STRESS CORROSION CRACKING OF STAINLESS STEELS

A Bibliography (1962-1971)

Compiled by:
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STRESS CORROSION CRACKING OF STAINLESS STEELS

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STRESS CORROSION CRACKING WHICH CAN BE RIGHTLY TERMED AS THE CANCER OF METALS, PRESENTS MAJOR PROBLEMS WITH STAINLESS STEELS IN APPLICATIONS WHERE THEY ARE OTHERWISE IDEALLY SUITED. THE SIGNIFICANCE OF THIS FACT IN NUCLEAR INDUSTRY, WHICH USES THESE STAINLESS STEELS IN LARGE QUANTITIES, IS OF NO SMALL IMPORTANCE. A THOROUGH KNOWLEDGE OF THE MECHANISM OF THIS DETERMINENT PROCESS AND THE MITIGATION PROCEDURES TO BE ADOPTED TO AVERT THE OCCURRENCE OF MAJOR MECHANICAL FAILURES WOULD BE OF GREAT INTEREST TO THE CORROSION ENGINEER. AN EXHAUSTIVE BIBLIOGRAPHY ON THE SUBJECT IS PRESENTED HERE, EMBRACING ALL ASPECTS OF THE PROBLEM. SPECIFIC REFERENCE HAS BEEN MADE ON THE CRACKING OF AUSTENITIC STAINLESS STEELS. THE COMPILATION COVERS THE PERIOD JANUARY 1962 - JUNE 1971. THE SOURCES CONSULTED ARE:

1. Nuclear Science Abstracts
2. Chemical Abstracts
3. Metals Abstracts
4. INIS Atomindex.

387 REFERENCES HAVE BEEN CITED AND ARRANGED ALPHABETICALLY BY FIRST AUTHOR. EACH ENTRY IS PROVIDED WITH AN ABSTRACT. AUTHOR AND KEY WORD INDEXES ARE PROVIDED.
Mech. resistant alloys contg. C ≤ 0.15, Cr 15-22, Ni 3-8, Si 1-4, Mn 0-2.5, Mo 2-4, and one or more elements such as Nb, Ta, and Ti 1.5 wt. % max., the rest being Fe, possess high resistance to corrosion under stress and to corrosion by pitting and are easily worked and welded. The proportion of elements in the alloy is detd. by the formulas Si ≤ 0.15Cr-1.7 and 23.0 ≥ Cr +3 Si +Mo+10Ti+4Nb+ 2Ta-Ni-0.5Mn -20C-10N ≥ 18.0, where the chem. symbols represent quantities in %, in order that the steel contains 40-95% by vol. ferrite, the rest being Fe, and conng. C 0.044, N 0.021, Nb 0.67, Ta 0.05, Si 1.80, Mn 1.63, Cr 18.7, Ni 6.8, and Mo 2.61 wt. %, the rest being Fe, and conng. 70% A 2-phase and 30% B 2-phase, was annealed for 1/2 hr. at 975° and was tempered in H.O. The alloy had solns. While in contact for 7 days with boiling 10% oxalic acid, the alloy was not affected. The alloy was also not affected by pitting corrosion in a 1% KCl soln. having a pH of 3 or in a 7.5% KCl soln. having a pH of 7.

2. Alekseenko, M F et al

EFFECT OF TEMPERING TEMPERATURE, MECHANICAL TREATMENT, CHA APPLIED STRESSES ON THE SENSIVITY OF CHROMIUM-NICKEL STEEL 1Kh12N2VMPA TO CORROSION CRACKING. (In Russian)


The effect of tempering temp. and mechanical treatment on the sensivity of Cr-Ni steel 1Kh12N2VMPA to corrosion was studied. The steel in the as-quenched state was very liable to corrosion cracking, but on raising the tempering temp. this tendency diminished, except in a restricted temp. range close to 475°. Steel parts to be used in contact with sea-water required high tempering in order to prevent corrosion cracking.
3. Andreev, Yu V et al

INFLUENCE OF SURFACE CONTAMINATION OF AUSTENITIC STAINLESS STEEL ON STRESS CORROSION CRACKING AT VARIOUS TEMPERATURES. (In Russian)


Strips of austenitic stainless steel 1Kh16N10T were bent into a U-shape and the tips were clamped with a force of \( \approx 53 \text{ kg/mm}^2 \). The specimens were then thoroughly cleaned and covered with a film of saturated NaCl, satd. FeCl_3, 50% FeCl_3 + 50% CuCl_2, 50% FeCl_3 + 50% NiCl_2, and 50% FeCl_3 + 50% KNO_3. The specimens were then exposed to a steam-air mist at 100-10° and to air at 25°. Metallographic analyses showed that the presence of trivalent Fe and Cu ions as chlorides induces corrosion in conditions of high humidity even at room temp. To prevent cracking Cu ions must be removed.

4. Aravindakshan, C et al

STRESS CORROSION CRACKING OF 18-8 CHROMIUM-NICKEL STAINLESS STEELS IN AMMONIUM SULFATE VESSELS.

Technology 5:2, 95-92; 1968.

Samples were cut from severely cracked areas of 7 AISI type 321 stainless steel vessels used in the manufacture of (Fe)_2SO_4 by the gypsum process. Filings from these samples were examined by x-ray diffraction. Corrosion products were identified as \( \gamma '-\text{Fe}_2\text{O}_3 \), \( \delta -\text{Fe}_2\text{O}_3 \), H_2O, \( \text{NH}_4\text{Fe} (\text{SO}_4)_2 \), and \( \text{NH}_4\text{Cu} (\text{SO}_4)_2 \). Although the steel is supposed to be austenitic, ferrite was found in all metallic filings, in amounts ranging 6-41%. Six of the bulk samples were nonmagnetic when tested with an ordinary magnet, though all showed traces of ferromagnetism in an electromagnetic field \( \geq 5000 \text{ gauss} \). Ferrite could not be detected by back-reflection x-ray diffraction from one such sample. These data show that a slight amnt. of applied stress can transform some austenite of type 321 stainless steel into ferrite. The residual stresses from forming and welding the vessels gave rise to plastic deformation and phase transformation; these in turn create compo. gradients and lattice defects which are sites for local electrochem. effects and subsequent stress-corrosion cracking.
5. Armijo, J S

INTERGRANULAR STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS IN OXYGENATED HIGH-TEMPERATURE WATER.

Corrosion 24:10, 319-25; 1968.

A bellows arrangement for controlling high temp., high pressure, stress corrosion tests of thick specimens was used to study the intergranular stress corrosion cracking of type 304 stainless steel and Incoloy 800 in oxygenated (≈100 ppm) 288° water. Complete intergranular fracture of sensitized type 304 stainless steels occurs after 10.4 hrs. exposure at stress levels of 14,000-17 psi. Cracking of Incoloy 800 requires longer exposures at high stress. Crevices are not necessary to initiate cracking of sensitized alloys. The effects of dissolved corrosion products and soln. pH must be deter. before the intergranular stress corrosion cracking of austenitic stainless steels in oxygenated high-temp. water can be understood.

6. Asawa, M

STRESS CORROSION CRACKING OF 18:8 AUSTENITIC STAINLESS STEEL IN SULPHURIC ACID CONTAINING SODIUM CHLORIDE. (In Japanese)


18:8 austenitic stainless steel in the form of U-shape specimens was exposed to H_2SO_4 contg. NaCl and Na_2SO_4 and the effects of H ions, sulphate ions, and chloride ions on the corrosion at temp. between 25 and 65°C was observed. In the strong acid solutions, the corrosion rate was decreased by the adsorption of chloride ions on the metal surface. Stress corrosion cracking was produced when dissolution, accelerated by the interaction between the stressed metal and chloride ions, was localized by the adsorption of chloride ions and sulphate ions. 16 references.

7. Ashbaugh, W G

STRESS CORROSION CRACKING OF PROCESS EQUIPMENT.


Principles and parameters of stress cracking failures in materials are reviewed. Examples of chloride and caustic stress cracking in Inconel, stainless steel, and carbon steel are discussed.
8. Babakov, A A et al

**CORROSION CRACKING OF STAINLESS STEELS IN 42% MAGNESIUM CHLORIDE.**


9. Babakov, A A et al

**STRESS CORROSION CRACKING OF STAINLESS STEELS IN BOILING 42% MAGNESIUM CHLORIDE.** (In Russian)


The resistance to corrosion cracking of various stainless steels in boiling 42% MgCl₂ (b. 154°) was studied by plots of strength vs. time to cracking. Cr-Mn-Ni steels were not as stable as Cr-Ni steels. In austenite-ferrite steels the stability depended on the \( f' \)-ferrite area, with the fact that 2-phase steels are stronger than pure austenitic steels. Alloying with \( \sim \) 2% Mo lowered the stability. The ratio of long term strength to the yield point may be used to evaluate the stability of steels. Steels OKh17T and Kh25T of the ferrite class did not crack.

10 Babakov, A A. et al

**CORROSION CRACKING OF STAINLESS STEELS IN BOILING 42% MAGNESIUM CHLORIDE.** (In Russian)


The corrosion cracking in boiling 42% MgCl₂ of a number of types of Cr-Ti and Cr-Ni stainless steels was studied. Two types of Cr-Ti steel of the ferritic class, in particular, were not susceptible to corrosion cracking. For two-phase steels the resistance to corrosion cracking increased considerably if 10-30% \( f' \)-ferrite was present in the steel. The presence of Mo \( \geq 2\% \) reduced the resistance of stainless steels to corrosion cracking, both in the case of austenitic and ferritic-austenitic materials. 7 references.
11. Backensto, E B; Yurick, A N

STRESS-CORROSION CRACKING STUDIES OF AUSTENITIC STAINLESS STEELS IN AQUEOUS AMMONIUM CHLORIDE SOLUTIONS.

Corrosion 18, 169t-175; 1962.

12. Badart, A et al

STUDY OF STRESS CORROSION AND OF GENERAL CORROSION OF STAINLESS STEELS IN DILUTE SOLUTIONS OF CHLORIDES AT 350°C TO 360°C AND IN STEAM AT 500°C. EVOLUTION OF THE MECHANICAL PROPERTIES AND OF THE STRUCTURE AT THESE TEMPERATURES POSSIBILITY OF MAKING USE OF PROTECTION BY SURFACE CHROMIZATION. (Final Report)


Tests were performed on eight grades of stainless steel four with an austenitic structure and four with austeno-ferritic structure. The influence of molybdenum and/or silicon additions were studied. Silicon steels display a certain tendency to embrittlement, toward 300 to 400°C for austeno-ferritic steels and 500 to 600°C for austenitic steels. The effect of silicon in stronger than that of molybdenum additions which produces also a certain embrittlement in the case of austeno-ferritic steels, toward 350°C to 400°C. Silicon improves the mechanical characteristics and the resistance to creep for short times. Molybdenum improves the resistances to creep. The diminishing resistance to creep of silicaon steels, over long durations, is probably due to structural transformations making it useful to study these transformations by the technique used in physical metallurgy.

13. Bade, J; Dodd, R A

CARBON AND NITROGEN EFFECTS IN THE STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS.


