad (8)$$

where

T_B = temperature of bulk solution,

h = heat transfer coefficient,

A = heat transfer area, and

q'' = surface heat flux.

Internal heat generation is given by

$$\dot{q} = \frac{3.413 V^2}{\rho \ell^2} \quad , \quad (9)$$

where

V = voltage across specimen

ρ = resistivity of specimen

ℓ^2 = specimen length

The temperature difference between the center of the wire and the bulk solution is given by

$$T_c - T_B = 10.24 \left(\frac{V^2}{\rho} \right) \left(\frac{r_o}{\ell} \right)^2 \left[\frac{1}{k} + \frac{24}{r_o h} \right] \quad . \quad (10)$$

with r, ℓ in inches, ρ in ohm-inches, h in BTU/hr-ft²-°F, k in BTU/hr-ft-°F, V in volts.

In order to evaluate the heat transfer coefficient, h , it was assumed, conservatively, that natural convection applies inside the autoclave. Using equations from McAdam's Heat Transmission (McGraw Hill) and data

on the properties of water at 2000 psi at temperatures to 620°F, it was concluded that a good average heat transfer coefficient would be 40 BTU/hr-ft²-°F. Equation 10 can also be rewritten in terms of electrical current as follows:

$$T_c - T_B = 1.04 \frac{I^2 \rho}{r_o^2} \left[\frac{1}{k} + \frac{24}{r_o h} \right] , \quad (11)$$

where

I = current in amps and other quantities having the same dimensions as equation (10).

If the monitoring current were as high as one amp, the $\Delta T (T_c - T_o)$ in a 0.015"-diameter would be about 0.074°F for an assumed resistivity of 4×10^{-5} ohm-in. This would contribute negligible thermal stresses, therefore the consequence of resistive heating in altering the stress picture will not be considered further.

Considering only the film drop ($T_o - T_B$), a one-amp current would produce a 60°F temperature rise at the specimen surface. Clearly this would alter considerably the rate of corrosion attack. If a criterion of a maximum film drop of 1°F is established, the maximum current allowed would be about 40 ma. The film drop ($T_o - T_B$) is plotted in Fig. 22 versus current for various wire radii and various resistivities. Based on a review of resistivity for various iron-chromium-nickel alloys, the maximum resistivity at temperatures up to 700°F appears to be about 4×10^{-5} ohm-in. For the pure alloys in this study, the resistivities should be lower. Thus, according to Eq. 11, the film drop, given by

$$T_o - T_B = 25 \frac{I^2 \rho}{r_o^3 h} , \quad (12)$$

will be reduced when the resistivity is reduced. By selecting an appropriate model of event recorder, the current in the monitoring circuits will be about 20 ma.

Figure 22. Relationship among specimen resistivity, current through specimen, diameter of specimen, and difference in temperature between metal surface and the environment

IV. PHYSICAL METALLURGY

The main aim of the physical metallurgy portion of the program is to correlate the defect structure of iron-chromium-nickel alloys with their susceptibility to stress corrosion cracking. This will be done mainly by studying the load-elongation characteristics of single crystals as a function of temperature, studying the defect patterns in thin film using electron microscopy, conducting strain aging experiments, and studying twin frequency. Initial work on fabrication single crystals is described in Section II. Electron microscopy on thin films and strain aging experiments will not begin until the ingots described in Fig. 2 become available.

Preliminary work on studying twin frequency has begun and is being conducted on already available material to determine the range of annealing temperature and prior cold work which should be used in studying twin frequency on the alloys described in Fig. 2.

The following variables will be evaluated in the preliminary study of twin frequency:

Annealing Temperature: 1400, 1670, 1930, 2200°F;

Annealing Time: 5, 10, 30, 60, 120 minutes;

Cold work: 40, 60, 80, 90%; and

Materials: Type 304, Type 309, Inconel-600, 85Ni-15Cr, 85Ni-15Cr-0.02N.

Twin frequency is being studied because twins appear to be related to stacking faults, and the frequency of twins appears to be related to stacking fault energy (i.e., a high number of twins would indicate a low energy required to form stacking faults or a low stacking fault energy, and a low number of twins would indicate the opposite). In face-centered cubic metals the standard packing of 111 type planes is ABCABCABCABC ... If a twin exists the packing is ... ABCABCACBACBA. In the case of a stacking fault the stacking is ... ABCAABCABC ... It appears that a stacking fault may be considered as two successive twins so that the stacking fault energy may be considered as approximately twice the energy for forming a twin.

Susceptibility to stress corrosion cracking has been related to lowered stacking fault energy in copper base alloys and austenitic stainless steels by several authors.^{1,2} Susceptibility, in turn, has been related to an increasing twin frequency by Robertson and van Rooyan.^{3,4} The actual role of the lowered stacking fault energy is not completely clear. Lowered stacking fault energy contributes to the extension of dislocations, restricted cross slip, stronger crystallographic barriers to slip, and to sites for diffusion and accumulation of solute atoms.

A number of papers^{3,5,6} have shown a definite relationship between microscopic corrosion tunnels and the crystallography of various alloys. There are strong implications from this work that defect structure plays an important role in this tunnelling.

An important factor not explained by work on defect structure is the effect of environment composition. Not all environments lead to stress corrosion cracking but the defect structure inside a metal should be independent of the chemistry of the environment.

By examining a wide range of alloys in a variety of environments, it is hoped that a much clearer picture of the interaction of environment and defect structure will be forthcoming.

V. ELECTROCHEMISTRY

The major portion of this work will not begin until alloys shown in Fig. 2 become available. The cell and potential controller unit for this work is shown in Fig. 23.

ACKNOWLEDGEMENTS

The assistance being arranged by the following organizations is gratefully acknowledged.

Battelle Memorial Institute -- melting of ingots and preparation of specimens

The Duriron Company, Inc. -- chemical analyses

International Nickel Company, Inc. -- donations of Ni-270 melting stock and commercial alloys

United States Steel Corporation (Monroeville) -- donations of commercial alloys, levitation melting, and specimen preparation

United States Steel Corporation (American Steel and Wire Division) -- donations of wires of commercial stainless steel wires

Stellite Division of Union Carbide -- donations of wires of Hastelloy-type alloys

Fig. 23. Glass cell to be used in anodic polarization studies. At right is potential controller

The assistance of Messrs. Farrar, Cowan, Dean, and Smith in the metallography, X-ray studies, performing of experiments, and constructing of equipment is acknowledged.

Technical contributions to this report were made by Messrs. R. L. Beauchamp, R. W. Staehle, and J. R. Upp.

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