The effects of N and C on the stress cracking of austenitic stainless steels in chloride environments vary with the compn. of the steel. Steels which intrinsically are either highly crack-susceptible or highly crack-resistant are little affected by high interstitial contents. Steels of intrinsically moderate crack resistance are made more crack-prone by N addns., and rather less crack-prone by C addns.
Transmission electron metallography indicates that these interstitials may exert significant influences on the defect structure, depending on the initial stacking fault energy, but the overall correlation between defect structure and stress cracking propensity is poor. Since C and N seem to exert their greatest effect in the region of the Fe-Cr-Ni phase diagram where austenite is unstable, these elements may play some important role in the structural stability of alloy atoms at the crack tip. Changes from austenitic to ferric structure are accompanied by a chem. change. This local chem. change may provide a local dissoln. at the crack tip.

14. Bailey, S O

STRESS CORROSION CELL.


The cell is designed to indicate effects of differential aeration on stress corrosion performance of metals. The metal specimen is clamped over an opening, from which a passage leads to a reservoir of electrolyte within the cell. A reference electrode, usually consisting of a sep. specimen of the same metal, is clamped to an inner support member at a level above that of the electrolyte. A strip of medical gauze or capillary strip is placed over the reference electrode and dips into the electrolyte which rises by capillary action to maintain a film over the surface of the metal reference electrode. As the film is thin and is exposed to the air within the cell, it remains satu. with air, whereas the electrolyte in contact with the metal specimen under observation soon becomes depleted in dissolved gases. Provision is made for circulating air in the chamber above the electrolyte. The 2 electrodes are connected to a suitable circuit to measure potential and current flowing. The ends of the test specimen are accessible for applying suitable stress during the test. In this way corrosion generated by differential aeration can be measured, and the effects of stress on their magnitudes detd.

15. Baker, H R et al

FILM AND pH EFFECTS IN THE STRESS CORROSION CRACKING OF TYPE 304 STAINLESS STEEL.


Rapid stress corrosion cracking of 304 stainless steel in MgCl₂ - FeCl₃ solutions at 125°C occurred only when the pH of the corrodent liquid within the crack lay between 1.2 and 2.5. A film of more acidic corrodent solution is raised to pH=1.2 by reaction with the metal within a few seconds after isolation in a pit, crack or crevice.
MgCl₂ solutions of pH higher than 2 became more acidic when the contact with stainless steel as a result of corrosion processes. The pH of small amounts of such solution isolated in pits or crevices eventually fell to near 1.5, where stress corrosion cracking could occur. This pH range is considered to be critical for stress corrosion cracking of 304 stainless steel because it is the range in which a corrosion resistant protective film is formed in the presence of the corrodent solution. This film is essential to crack propagation. If there is added to a corrodent solution in this pH range an organic complexing agent such as glycerine or glycol, which prevents formation of the protective oxide film, the general corrosion process continues unchecked, but no stress corrosion cracking occurs. The data support a model in which stress corrosion cracking is driven by a highly localized galvanic cell within the crack. The cell operates in such a way that there is no large change in pH of the solution in the crack. These results emphasize the importance of the corrosion resistant film in the chemical aspect of the stress corrosion mechanism. 22 references.

16. Baker, H R et al
   FILM AND pH EFFECTS IN THE STRESS CORROSION CRACKING (SCC) OF TYPE 304 STAINLESS STEEL.
   An expnl. study of the rapid SCC of U-bend specimens of 304 stainless steel in MgCl₂ solns. at 125° showed that the pH within an active stress corrosion crack was 1.2-2.0 (as measured with indicator paper in cooled soln.) Cracks were initiated in the largest nos. when the pH of the main corrodent soln. is 1.2-2.0. Under the conditions studied the formation of a corrosion resistant film on the crack walls was an invariable and probably a necessary feature of the SCC process.

17. Barnhartt, S
   SYMPOSIUM ON CORROSION THEORY. GENERAL CONCEPTS OF STRESS-CORROSION CRACKING.
   Corrosion 18, 322t-331; 1962.
   The periodic electrochemical mechanism of cracking appears to be generally applicable to and has been confirmed with stainless steels and copper alloys.
18. Barnwell, V L et al

EFFECT OF GRAIN SIZE ON STRESS CORROSION OF TYPE 302 AUSTENITIC STAINLESS STEEL.


18:8 Type stainless steel gave decreased resistance to cracking for increased grain sizes in boiling 42% MgCl₂ soln. This effect was associated tentatively with a decreased incubation period and is discussed in terms of a dislocation model for crack initiation with grain-size dependence. 15 references.


STRESS CORROSION CRACKING MECHANISM IN PURIFIED 16% Cr-20% Ni STAINLESS STEELS.


Further data are presented on the electrochem. behavior in boiling MgCl₂ soln. on the nature of cracking propagation and slip in 4 16% Cr-20% Ni stainless steels, with and without single-element addns.; of Mn, Mo, and Ti at the 1.5, 1.5, and 0.5% levels, resp. Corrosion potentia. curves were little affected by applied stress up to 4 x 10⁴ lb./sq. in. for the parent alloy and that contg. Mn; Ti and Mo imparted susceptility, esp. the latter. A potentiostatic test at -340 mv. produced no cracking in any of the 3 modified alloys; pitting attack resulted in ultimate metal fracture. Crack propagation in the Ti and Mo alloys was similar; dislocations appeared coned along parallel slip planes in each alloy, in agreement with theory, and a low stacking-fault energy was indicated. The 2 immune alloys were expected to show easy cross slip; this was confirmed, and the data generally with the restricted-slip model of stress corrosion cracking. The general corrosion of stress cracking and stacking-fault energies of 25 ergs/cm.² were deduced for the basic alloy and its modification with Mn., while values of 20 and 15 ergs/cm.² were given for the Ti-and Mo-Contg. comps. 20 references.

20. Bates, E F; Loginow, A W

PRINCIPLES OF STRESS CORROSION CRACKING AS RELATED TO STEELS.

Corrosion 29:6, 189t-197t; 1964.

The mechanism of stress corrosion cracking in discussed with special reference to Fe alloys as well as the effects of steel compn., stress level, cold welding, and corrosion enviroment on susceptibility. Preventive measures are reviewed. 31 references.

THERMOMECHANICAL EFFECTS ON STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS.


Thermomechanical treatment of austenitic stainless steels enhance mechanical properties and resistance to stress corrosion cracking. The effects of this treatment are small but real for stable austenite USS 18-18-2 and more pronounced for metastable austenitic stainless steel.

22. Bates, J F

THERMOMECHANICAL EFFECTS ON STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS.


Variations in cold reduction, refrigeration and annealing times and temp. can markedly affect resistance to stress corrosion cracking. In these studies, cold reduction prior to the final anneal was beneficial and low-temp. annealing was detrimental to a stable austenite. Thermomechanical treatment of a metastable alloy affected its resistance to stress corrosion, 21 references.

23. Bates, J F

EFFECT STRESS ON CORROSION.


A review of stress corrosion and corrosion-fatigue phenomena in the press industries. 57 references.

24. Baumel, A

TRANSCRystALLINE STRESS CORROSION CRACKING OF AUSTENITIC MANGANESE STEELS IN MEDIA CONTAINING CHLORIDE IONS. (In German)

Tests were carried out in U-shaped test pieces of 0.5%-20% Mn-0.2-2.7% Cr steels in sea water at room temp. and b.p., under loads of 30-45 kg/mm². The electrochemical behaviour of steels contg. <0.5% Cr at room temp. is the same as that of ferritic shipbuilding steels. Addition of Ni, Co, and Cu have little effect on the potential behaviour. In boiling sea-water, transcrystraline corrosion occurs, which is accelerated by tension and anodic polarization, and slowed by cathodic polarization.

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Contd:...
Co and Ni additions reduce specimen life. At Cr contents 1.7-2.7%, intercrystalline corrosion supersedes transcrystalline cracking susceptibility. There are parallels between the behaviour of Cr-free austenitic Mn steels in sea water, and that of austenitic stainless steels in CaCl₂ solutions. 10 references.

25. Beck, F H et al
A STUDY OF THE MECHANISM OF STRESS CORROSION CRACKING IN THE IRON NICKEL-CHROMIUM ALLOY SYSTEM. (Quarterly Report, March 17-June 16, 1964)
C00-1319-15 (1964)

26. Beck, F H et al
C00-1319-12 (Mar. 31, 1964)

27. Beier, E
CAUSES AND CURES OF STRESS CORROSION. (In German)
Blech 14:1, 22-5; 1967.

Stress corrosion may be due to unsuitable materials, specific environments, tensile and residual stresses, hardness differences, tensile and residual stresses, hardness differences, presence of ferrite (in some types of AISI 410), and differences in heat treatment. Specific susceptible materials and susceptible materials and respective environments are: Al in NaCl solns., and seawater; austenitic stainless steels in acid chloride solns. (pH 1-5); seawater, caustic solns.; Pb in Pb acetate solns.; mild and low alloy steels in NaOH-Na₂SiO₃ and NaOH solns.; Inconel in caustic solns., molten caustic soda; Pb compds. in hot aerated water; Cu in NH₃ vapors and solns., amines, Hg salts; Mg in NaCl and K chromate soln., rural and marine atm., distd. water; Montel in Aurosilicic acid; Ti in fuming red HNO₃. Stress corrosion susceptibility can be decreased by substitute materials, working below dangerous stress levels, and special heat treatments. Suitable design includes prevention of stress buildup, formation of compressive stress on metal surfaces (e.g., by blasting), prevention of poorly accessible locations with stagnant liquids or deposit formation, and normal corrosion protection measures.
28. Bellot, J et al

INTERCRYSTALLINE CORROSION IN NITRATES AND MOBILITY OF INTERSTITIAL ELEMENTS IN FERRITE. THE CASE OF PLAIN-CARBON AND LOW-ALLOY MILD STEELS. (In French).


The corrosion behaviour of plain-C and low-alloy mild steels was examined in nitrate solutions as a function of metal composition, surface condition, and solution purity, by potential and potentiokinetic measurements. The mobility of interstitial elements (C and N) in ferrite was examined using internal-friction and electrical-resistivity measurements. Crack propagation under constant stress or progressive deformation in a nitrate solution was examined and the interplay of electrochemical and mechanical factors discussed. 23 references.

29. Beloua, V N et al

EFFECT OF OXIDIZING AGENTS ON THE CORROSION CRACKING OF KH18N10T STEEL.


30. Bergen, C R

STRESS CORROSION CRACK INHIBITORS.

U.S. 3,376,411 Apr. 1968. (Pant)

Stress corrosion cracking of austenitic stainless steel in chlorine atm. is inhibited by partially electroplating the oxide-coated steels with 2 g./cm.² of Ag, Pb, or Co or by partially burnishing with Pb or Ag. Thus, 304 stainless steel U-shaped bodies are coated with 1.5 g. Ag/cm.² in Ag cyanide bath at 7 v. and refluxed in GaCl₂ soln. at 132°. No cracks appeared for 120 hrs. as compared to 9 hrs. for unprotected specimens. The proposed mechanism is based on the strong affinity of the impurity ions for chloride ions which conc. at points of high tensile stress.
31. Bergen, C R

INITIATION OF STRESS CORROSION CRACKING: MIGRATION OF CHLORIDE IN OXIDE FILMS ON AUSTENITIC STAINLESS STEEL.

Corrosion 20:9, 269-27; 1964.

In a number of corroden-crack-susceptible alloy systems the specific ion responsible for cracking is relatively large. The corrosion product formed in a corroding medium contg. such ions would imbibe them. Under appropriate conditions, due to their size, the larger ions would tend to diffuse to the region of the oxide film under highest tensile stress where local high tensile stress in the base alloy would be reflected. It is postulated that the appropriate conditions for diffusion are present and that the migration of the ion to which cracking is ascribed leads to high local concns., in turn causing a local increase in corrosivity. Stress corrosion cracking results where the phys. properties of the alloy are such that crack propagation can occur. The hypothesis was confirmed with the chloride-austenitic steel system. Chloride will migrate reversibly under the influence of tensile stress. The presence of Ni will inhibit the migration of chloride up a tensile gradient and the immunity to cracking of high-Ni austenitic stainless steels is attributed to this effect.

32. Berggreen, J

APPLICATION OF FRACTURE MECHANICS PRINCIPLES TO THE INVESTIGATION OF THE SUSCEPTIBILITY OF MATERIALS TO STRESS CORROSION CRACKING (A SURVEY OF TEST METHODS).


The suitability was investigated of the various specimen shapes, used in fracture mechanics studies, for the investigation of stress corrosion susceptibility. The DGB specimen was simplest; only one specimen being required per test, this can also be used for determining the crack propagation rate and the state of stress most susceptible to stress corrosion cracking; no data are obtained on the corrosion mechanism. The specimen is unsuitable for highly ductile material as the dimensions required would be impracticable. 45 references.
Some facts about stress corrosion of austenitic stainless steels in reactor systems.

Examples of stress corrosion cracking of austenitic stainless steels encountered in established reactor systems are presented. These include: the Homogeneous Reactor, Savannah River Reactor Plant, heat exchange at Capenhurst, Nautilus nonregenerative heat exchanger SLW Reactor Plant, Superheat Advance Demonstration Experiment, Shippingport Pressurized Water Reactor, and Dresden control-rod components. Measures to eliminate stress corrosion cracking susceptibility are discussed, including: reducing stress levels, altering the chemistry of the environment, cathodic protection, changing the design or operating conditions, substituting alternative materials, and, on a long-range basis, understanding the mechanism of cracking. Various theoretical and experimental attempts to analyze and explain the cause of stress corrosion are summarized.

Stress corrosion cracking is reviewed from a nontechnical viewpoint. The recognition of this form of corrosion cracking is discussed. The environments most likely to cause stress corrosion cracking are pointed out for each alloy system. The effects of material composition, stress, environment, temperature, and time on stress corrosion cracking are discussed, and suggestions are made for controlling these variables. The roles of protective coatings, inhibitors, and cathodic protection in reducing cracking susceptibility are considered. A bibliography of some of the more recent articles on stress corrosion cracking is included.

The title stress corrosion cracking test has been used at the Phys. Metallurgy Division to test the cracking susceptibility of a number of high-strength steels. Results are reported which were obtained in stress corrosion tests on an 18% Ni maraging steel.
an HP-9-4-25 steel, a Cu-Ni low-alloy steel developed at the phys. Metallurgy Division, and a 17/4 PH stainless steel in each of the H900 and H1000 conditions. For each of these steels, the tendency to fracture under dry conditions was compared with that resulting from immersion in 3.5% NaCl soln. in the unpolarized state. The effects of cathodic protection by 5083 Al alloy and Zn were also investigated.

36. Birley, S S; Tromans, D

STRESS CORROSION CRACKING OF 304L AUSTENITIC STEEL AND THE MARTENSITE TRANSFORMATION.

Corrosion 27:2, 63-71; 1971.

Studies have been conducted on the failure of notched and annealed rods of 304L austenitic steel stressed in tension in aq. soln. of MgCl₂ boiling at 154°. The phases present on the actual fracture surfaces were studied by electron diffraction techniques. Martensite etching techniques were used to detect the presence of martensite phases adjacent to stress corrosion cracks and to relate stress corrosion crack topog. with the morphol. of martensite formation. The observations were consistent with a mechanism of stress corrosion cracking involving formation of bcc α'-phases adjacent to the crack tip and subsequent propagation of the crack through this phase. The possible mechanism by which α'-phases is formed and the possible mechanism of crack propagation through the α'-phase are both discussed.

37. Bollant, G

THEORIES OF STRESS CORROSION CRACKING AND HYDROGEN EMBRITTLEMENT.

(In Italian)


Mechanisms of delayed fracture as in stress corrosion and H embrittlement are considered in three phases; incubation, initiation, and propagation and the alternative proposals are illustrated diagrammatically. Results of stress corrosion tests carried out could be expressed in an equation analogous to the weibull fatigue equation: \((\sigma - \sigma_0)^k \cdot t = c\) (σ = applied stress, \(\sigma_0 = \) stress limit of delayed fracture, \(t = \) time to rupture, \(k, c = \) numerical constants).
EFFECTS OF COMPOSITION ON THE STRESS CORROSION CRACKING OF FERRITIC STAINLESS STEELS.


Stress corrosion tests were made on U-bend and axially loaded tensile-type specimens in boiling 140° MgCl₂ soln. The exptl. ferritic alloys tested contained Cr 17-25, Ni and Cu did not undergo stress corrosion cracking. Ferritic stainless steels contg. 17-25% Cr and up to 5% Mo (no Ni, Cu, or Co) are highly resistant to stress corrosion cracking. A 17% Cr alloy, when Cold-worked, is susceptible to stress corrosion cracking with 1.5 Ni, but is resistant with ~1%. Cr-Mo stainless steels that contain Ni, Cu, or Co are resistant to stress corrosion cracking in MgCl₂ only when less than some crit. amts. of these residual elements are present. Transgranular cracking of ferritic stainless steels in boiling MgCl₂ is not assoed. with the presence of retained austenite nor is it caused by H embrittlement.

RESISTANCE OF FERRITIC STAINLESS STEELS TO STRESS CORROSION CRACKING.


Stress corrosion cracking tests were carried out on wires in boiling solns. of MgCl₂, Ca(NO₃)₂, and NaOH. Austenitic stainless steels failed in 6-46 min. in MgCl₂ soln., but ferrite stainless steels (types 430 and 434) were immune under similar conditions. They were, however, subject to intergranular corrosion in boiling Ca(NO₃)₂ and NaOH solns. when heat-treated at 1800°F. Stressed specimens of ferritic stainless steels did not fracture in boiling 55% Ca(NO₃)₂ or 25% NaOH solns., even after heat treatments causing intergranular corrosion. Type 430 stainless steel is liable to pitting corrosion in boiling MgCl₂ soln., but this is decreased by the addn. of 1% Mo.

DIRECT OBSERVATION OF THE START OF STRESS CORROSION CRACKING IN THE AUSTENITIC CHROMIUM-NICKEL STEEL (GERMAN MATERIAL NUMBER 4986) IN BOILING MAGNESIUM CHLORIDE SOLUTION. (In German)


The stress corrosion cracking of the title steel contg. C 0.06, Si 0.4, S 0.005, P 0.02, Mn 1.3 Cr 16.7, Ni 13.2, Mo 1.4, V 0.8, and Nb 0.2% in boiling aq. MgCl₂ at 135-60° and stressed at 70% tensile strength...
was studied microscopically and by elongation measurements. The direct surface observation enables a better distinction between the initiation and propagation periods than the anal. of the elongation vs. time curve. The start of the surface reaction indicated by the onset of the $H$ evolution coincides satisfactorily with the cusp of this curve.

41. Borgstedt, H U et al

INVESTIGATION OF STRESS CORROSION OF AUSTENITIC STEEL AND NICKEL ALLOYS.


42. Boulton, J

SOME ASPECTS OF MATERIALS IN ORGANIC COOLED REACTORS.


The results of development work on the use of 4 different sintered Al products and Zr alloys in Santowax OM and HB-40 org. reactor coolants are summarized. The behaviour of Zr alloys now in use as fuel cladding and pressure tube material is discussed in detail in regard to operating life and hydriding susceptibility. The stress corrosion cracking of stainless steel in Cl-contaminated coolant is examined briefly.

43. Bourrat, J; Hochmann, J

STRESS CORROSION IN AUSTENITIC STAINLESS STEEL.


Stress corrosion tests of austenitic steels of the 18/10 type in boiling $42\% MgCl_2$ soln. were made after different surfaces treatments of the stainless steel. Addn. of $3.5\%$ of inhibits stress corrosion in annealed or work-hardened steel. Steel contg. $5.4\%$ Si resisted the corrosion for 1000 hrs.
44. Bowersock, R V

A CRITICAL REVIEW OF STRESS CORROSION CRACKING AS ASSOCIATED WITH THE FFTF DRIVER FUEL CLADDING.


45. Boyd, W K

CAUSES OF STRESS CORROSION CRACKING.

Battelle Tech. Rev. 15:11, 5-10; 1966.

Mech., electrochem., and surface-energy theories of stress corrosion cracking, and the influences of H in the various mechanisms, are reviewed. Electrochem., rather than mech., factors are considered the most likely promoters of crack initiation and propagation. 18 references.

46. Boyd, W K

CAUSES OF STRESS CORROSION CRACKING.

Battelle Tech. Rev. 15:11, 5-10; 1966.

Various theories of stress corrosion cracking (SCC) were reviewed. It appeared highly unlikely that SCC could be caused by mech. means as a result of high stress at the base of a pit or other stress raiser. There is strong evidence to support the electrochem. initiation and propagation, as SCC might not be true cracking in the sense of brittle cleavage of the walls of the crack. According to the electrochem. mechanism theory, SCC occurred by dissoln. of the metal in every narrow area at the apex of the crack with little or no dissoln. occurring along the crack walls; the same could be referred to as exceptionally deep and narrow fissures. Although the above theory was applicable to most of the Al alloys; greater exptl. data were needed to establish completely the electrochem. mechanism theory of SCC in the light of and the extent to which the various factors, such as yielding of metals H absorption film rupture, and the chem. environment in relation to crit. cracking potential, influenced the SCC; thus it could be furthur inferred that artificial cracking can be induced in most of the electrolytes by the application of impressed currents.
47. Brabers, M.J

STRESS CORROSION OF AUSTENITIC STEEL.

Ingenieursblad 37:15-16, 572-7; 1968.

The mechanism of initiation and propagation of stress corrosion fissures based on experiments and literature references is discussed. These fissures start usually from a surface defect: inclusion, crack, pit, or crystallite dislocation line. More specifically, in austenitic steel the initial tear point is located at the intersection of 2 (111) austenite slip lines. Electron microscopic photographs show that the tear proceeds at first slowly along a slip line. Subsequently, a more rapid corrosion starts in the direction of the crossing slip lines located perpendicularly to the stress direction. The tear travels across austenite crystallite and contours the original ferrite grains, which act as a stress corrosion barrier. Autoradiographs show that chloride, which promotes the stress corrosion, can be present in large amounts around silica inclusions, but does not appear at the hair thin end of the fissure. The detrimental action of chloride increases with the adsorbability of the associated cation, being progressively greater with NaCl, CaCl₂, and MgCl₂. The corrosion breaking time decreases also with increasing concentration of acid and oxidizing compound, contact with cement, and the presence of finger prints, even on stainless steel. The breaking time decreases linearly with the logarithmic increase of the tension. The breaking time decreases also through moderate cold-working but increases through tempering and through strong cold-working which changes the coplanar micro pattern of the crystallite into a claw-type one. The breaking time decreases with Mn content from 0 to 8-10% but increases with further Ni content up to 40% and decreases again above this content. Austenitic steel can be completely protected from stress corrosion through cathodic protection at -150 mV, while anodic polarization shortens the corrosion breaking time.

48. Brauns, E; Ternes, H

TRANSCRYSTALLINE STRESS CORROSION CRACKING OF AUSTENITIC CHROMIUM-NICKEL STEEL IN HOT CHLORIDE SOLUTIONS. (In German)


The transcrystalline stress corrosion cracking of austenitic steel rods of X 5Cr Ni 18-9 (corresponding to AISI 304), after twice heating to 1050° and water quenching was studied in hot-coned MgCl₂ solutions (usually 45% solutions, b. 155°). The occurrence of stress corrosion cracking for each stress at unnoble potentials is rather sharply limited, while on the nobler side, stress corrosion cracking increases with increasing life and pitting is intensified.

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Contd......
Decrease in temp. and concn. as well as increasing pH and increasing cold deformation ordinarily displace the potential-life curves more of less strongly to more noble potentials. A purely electrochem. mechanism of stress corrosion cracking of austenitic Cr-Ni steels in hot concn. chloride solns. is not proven, but appears to be possible. 107 references.

49. Brenner, P

REALISTIC STRESS CORROSION TEST.


50. Brunet, S et al

EFFECTS OF VARIOUS FACTORS ON CHLORIDE STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS. (In French)


In this test program, a stress to give 2.5% permanent deformation, Cl-ions at 5.3g./l., pH 6.0, and 1500 hrs. exposure were used. The influential factors were: 1) the cation accompanying the Cl- (corrosivity Mg2+ >> Ca2+ > Na+); 2) the presence of O2 in the environment greatly increases the incidence of cracks (this effect may be by O2 attack to form a pit and the pit later becomes the locua for the formation of typical stress corrosion cracks); 3) the addn. of Mo to the steel lessens cracking (probably by prevention of initial O2 pitting).

51. Bryant, R E; Greet, J B

INHIBITION OF CHLORIDE STRESS CORROSION CRACKING OF STAINLESS STEEL ALLOYS.


Stress corrosion cracking is the primary reason stainless steel alloys are avoided in equipkent construction. The susceptibility of various Austenitic stainless steels to cracking in boiling 42% MgCl2 and inhibition of 304 and 316 stainless steel by nitrate and carbonate additions by using flat samples stressed with Brinnell impressions are discussed. Two new, low-Ni alloys were found to be the best choice for controlling stress corrosion cracking.
52. Bryant, R E; Greet, J B

CHLORIDE STRESS CORROSION OF VARIOUS STAINLESS ALLOYS AND INHIBITION BY NITRATES.


Different austenitic stainless steel alloys were tested for stress corrosion cracking (SCC) in boiling MgCl$_2$ solutions and in MgCl$_2$ solutions containing additions of KNO$_3$. Two austenitic stainless steel alloys containing 18-20% Ni are immune to SCC in boiling MgCl$_2$. Inhibition of SCC by KNO$_3$ is possible for the 300 series stainless steels.

53. Burkart, E R et al

EFFECT OF COLD WORK ON STRESS CORROSION OF TYPE 309 (24:12 CHROMIUM-NICKEL) AUSTENITIC STAINLESS STEEL.


Stress Corrosion tests of 24:12:1.4 Cr-Ni-Mn-Si steel in boiling 42% MgCl$_2$ soln. and under uniaxial tensile stresses of 10000-30000 lb/in$^2$ indicated that failure generally occurred above the vapour/liquid interface. Average times-to-failure decreased with increasing amounts of cold work, and branch-type cracking was observed.

54. Carter, C S et al

STRESS CORROSION PROPERTIES OF HIGH STRENGTH PRECIPITATION-HARDENING STAINLESS STEELS IN 3.5% AQUEOUS SODIUM CHLORIDE SOLUTION.


The plane strain fracture toughness $K$ (Ic) and stress corrosion threshold $K$ (Iscc) have been detd. for the following high strength, pptn.-hardening steels: 17-7 PH (RH 950, TH 1050), PH 15-7Mo RH 950, TH 1050), AM 355 (SCT 850, SCT 1000), AM 362 (H 900, H 1000). AM 364 (H 850, H 950, H 950), 17-4 PH (H 900, H 10000), 15-5 PH air melted and vacuum melted (H 900, H 1000), PH 15-8Mo (H 350), and Custom 455 (H 950). Correlations of $K$ (Kscc) with service performance, smooth-specimen test data, and chem. compns. are discussed.
BOILING TEMPERATURES OF MgCl₂ SOLUTIONS—THEIR APPLICATIONS IN STRESS CORROSION STUDIES.

Corrosion 23:10, 314-17; 1967.

Temps. of boiling MgCl₂ solns. used to detect susceptibility of austenitic stainless steels to stress corrosion cracking have a pronounced effect on the time to failure for these alloys. Available atm. b.p. data for solns. in the range 0.46% MgCl₂ have been assembled and supplemented by new expnl. detns. An equation relating b.p. and concn. for 40-6% solns. have been derived. Because of variations in water of regent-grade MgCl₂·6H₂O, it is proposed that measuring the boiling temp. of a soln. is the preferred means both of detg. the MgCl₂ concn. and of controlling this concn. during stress corrosion tests. Consideration should be given to the general use of a 45.0 wt. % MgCl₂ soln. (boils at 155.0°) for stress corrosion tests. 18 references.

56. Chaudron, G

QUARTERLY SUMMARY (REPORT) NO. 9 (ON CORROSION OF STAINLESS STEELS UNDER STRESS), JULY 1-SEPTEMBER 30, 1-SEPTEMBER 30, 1964.

Work performed under United States–Euratom Joint Research and Development Program.

57. Chaudron, G

QUARTERLY REPORT NO. 18 (ON STRESS CORROSION OF STAINLESS STEELS, APRIL 1-JUNE 30, 1967.

EURAEC-1932 15p.

Work performed under United States–Euratom Joint Research and Development Program.

The stress corrosion of stainless steel was studied and the influence of the structure of the steels and the effect of a noble metal such as Pt addition to the steel were determined. The part played by martensite and austenite in stress corrosion was noted. The resistance to stress corrosion of austenomartensite steels was due to an electrochemical mechanism caused by the martensite and the electronegative protection of the austenite. The addition of Pt to a Cr-Ni type steel intensifies the process of triangular cracking in boiling solutions of magnesium chloride. Both corrosion and pitting were found to depend on the physical and chemical surface conditions.
INTERGRANULAR CORROSION CRACKING OF TYPE 304 STAINLESS STEEL IN WATER COOLED REACTORS.


Nuclear pressure vessels, primary piping, core components and fuel-element cladding are subject to cyclic thermal and mechanical stresses due to the high pressure and temp. of the fuel coolant. When 304 stainless steel is used as material for these parts, potential intergranular corrosion failures due to the combined action of corrosion and low cyclic stress or high static stress need critical evaluation. Reviews 304 stainless steel with respect to service failures other than chloride or caustic cracking in water-cooled reactors, various corrosion studies on intergranular cracking and the proposed mechanism of intergranular corrosion cracking. 44 references.

SIGNALS OF CORROSION DEPOSITS ON A SYNTHESIS GAS SATURATION COLUMN. (In German)


After 3000 operational hrs, a column of 10r18N19Ti in which gas is cooled from 1300° to 240° by water spraying, developed transcrys. cracks because of stress corrosion cracking which was accelerated by tensile stresses on the sprayed side and by erosion which preceded the stress corrosion cracking at the inlet to the column. The deposit taken at various sites of corrosion contained Na⁺ 0.130, Ca²⁺ 0.3-9.8 Mg²⁺ 0.48, and Cl⁻ 0.11%. The corrosion is due to the presence of Cl⁻ in the water, the high wall temp., and the high stress in parts of the column. The stress corrosion cracking can be avoided by using Cr- 40% Ni-Si, Cr-Mg, ferritic-austenitic and corrosion-resistant Cr steels.

STRESS CORROSION CRACKING OF STAINLESS STEELS. (In Czech)


Failures caused by stress corrosion cracking phenomena are described for a satn. column for cracked gas. The entering gas temp. in the column is 1300°, the gas is cooled by means of injected water so that the mean temp. in the lower part of the column outlet is ~200°.
The satn. column is made from a steel sheet 8.8 mm. thick (18-20% Cr and 8-11% Ni, stabilized by Ti). The most important causes of stress corrosion cracking were (1) the presence of chlorides in the water; (2) the high temp. of the satn. column walls which favors concn. of the chlorides at the walls as well as the stress corrosion cracking progress, and (3) increased stress in certain parts of the column resulting from the irregular temp. distribution. An increased Ni content in stainless steels will suppress stress corrosion cracking tendencies. Enhanced corrosion resistance is assumed to be obtained with austenitic Mn-Cr steels contg. either a low content of Ni or without Ni and N.

61. Cihal, V; Poboril, F

CHROMIUM-MANGANESE AUSTENITIC STEELS RESISTANT TO STRESS CORROSION CRACKING IN SOLUTIONS OF MAGNESIUM AND CALCIUM CHLORIDES. (In French)


The resistance of various austenitic steels to stress corrosion cracking was examined in concentrated solutions of Ca and Mg chlorides. Cr-Mn steels were significantly better than either Cr-Ni or Cr-Mn-Ni types even when the latter were alloyed with N; the Cr-Mn steels were developed primarily for their good creep resistance. 30 references.

62. Clevinger, G S

THE RELATIONSHIP OF NITROGEN CONTENT OF AUSTENITIC STAINLESS STEELS TO STRESS CORROSION. QRNO.438-17


63. Clevinger, G S

THE RELATIONSHIP OF NITROGEN CONTENT OF AUSTENITIC STAINLESS STEELS TO STRESS CORROSION. (Quarterly Report No. 438-18.)


64. Clevinger, G S

THE RELATIONSHIP OF NITROGEN CONTENT OF AUSTENITIC STAINLESS STEELS TO STRESS CORROSION. (Quarterly Report No. 438-19.)

65. Clevinger, G S

THE RELATIONSHIP OF NITROGEN CONTENT OF AUSTENITIC STAINLESS STEELS TO STRESS CORROSION. (Report 438-20 Quarterly Report No. 20)


66. Clevinger, G S

RELATIONSHIP OF NITROGEN CONTENT OF AUSTENITIC STAINLESS STEELS TO STRESS CORROSION. (Final Report. Report No. 436-F.)


67. Clevinger, G S; Lytton, J L.

THE RELATIONSHIP OF NITROGEN CONTENT TO THE SUSCEPTIBILITY OF AUSTENITIC STAINLESS STEELS TO STRESS CORROSION. (Quarterly Report No. 1, June 1, 1970-Aug. 31, 1970.)


68. Clevinger, G S; Lytton, J L.


69. Cochran, R W; Stachle, R W.

EFFECTS OF SURFACE PREPARATION IN THE STRESS CORROSION CRACKING OF STAINLESS STEEL.

70. Cochran, R W; Staehle, R W

EFFECTS OF SURFACE PREPARATION ON STRESS CORROSION CRACKING OF TYPE 310 STAINLESS STEEL IN BOILING 42% MAGNESIUM CHLORIDE.

Corrosion 24:11, 369-78; 1968.

Effects of various surface prepns. on stress corrosion cracking of type 310 stainless steel wires in boiling (154°) aq. MgCl₂ solns. were studied. Relatively large nos. of specimens were used and the time-to-breaking data followed log-normal behavior. Mean cracking times statistical scatter were obtained. Mean cracking times varied by as much as a factor of 4. The effect of the various surface prepns. is related to the effect of surface roughness on the electrode processes, primarily the redn. kinetics. The greatest amt. of statistical scatter was related to manually prepd. surface prepns. as compared with chem. prepns. Scatter was not proportional to the mean cracking time. Conclusions obtained herein on the possible influence of surface prep. on cracking should be applied to other alloy systems only where the controlling process involves electrode kinetics.

71. Copson, H R

EFFECT OF NICKEL CONTENT ON RESISTANCE TO CRACKING UNDER TENSION OF Ni-Cr-Fe ALLOYS IN CHLORIDE MEDIA.


The lab tests (loc. cit.) which result in stress-corrosion cracking in alloys contg. < 45% Ni are more severe than service conditions. Alloys resistant to stress-corrosion cracking should also resist other types of corrosion, be easily worked, have acceptable phys. and mech. properties, and be com. available. By reducing stress, eliminating the chlorides and O₂, and controlling the pH, the stress corrosion cracking is minimized, to permit the substitution of austenitic stainless steel for the over 45% Ni alloys.

72. Copson, H R; Economy, G

EFFECT OF SOME ENVIRONMENTAL CONDITIONS ON STRESS CORROSION BEHAVIOR OF NICKEL-CHROMIUM-IRON ALLOYS IN PRESSURIZED WATER.

73. Copson, H R; Economy, C.

EFFECT OF SOME ENVIRONMENTAL CONDITIONS ON STRESS CORROSION BEHAVIOR OF NICKEL-CHROMIUM-IRON ALLOYS IN PRESSURIZED WATER.
Corrosion 24:3, 55-65; 1968.

Stress corrosion tests in pressurized water at 316° were made of periods up to 3000 hrs., by using double U-bends and double bend beam specimens. Gas compn. show that water and pH were controlled. Tests were made on com. heats of Inconel 600, Inconel 625, Incoloy 800, and stainless steel Types 304, 304L and 347, Inconel-alloy 600, weldments and some exp. compns.; some specimens were heat-treated. The combined action of high stress, high O concn., and cracking in the crevice area in all alloys tested. Attack severity increased with O concn. and man specimens annealed specimens. Sohn. heat treatment, low C content, or the presence of carbide stabilizers did not eliminate the attack. Weld metal deposits behaved mote or less like base metal. Variations in compn. within the normal range of Alloys 600 were unimportant and differences in behavior among the several alloys tested were monor. compared to environmental effects. No attack was observed in specimens stressed at 90% of room temp. yield strength, when H constituted the gase phase or when crevices were absent. The combined conditions causing cracking can be considered an overtests, as they would not be expected to the same extent in normal operating pressurized water systems. In actual service where concn. is maintained near zero, Alloys 600 heat exchanger tubing performs well. 30 references.

74. Coriou, H et al

SENSITIVITY TO STRESS CORROSION AND INTERGRANULAR ATTACK OF HIGH NICKEL AUSTENITIC ALLOYS.

High-Ni alloys and various analyses of Types 304L, 316 and 347 as well as European com. steels of similar analyses were tested in demineralized water at 350° and steam at 650° for varying periods up to 5 mos. High-Ni austenites were susceptible to intergranular stress corrosion cracking different from the transgranular cracking in austenitic stainless steels. Tests in 650° steam show cracking of high-Ni alloys increased with right plastic deformation while 18-10 and 10-25 stainless were unaffected. Severe intergranular attack was observed in high-Ni alloys in highly oxidizing acid media. A structural element in these susceptible alloys may be responsible for attack. Pb or O contamination of test water cannot explain the results reported, which are at variance with numerous test and service results on the same material in like environments.
Pb or O contamination of test water cannot explain the results reported, which are at variance with numerous test and service results on the same material in like environments. Pb was not detected in later expets and the O content was \(< 0.003\text{ mg/l.}\), equal to the sensitivity of the anal. method. cracking observed satisfactory industrial experience with Inconel can be attributed to low stresses. 27 references.

75. Coriou, H et al

STRESS CORROSION CRACKING OF CHROMIUM-NICKEL-IRON AUSTENITES IN ALKALINE MEDIA AT HIGH TEMPERATURE. (In French)


The results of stress corrosion tests in alk media at 360°C of 18/10 type stainless steels and of Cr-Mn-Fe alloys (with 17% Cr and Mn varying from 10% to 27%) are given; NaOH and KOH are much more corrosive than Li hydroxide. The morphology of cracking can vary greatly with different test conditions: inter granular, transgranular, or both inter-and transgranular types of propagation were noted. O increases the corrosiveness of the environment. A higher Mn content of alloys reduces the susceptibility to stress corrosion cracking.

76. Gouper, A S

MINIMIZING STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS.


Austenitic stainless steels and type 406 stainless steel, if stressed, can crack in aerated Cl solns. \( \sim 100^\circ\text{F.}\) but not in dry chlorides. Bromides cause cracking less readily, whereas iodides and fluorides apparently do not crack austenites. All austenitic 18-8 stainless steels in all metallurgical conditions are equally susceptible to Cl cracking if stressed above a threshold level that is low enough to be present in most fabricated equipment, including claddings on low-alloy steels. However, the time to crack increases logarithmically with decreases in both soln. temp. and Cl or Br concn. if alloys susceptible to Cl or Br stress-corrosion cracking are used, the probability of cracking can be minimized by controlling exposure conditions. Also, equipment should be kept dry. Protective measures include: avoiding evapn. and condensation conditions that can conc. halides, by using air-free water, drying the equipment before heating, and quickly completing any work that must be done under conditions that can cause cracking. Nitrates added to the water can inhibit stress-corrosion cracking, as can org. inhibitors if their concns. are maintained high enough.

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Cathodic protection by applied currents and by Al or steel sacrificial anodes prevents stress corrosion cracking probably by causing changes in the soln. at the metal surface. This will not protect equipment in splash zones, vapor phases, or nonconductive environment alloys with high Ni contents are more resistant to stress corrosion cracking and may be economically justifiable for some equipment. Alternatively, ferritic or martensitic steels can be used to resist halide cracking with some redn. in resistance to general corrosion. 12 references.

77. Couper, A S

MINIMIZING STRESS CORROSION CRACKING. TESTING AUSTENITIC STAINLESS STEELS FOR MODERN REFINERY APPLICATIONS.


To minimize the probability of stress corrosion cracking susceptible alloys should be avoided as much as possible, alloys should be designed to minimize stress level and the environment should be controlled to keep unavoidable halide solutions dilute, cold, air-free, possible inhibited, and in contact for as short a time as possible. 12 references.

78. Cox, T B

THE RELATIONSHIP OF NITROGEN CONTENT OF AUSTENITIC STAINLESS STEELS TO STRESS CORROSION. (Quarterly Rep. No. 438-9, July 1-Sept. 30, 1966.)

EURAEC-1755 18p.

79. Cox, T B

THE RELATIONSHIP OF NITROGEN CONTENT OF AUSTENITIC STAINLESS STEELS TO STRESS CORROSION. (Quarterly Rep. No. 438-12.)


80. Cox, T B

THE RELATIONSHIP OF NITROGEN CONTENT OF AUSTENITIC STAINLESS STEELS TO STRESS CORROSION. (Quarterly Rep. No. 438-16.)

81. Cox, T B; Eckel, J F

THE RELATIONSHIP OF NITROGEN CONTENT OF AUSTENITIC STAINLESS STEELS TO STRESS CORROSION. (Quarterly Report No. 438-10.)

EURABEC-1806 24p.

82. Crossley, F A

RESEARCH ON THE BASIC NATURE OF STRESS CORROSION FOR VARIOUS STRUCTURAL ALLOYS AT ROOM AND ELEVATED TEMPERATURE.


Wrought, high strength Al alloys characteristically have markedly inferior resistance to stress corrosion in the short transverse direction relative to resistances in the longitudinal and long-transverse directions. The anisotropy of resistance is due to marked anisotropy of microstructure. A study of of exptl. and com. 1-in-plate shows that the elongated, plate-like grain structure usually found in com. materials was assoc. with short life, while equixed or irregular grain structure was assoc. with longer life. Excess alloy content resulting in 2nd-phase particles in the microstructure contributes to the development of the undesirable elongated grain structure. Exposure at 650°F, under stress for 1400 or 2000 hrs. gave no indication that the steels pH 13-8 Mo and pH 14-18 Mo are susceptible to hot salt stress corrosion cracking Ti-8 Al-1Mo-IV alloys are described. Cracking was observed at 500°F., 50°F. lower than the lower temp. limit reported in prior studies.

83. Da Cunha Belo, M et al

STRESS CORROSION RESISTANCE OF HIGH-PURITY STAINLESS STEELS.

(In French)


A new technique, based on the fusion, in an inductive plasma furnace, of very high purity metals, obtained, by zone melting, allowed reaching a new stage in the purification of metals and alloys. The purified stainless steel specimens, were subjected, under a high bending stress of 33 kg/mm², to a stress corrosion phenomenon was composed of 2 succesive steps: the surface formation or initiation of cracks, and their transgranular propagation. These 2 steps correspond to 2 different electrochem. mechanisms; the initiation resulted from the particular nature of the passive surface layer formed on contact with the reagent; the propagation was due to the anodic discoln. of the crack according to preferential paths, sensitizd by the segregation of certain impurities.

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Contd....
There was prepared a material composed of 2 layers of industrial 18/10 steel, sensitive to tension corrosion, covering a layer of 18/14 stainless steel of very high purity. This composite material allowed studying the resistance of high purity austenite to crack propagation initially formed in the external, less pure, austenite. A micrograph study, after prolonged keeping under stress in MgCl₂, showed the very clear stopping of the crack propagation at the level of the pure steel layer. Stainless steels of sufficiently high purity are rigorously insensitive to cracking under stress; the resistance of these very pure alloys is complete, from the point of view of the initiation as well as that of the crack propagation.

84. Davis, J A

RESISTANCE OF 18 CHROMIUM-18 NICKEL-2 SILICON STAINLESS STEEL TO STRESS CORROSION CRACK PROPAGATION IN BOILING MAGNESIUM CHLORIDE.

Corrosion 26:3, 95-6; 1970.

The crack propagation resistance of a steel cannot be determined by conventional testing procedures if the steel is resistant to crack initiation, thus resistance to crack propagation was determined with preinitiated cracks. Two lab. heats of steel were prepared, one with the typical 18-18-2 stainless steel composition and the other with essentially the same composition, except for high P and Mo, to make it susceptible to cracking. The steels were roll-bonded together and sheet specimens prepared in the annealed, cold worked, and sensitized conditions. U-bend specimens were prepared, half of them with the susceptible steel on the tension side and the other half with the resistant steel on the tension side. The specimens were exposed to boiling MgCl₂ (150°C). When cracks appeared, specimens were retained in the soln. for a min. of 3-4 additional weeks to allow the cracks to propagate. No cracks: initiated in the 18-18-2 stainless steel propagated to the interface and stopped. No cracks were observed that propagated into 18-18-2 stainless steel, even for specimens that cracked in 70 hr and were not removed for 5 months. Stainless steel is resistant to crack propagation.

85. Davis, J A; Wilde, B E

ELECTROCHEMICAL MEASUREMENTS ON AUSTENITIC STAINLESS STEELS IN BOILING MAGNESIUM CHLORIDE.


Electrochemical measurements were made on AISI type 304 and USS 18-18-2 stainless steels in magnesium chloride boiling at 150°C.

Little difference in the cathodic Tafel constant was noted to the observed values being equal to that expected from a charge transfer rate-determining step.
Steady-state corrosion currents increased in the order type 304 > USS 18-18-2 for the unstressed and the stressed condition. Analysis of corrosion potential vs. time and cyclic-polarization data indicates the presence of a film on the corroding surface which affects the corrosion kinetics. The presence of two mixed potentials during cyclic polarization does not support the noble-metal enrichment concept of crack propagation, but rather, the film-rupture model. 20 references.

86. Davies, M.J et al.
STRESS CORROSION OF IRRADIATED STAINLESS STEELS.
AERE-R-5014

87. Denhard, E.E Jr.,
STRESS CORROSION RESISTANT STAINLESS STEEL.

A fully austenitic stainless steel is provided which readily lends itself to a variety of hot-working and cold-working operations, which may be fabricated by way of common welding techniques, and which possesses a combination of good general corrosion resistance, good resistance to intergranular corrosion, and good resistance to corrosion under stresses commonly encountered in use. A preferred steel consists of Cr 18, Ni 9, C 0.6-0.85%, and Fe the remainder. The steel is made in an electric arc furnace. The metal is cast in the form of ingots which are then converted into slabs, blooms, and billets. These forms are reheated and converted into plate, sheet, strip, tubes, bars, rod, and wire in a hot mill. The products are further converted into cold-rolled sheet and strip or cold-drawn wire and fashioned into various items.

88. Denhard, E.E Jr.; Gaugh, R.R.
APPLICATION OF AN ACCELERATED STRESS CORROSION TEST TO ALLOY DEVELOPMENT.

Samples of com. and exp. alloys contg. 30-50% Ni were immersed in heated MgCl₂ soln., and stressed. Welded samples, and welded samples that were bent across the weld, were inspected for cracks. An exp. alloy, nominally 0.03C-20Cr-45Ni-5Mn, had the best welding and anticorrosion properties.

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Contd....
The alloy 17-4 PH, after heat treatment, was more resistant to stress cracking in 6% NaCl-0.5% HNO₃ soln. satd. with H₂S than the alloy 410, which had been tempered.

89. Despic, A R; Raicheff, R G

THE CRACK PROPAGATION RATE IN TERMS OF THE ELECTROCHEMICAL MECHANISM OF STRESS CORROSION CRACKING OF METALS.


The rate of crack propagation in mechanically-stressed metals in direct contact with corrosive solutions is discussed theoretically in relation to the electrochemical parameters of the corresponding systems. Equations are derived for the mean rate of crack propagation in both the active and passive range of electrode potentials, allowing for the effects of passive surface films in the second case. The equations are strictly only valid for simple metals, but by a simple modification may be applied to alloys as well. 10 references.

90. Desestret, A; Wagner, G H

INFLUENCE OF SILICON AND MOLYBDENUM ON THE STRESS CORROSION-CRACKING SUSCEPTIBILITY OF AUSTENITIC AND AUSTENITIC-FERRITIC CHROMIUM-NICKEL STEELS. (In German)


Austenitic steels (C 0.03, Cr 17.5, Ni 12-15.5%) and austenitic-ferritic steels (C 0.05, Cr 20-1 Ni 8-10, ferrite 30%) with addns. of 2.5% Mo and (of) 3-4% Si were tested in boiling solns. of MgCl₂, CaCl₂, 5N NaCl, in water at 150, 200, and 350°, and in steam at 500°. Addn. of Si retarded crack propagation, while Mo accelerated the recuperation of a protective layer, esp. on the sides of cracks, but without inhibiting the crack formation in concd. solns. Effects were marked in more dil. soln. and water contg. Cl, than in concd. MgCl₂.

91. Desestret, A et al

STRESS CORROSION OF DIFFERENT STAINLESS STEELS IN CHLORIDE SOLUTIONS IN THE HOT STATE.

EUR-3764f, 223p 1968.

-32- Contd....
General corrosion and stress corrosion of austenitic stainless steels was investigated in solns. at temps. $\leq 300^\circ$ and in steam $\leq 500^\circ$. Eight grades of stainless steels were tested, 4 of which were austenitic grades and 4 austenitic-ferric grades, with sep. of simultaneous addns. of Mo and Si. The steels were studied in Mg, Ga, and NaCl solns., for the effects of phys. and chem. phenomena on the microstructure. Corrosion behavior was also studied in the presence of water with traces of chlorides added. Changes in the mech. properties and in the microstructure were observed, and the use of chrome plating for corrosion retardation as considered.

92. DeVries, G

CORROSION OF METALS BY MOLTEN LITHIUM.


CONF-691007

A number of metals were tested to find their corrosion resistance to contaminated molten lithium at 600°F and 900°F. The effect of lithium on microstructure, tensile strength, and stress corrosion was found. The austenitic stainless steels, Types 302, 303, 304, 316, 347 and the ferritic stainless steels, Types 446, 430, 405 apparently were not impaired. Hardenable stainless steels were corroded when hardened but not when annealed. Alloy steels showed increased resistance when tempered at 1100°F for 24 hrs. Titanium, molybdenum, tungsten, and chromium showed no evidence of attack.

93. Dirian, J

STRESS CORROSION (In French)

Bibliography No.2.
CEA-BIB-2

A bibliography is presented with 240 references to published literature. The references deal with stress corrosion from both a theoretical and practical point of view, with regard to steels, light alloys, and other metals and alloys.
Benefits of increasing Ni in stainless steels, esp. in the absence of N, apparently are in raising the stacking-fault energy and enhancing cross-slip and dislocation tangling, thereby reducing the tendency for preferential chem. or electrochem. attack. N is detrimental because it enhances short-range order and causes dislocations to remain coplanar. Any nonrandom solid soln. which deforms by motion of groups of coplanar dislocations (low stacking-fault energy or strong short-range order) is therefore expected to be susceptible to stress-corrosion cracking. Hence, susceptibility cannot be decided from stacking-fault energy alone. The alloying elements Cr, Nb, Ti, and Mo are detrimental because they lower the stacking-fault energy of austenitic steels and have a strong affinity for interstitial solutes. The model proposed explains susceptibility dependence on compn., type of solid soln., heat treatment, and magnitude of plastic strain.
High purity alloys are far more resistant to intergranular attack and cracking than common stainless steels in both test media (increasing Si and P content increases susceptibility to intergranular attack). Intergranular corrosion susceptibility of austenitic stainless steels is strongly influenced by the concn. of selected impurities rather than by variations in the Cr and Ni contents. Intergranular corrosion susceptibility of austenitic stainless steel alloys is attributed to solute segregation of selected impurities in the grain boundaries. A model was developed to explain the effects of several variables on the intergranular corrosion susceptibility of nonsensitized austenitic stainless steels.

97. Eckel, J P; Clevinger, G S

AGING OF AISI TYPE 304 AUSTENITIC STAINLESS STEEL CONTAINING NITROGEN AND ITS INFLUENCE ON STRESS CORROSION CRACKING.

Corrosion, 26:8, 251-55; Aug. 1970.

Type 304 stainless steel containing various amounts of N was strained and subjected to an aging treatment prior to exposure to boiling 42% MgCl₂. Comparisons of susceptibility between unaged specimens, specimens aged at 154°C and specimens aged at 200°C show that susceptibility is materially increased by the aging treatment.

98. Eckel, J F et al

THE RELATIONSHIP OF NITROGEN CONTENT OF A HIGH-PURITY 20:20 AUSTENITIC STAINLESS STEEL TO STRESS CORROSION.


Phys. characteristics of the alloy as affected by N content were determined and related to promotion of a ageing reactions which could be associated with stress corrosion cracking. Dilatometric analyses were performed as a function of N content up to 180°C and solid-state reactions in this temp. range were observed. The design of a dilatometer which permits the appn. of a const. tensile stress is described. Internal-friction measurements were also carried out up to 300°C.
CORROSION CRACKING OF STAINLESS STEELS AND NICKEL ALLOYS.


Various theories concerning stress corrosion cracking in f.c.c. alloys are discussed, and observations regarding the effect of stacking fault energy and order transformations on the susceptibility of these metals to similar failure are considered. Austenitic stainless steels of the 18-8 type, stainless steels with increased Ni content, ferritic-austenitic steels, and Ni alloys (600, 800, INCONEL X, etc.) were subjected to 2000 hr. stress corrosion tests in 0.1 M NaCl, pH = 5, pressure 100 atm., temp. 295° in a specially designed autoclave, simulating nuclear reactor thermal conditions. Radiation was simulated by labeling some of the sample alloys with 182Ta. Highest resistance to stress corrosion cracking was inherent to ferritic-austenitic steels, Ni alloys, and austenitic steels contg. 20% Cr and 25% Ni. Ti-stabilized 18-8 steels were more readily attacked by cracking than other 18-8 alloys, while Mo increased resistivity. No radiation effects were detectable in 18-8 alloys subjected to 182Ta irradn. The simultaneous presence of Nb and Mo in 18-8 steels eliminated completely stress corrosion cracking. INCONEL and Cr-Ni-17-4 pH steel resisted cracking or pitting, and thermal pretreatment had no effect upon corrosion behavior. The springs that were used for stressing the samples during the tests were made of Ni alloys 600. Some of them collapsed during the test runs owing to stress corrosion cracking. Exptl. data are still inadequate to provide a comprehensive explanation of the effect of Ti and Mo upon corrosion. Ni alloys are resistant to transcryst. stress corrosion cracking, but are susceptible to intercryst. cracking as proved by the failure of the springs.

A MECHANISM FOR STRESS CORROSION EMBRITTLEMENT.


The stress corrosion cracking behavior of 304 stainless steel in MgCl$_2$ at 140° was studied. In static tensile tests, the time to failure decreased with applied stress, in agreement with previous work. No. incubation period prior to the onset of cracking was noted, while varying the time in soin, prior to the application of stress had no effect on subsequent stress-induced failure. Prestress at various temps. in air in the range 140°-500° affected subsequent time to failure at 140° in MgCl$_2$. 

Contd....
Cyclic loading treatments had no effect on time to failure, and there was no evidence of rapid crack propagation characteristic of brittle fracture. Prior deformation carried out at various temps. reduced the susceptibility of 304 stainless steel. Microstructure was also found to affect cracking behavior strongly; strain-induced martensite resulted in a marked increase in resistance to failure. It was demonstrated that the mechanism of stress-corrosion cracking depended on the simultaneous action of both electrochem. and mech. processes.

101. Feldman, M-S

STRESS CORROSION CRACKING OF STAINLESS STEEL.
(A bibliography)

102. Perry, B N

THE RELATIONSHIP OF NITROGEN CONTENT OF AUSTENITIC STAINLESS STEELS TO STRESS CORROSION. (Quarterly Report No. 2,.) EURAEC-1322 (Dec. 1964).

103. Perry, B N


104. Perry, B.N; Eckel, J F


Work performed under united states-euratom joint research and development program.

Results of studies associated with dilatometry of AISI type 304 steel wire are reported. A linear regression analysis was performed on the dilatometer calibration curve to obtain values for sigma and the confidence interval at the mean temperature of each line segment resulting data are included. Specimens of nitried type 304 stainless steel were tested in the dilatometer at 50 to 170°. An analysis of dilatometer test results is included with plates showing wire microstructure changes.
105. Fokin, M N et al

CREVICE CORROSION AND PITTING OF STAINLESS STEELS IN CHLORIDE SOLUTIONS AT TEMPERATURES UP TO 100°.


A potentiostatic method was used in an electrochem. investigation concerning the effects of acid-reducing properties of NaCl test solns. under N atm. on the anodic dissoln. of stainless steels. Data concerning pitting corrosion at ≤ 100° are presented graphically, and an evaluation of these data is included.

106. Freid, M Kh; Suprunov, V A

INFLUENCE OF HEAT TREATMENT ON THE CORROSION RESISTANCE OF STEEL Kh18N10T (CHROMIUM-NICKEL-TITANIUM) 15% SULFURIC ACID SOLUTION.
(In Russian)


The heat treatment of type Kh18N10T stainless steel (Mn 1.31, Si 0.32, Ti 0.30, C 0.05%), by holding for 10 hr at 650-125° after quenching at 1030°, reduces the corrosion resistance of the steel toward exposure to 15% H2SO4, as evaluated by potentiostatic measurements. This results from the formation of δ-ferrite. The electrochem. instability of TiC at potentials > 0.5V leads to the formation of activation discontinuities. The magnitude of the anodic polarization current depends on the quantity of sep. carbide, which in turn is a function of the thermal treatment.

107. Frey, J W; Staehle, R W

EFFECT OF TEMPERATURE, STRESS AND ALLOY COMPOSITION ON THE ROLE OF STRESS CORROSION CRACKING IN Fe-Ni-Cr ALLOYS.

High purity water corrosion of metals, 35-41; 1968. (Met. A., 6909-72 0151)

Studies to assess the effect of temperature on stress corrosion cracking of Fe-Ni-Cr alloys are described. Experiments were conducted in a circulating, high-temperature autoclave system in a temperature range of 149 to 288°C (300 to 550°F), sodium chloride concentrations of 10 ppm and 0 concentrations of 10-18 ppm. Cracking was most rapid and progressed at approx. the same rate in a region of 177 to 260°C. At the higher temperatures there was a strong tendency for cracking process to be stifled, presumably because of the buildup of oxide films and the associated inhibition of slip step emergence. Cracking times for specimens exposed to boiling MgCl2 at 154°C were found to be in the same range as those for the dilute solutions at the same temperature.
108. Fugassi, P; Haney, E G

EFFECT OF HEAVY METAL IONS ON SUSCEPTIBILITY OF AISI 4340 FOIL TO STRESS CORROSION CRACKING IN DILUTE AQUEOUS HYDROCHLORIC ACID SOLUTIONS.

Corrosion, 16:3, 118-120; 1970.

The time-required for the cracking of AISI 4340 steel foil in dilute aqueous hydrochloric acid solution pH-1.5, is greatly increased by the presence of small amounts of Ca++ and Pb++ in concentrations as low as $10^{-4}$M. It is suggested that these heavy metals, whose sulfides have solubility products in the range, $10^{-29}$-$10^{-26}$, form sulfides more insoluble at pH 1.5 than can be formed by certain areas present on the surface of the foil. Sulfided areas on the surface of the foil are assumed to accelerate the absorption of H by the foil.

109. Gaul, G G et al.

STRESS CORROSION OF TYPE 304 STAINLESS STEEL IN SIMULATED SUPERHEAT REACTOR ENVIRONMENTS.

GEAF-4025 1962.

110. Gerasimov, V I et al

CORRELATION BETWEEN THE INTERCRYSTALLINE CORROSION AND THE CORROSION CRACKING TENDENCIES OF AUSTENITIC CHROMIUM NICKEL STEELS. (In Russian)


Austenitic stainless steels EP350 and Kh18N10T which after certain heat treatments (e.g., holding for 20 min. at 1080° followed by 2 hrs. at 650°) show a strong tendency towards intercryst. corrosion cracking in water at 320-50° and 115-168 atm. or in a 28% NaCl-0.5% K2Cr2O7 soln. at 200°, 16 atm. The overall corrosion rate in the NaCl soln. is greater than in the water. The cracking may be either transcryst or intercryst.
A study was made of the effect of pH value of chloride solutions on the resistance to corrosion cracking of two austenitic Cr-Ni steels: (i) Kh18Ni10T, 18:10 Cr-Ni Ti-stabilized steel, which has good resistance to corrosion cracking in concentrated Cl solutions; and (ii) Kh20M45B, 20:45 Cr-Ni Nb-stabilized steel, which at pH 4-5 is insensitive to this type of attack. Tests were conducted in autoclaves at 200°C and 16 atm pressure in 25% NaCl + 0.5% K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> with the pH adjusted by HCl and NaOH additions to values of 1,3,5,7,9,11 and 13. Specimens were examined at x7 and x25 magnifications after 1,3,5,7; and 10h, and then after intervals of 5h for a total period of 300h. Solutions were changed, where necessary, to keep the pH value constant. At pH 1-5 steel i) was subjected very rapidly to corrosion cracking, i.e. in 1-5h. Resistance improved with increasing pH, and pH 13 the first cracks appeared only after 50h (this agrees with the data of Hoar and Hines). The attack was transcrystalline, and pH had no effect on the form or distribution of the cracks. Steel ii) was resistant to these conditions under stress at all pH values and no cracking was found in 300h. Steel ii) may be used for structures operating in aggressive media over a wide range of pH. The reasons for the occurrence or non-occurrence of cracking are briefly discussed.
113. Gerasimov, V V

CORROSION OF REACTOR MATERIALS: A COLLECTION OF ARTICLES.
AEC-tr-5219  1962.

Contains a collection of 29 papers pertaining to the corrosion of reactor materials and is divided into the following 5 sections:
1) Method of corrosion and electrochemical investigations in water at high temperatures and pressures; 2) Influence of the water composition on the corrosion of construction materials; 3) Corrosion under stress; 4) Intercrystallite corrosion; 5) Corrosion of reactor materials.

114. Gerasimov, V V; Popova K A

AN INVESTIGATION OF THE MECHANISM OF THE CORROSION CRACKING OF ICr18N19T AUSTENITIC STAINLESS STEEL.
AEC-tr-4684  1960.

The effect of mechanical stresses up to 33-3 kg/mm² on the kinetics of the electrode processes of ICr18N19T steel was investigated in distilled water, 0.01 N-sodium sulfate, 0.001 N-nitric acid, 0.001 N-sodium hydroxide and 0.01 N-sodium chloride. It was shown that tensile stress on the stainless steel has no effect on the rate of the cathode process and the dissolution rate of the steel in the passive condition. Tensile stress on a sample in solution of sodium chloride, in contrast to the other media investigated, has a significant effect on the kinetics of the anode process by compressing the region of the passive state and by increasing the dissolution rate of the metal. An increase in chloride concentration in solution has an effect on the kinetics of the anodic process which is analogous to that obtained with an increase in tensile stress on the metal.

On the basis of the data of the electrochemical investigations, a hypothesis was advanced on the mechanism of the phenomenon of the corrosion cracking of ICr18N19T austenitic stainless steel. Methods of calculating the safe concentrations of oxygen and chloride in solution from the point of view of corrosion cracking were noted on the basis of the data of the electrochemical investigations.
115. Gerasimov, V V et al
INFLUENCE OF PROTECTIVE METALLIC COATING ON THE CORROSION CRACKING OF STAINLESS STEEL. (In Russian)

116. Gerasimov, V V et al
EFFECT OF PROTECTIVE METAL COATINGS ON THE CORROSION CRACKING OF STAINLESS STEEL. (In Russian)
Different coatings on Okh18N10T steel were evaluated as to their effectiveness in providing long-term protection against corrosion cracking in a Cl- containing environment at elevated temps. under stress. The coatings evaluated were flame-sprayed, plasma-sprayed, and hot-dipped Al, plasma-sprayed Alumel (Ni+2.5% Al), plasma-sprayed Nichrome (Kh 20N 80), electroplated Ni (from a Watts bath), and chem. deposited Ni (from acid soln.). Both of the sprayed Al coating, √100-µ thick, afforded the greatest resistance to corrosion cracking, while also providing electrochem. protection to the steel. Annealing of the sample after coating with Al, for 2 hr at 510, 700, or 870°C increased the resistance to corrosion cracking by at least a factor of 2; annealing temps. above the m.p. of Al (600°C) lead to the formation of a thick (≥3 µ) and brittle intermetallic layer, which tended to propagate cracking into the Al layer and thus, was inferior to the sprayed Al coating annealed at 510°C.

117. Gerasimov, V V et al
THE EFFECT OF THE CHLORIDE AND OXYGEN CONTENT OF WATER ON STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEEL.
Teploenergetika, 15:6, 40-41; 1968.
Data are given on stress corrosion cracking sensitivity of austenitic stainless steel (1Kh18N10T, 18-10Cr-Ni, Ti-stabilized) in water of varying Cl- and O contents at 330°C and 130-150 atm. With an O content of 0.1 mg/l, cracking of stressed specimens did not occur even when the Cl- content was 1000 mg/l; with 0 at 3 mg/l; with 0 at 3 mg/l, cracking occurred when the Cl- content was 0.1 mg/l. and for thermal generating plant with the latter 0 level the Cl- content must be ≤0.1 mg/l. In plant with O levels of 40 mg/l, the safe Cl- level is 0.02 mg/l. or less.
118. Gibson, S P et al

CHLORIDE STRESS CORROSION CRACKING IN THREADED 300 SERIES STAINLESS STEEL COMPONENTS.


The seriousness of chloride stress corrosion cracking is discussed, along with plates showing corrosive effects of failures in high temp. water system. The source of chloride, in some instances, was traced to chlorofluoro org. compds. used as lubricants for assembling the threaded components.

119. Glazkova, S M et al

STRAIN-AGEING AND ITS EFFECT ON THE TENDENCY OF AUSTENITIC STEEL TO CORROSION CRACKING. (In Russian)

The effect of strain-ageing on the corrosion resistance of austenitic Cr-Ni steel was studied in relation to the strain-ageing mechanism. Thus after working and ageing at 20-350°C a sharp 'tooth' indicative of strain-ageing appeared on the stress/strain diagram and the deformation resistance increased; at the same time there was an increased tendency towards corrosion cracking. These effects were attributed to the pinning of dislocations by point defects constituting interstitial atoms and possibly vacancies. 11 references.

120. Graf, L; Springe, G

CAUSES OF STRESS CORROSION OF STAINLESS, CARBONSTABILIZED AUSTENITIC CHROMIUM-NICKEL STEELS. (In German)


Potentiokinetic current-potential curves were detd. for steel W.Nr. 4306 and pure Cr, Ni, and Fe, in MgCl₂ soln. at 142°. Passivity of the steel was demonstrated and the absence of a Flade potential and the low c.d. in the passive region are discussed. Expts. under constant deformation showed the effect of rate of deformation on crack development. The relations between pinhole corrosion and stress corrosion cracking are discussed.

121. Graf, L; Springe, G

RELATIONSHIP OF DYNAMIC STRAINING AND PITTING EXPERIMENTS TO INTERPRETING THE MECHANISM OF CRACKING IN AUSTENITIC STAINLESS STEELS.

The causes of stress corrosion cracking of an austenitic stainless steel in MgCl₂ are shown to be the same as those in homogeneous, non-supersaturated nonferrous alloys, such as two solid-solution effects combined with a pronounced electrochemical process inside the cracks.

The former are intrinsic properties of solid solutions, therefore only the origin of the cathodic areas on the crack walls were to be determined because the potential difference between the flowing crack roots and the nonflowing crack walls is not sufficient. Nonstraining material is shown to form a stable protective film in boiling MgCl₂ which, moreover, acts cathodically on the crack walls whereas the plastic flowing crack roots are not passivated and act as anodes. With the help of schematic c.d.-potential diagrams, the potential range is shown in which stress-corrosion cracking can occur. Experiments in which pitting was allowed to commence prior to stressing showed that the onset of cracking, once stress had been applied, was significantly delayed. These pitting experiments show the importance of competing electrochemical processes and also verify the electrochemical nature of the cracking.

122. Graf, L; Springe, G

RELATION OF DYNAMIC STRAINING AND PITTING EXPERIMENTS TO INTERPRETING THE MECHANISM OF CRACKING IN AUSTENITIC STAINLESS STEELS.


The causes of stress corrosion cracking of an austenitic stainless steel in boiling MgCl₂ are the same as those in homogeneous, non-supersaturated, nonferrous alloys, i.e., 2 solid soln. effects combined with a pronounced electrochem. process inside the cracks.

The former are intrinsic properties of solid solns., therefore only the origin of the cathodic areas on the crack walls were to be detd., because the potential difference between the flowing crack roots and the nonflowing crack walls is not sufficient. Nonstraining material forms a stable protective film in boiling MgCl₂ which, moreover, acts cathodically on the crack walls whereas the plastic flowing crack roots are not passivated and act as anodes. With the help of schematic c.d.-potential diagrams, the potential range is shown in which stress corrosion cracking can occur. Expts. in which pitting was allowed to commence prior to stressing showed that the onset of cracking, once stress had been applied, was significantly delayed. These pitting expts. show the importance of competing electrochem. processes and also verify the electrochem. nature of the cracking.
123. Graefen, H

NEW RESULTS OF ELECTROCHEMICAL STUDIES OF STRESS CORROSION CRACKING
AND THEIR PRACTICAL APPLICATIONS. (In German)
Corros. Soc. 7:4, 177-95; 1967.

Results are given of electrochem. investigations of stress corrosion
cracking with particular references to mechanism. Data are presented
for intercryst. Stress corrosion of unalloyed C steel in NO_3^-contg.
cracking of austenitic Cr-Ni steels in Cl^-contg. media, in H_2SO_4, etc.

With unalloyed steel, there is a grain activation potential boundary
or cracking sets in the potential decreasing with applied stress in
NO_3^- media; in alk. media, the potential range in which cracking
in likely to occur very small with stress corrosion sensitivity being
suppressed by anodic protection. The level of the activation
potential in austenitic steels in Cl^- bearing media is clearly
dependent on stress load; cathodic protection for suppression of tranocryst. cracking is also dependent on the level of applied
stress, higher stressing moving the potential to neg. levels. In
the case of tranocryst. cracking of Cu-contg. austenitic stainless
steels in H_2SO_4 media, Cu-contg. protective layer formation is
important with local failures being facilitated by applied stress.

124. Green, R J et al

EFFECT OF GRAIN SIZE ON INCUBATION AND PROPAGATION OF STRESS
CORROSION CRACKS IN TYPE 302 STEEL.
Corrosion 24:5, 137-8; 1968.

The effect of grain size on the incubation and propagation of stress
corrosion cracks in annealed type 302 steel exposed to 42 wt. %
MgCl_2 was investigated. The incubation period was grain-size
dependent, and incubation times of 15 and 40 min. were detd. for
materials of grain size ASTM No. 5 and 9, resp. propagation rates
were nearly independent of grain size.

125. Griess, J C; Creak, G E

DESIGN CONSIDERATIONS OF REACTOR CONTAINMENT SPRAY SYSTEMS. Part X.
The stress corrosion cracking of types 304 and 316 austenitic stainless
steels are discussed.

126. Gromova, A I et al

EFFICIENCY OF VARIOUS METHODS OF PROTECTING 1KH18N10T CHROMIUM-NICKEL
STEEL FROM CORROSION CRACKING AT HIGH TEMPERATURES. (In Russian)
Harston, J D; Scully, J C

127. FRACTURE PATH OF STRESS CORROSION CRACKS IN AUSTENITIC STAINLESS STEELS.


Stress corrosion cracking in austenitic stainless steels having a nominal composition of either 18:10 or 18:18, some with additions of Cu or Co austenite stabilizers, was studied. Specimens were stressed as a U bend and exposed to concentrated MgCl₂ solution boiling at 154°C. Scanning electron microscopy shows that cracks follow a crystallographic path, an observation not made before. Such regions were always well below the original surface of the specimens. The crystallographic aspect of stress-corroded surfaces was apparent in both 18:18 and 18:10 alloys, but considerably modified in the latter alloy and apparently absent in 18% Cr-10% Ni-2% Cu alloys. 7 references.

Harston, J D; Scully, J C

128. STRESS CORROSION OF TYPE 304 STEEL IN H₂SO₄/NaCl ENVIRONMENTS AT ROOM TEMPERATURE.


The stress corrosion cracking of 304 stainless steel in 5NH₂SO₄ + 0.5N NaCl at room temp. has been studied by scanning electron microscopy. Specimens in the form of thin sheet with two grain sizes were subjected to simple U-bend tests. Cracking was initiated mainly as a consequence of grain-boundary corrosion but cracking was mainly transgranular below the outer layer of grains. Crack propagation occurred as a result of the formation of parallel tunnels across a grain. The width of tunnels was greater in the larger grain size material. The subsequent formation of the crack surface occurred partly as a result of lateral dissolution. Crack propagation occurred across (iii) planes in the large grain material, quenched from 1300°C. Cracking results from the interaction of dislocation pileups with the environment as a result of which transgranular dissolution occurs more rapidly than grainboundary corrosion. The relative rates of corrosion of these metallographic features are a function of alloy constitution and environment composition. 14 references.
EFFECT OF APPLIED STRESS AND COLD WORK ON STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEEL BY BOILING 42 PERCENT MAGNESIUM CHLORIDE.


The effect of applied stress on the stress-corrosion crack morphology resulting from the exposure of Types 304, 309, and 316 austenitic stainless steel wire specimens to boiling 42% by wt. MgCl₂ was studied. Crack morphology depended on applied stress; the depth of crack penetration was inversely related to the applied stress, while the cracks per unit length of specimen increased with applied strength. The area of greatest attack and failure was in the material exposed to the vapor phase of the environment, slightly above the liquid-vapor interface. Differences in resistance of Types 304, 309, and 316 to stress-corrosion cracking were minor, with Type 316 the most resistant the Type 304 the least. Introduction of air into the boiling solution reduced deleterious; the most severe condition occurs at approx. 10% cold work. The nature of stress corrosion cracking resulted in a rather wide dispersion of time-to-failure vs. stress data points. This dispersion increased generally with decreasing stress level or length of test.

Herbelebm G; Schwenk, W.

CRITICAL LIMIT STRESSES FOR PRODUCING STRESS CORROSION CRACKING OF MATERIAL (CHROMIUM-NICKEL) 4301 IN BOILING MAGNESIUM CHLORIDE SOLUTION (In German)


An attempt was made to determine the critical potential for the development of stress corrosion cracking in a tensile test bar of an austenitic Cr-Ni steel in boiling 42% MgCl₂ solution. The results show that there is a critical potential and a critical tensile strength which are interdependent; both must be exceeded for the occurrence of stress corrosion cracking. The results were in accord with earlier work.
Herbslev, G; Ternes, H

KINETICS OF STRESS CORROSION CRACKING OF AUSTENITIC CHROMIUM-NICKEL STEELS IN MAGNESIUM CHLORIDE SOLUTIONS. (In German)


Tests were carried out on the stress corrosion cracking of X5CrNi18 9, X5CrNiMo18 10, X5CrNiMo17 13, X10CrNiNb18 9, and X10CrNiMoNb18 10 steels in 42% MgCl₂ solution at 144 and 130°C. The cracking rate at the potential at the base of the crack, which depends on the surface potential limit towards more noble values below which no stress corrosion cracking occurs. The influence of temp. is restricted to the crack propagation period, and does and affect the incubation time (which is short, and accounts for ~10% of the specimen life). Increasing Ni contents may influence the effect of Mo additions.

19 references.

Hildebrand, J F

EVALUATION OF STRESS CORROSION RESISTANCE OF AISI 4340 AND 17-4PH STAINLESS STEEL MATERIAL.

N63-21648, 10p. 1963.

The heat treatment of the stainless steel specimens to the 200-20 x 10⁵ lb./m.² strength level is described. The stress-corrosion tests were run at increasing stress levels, starting at the proportional limit stress as detd. for each material by a stress-strain curve. Neither the AISI 4340 nor the 17-4PH bar stock showed any susceptibility to stress corrosion at 200-20 x 10⁵ lb./in.²

Hill, B; Trueb, L F

RESISTANCE OF EXPLOSION-BONDED STAINLESS STEEL CLADS TO INTERGRANULAR CORROSION AND STRESS CORROSION CRACKING.


Intergranular corrosion of stabilized austenitic stainless steel is not accelerated when this material is explosionclad to C steel. Heat treatment in the sensitization range causes C diffusion across the bond interface and precipitation of chromium carbides; this influences the corrosion rates within the diffusion band. Outside of this relatively small areas, corrosion rates are similar to those characteristics of nonclad material subjected to the same heat treatment. Stress corrosion cracking of both a stabilized and an unstabilized grade of austenitic stainless steel is not accelerated by explosion cladding to C steel. Stainless steel-to-steel explosion clads thus do not appear to pose any special corrosion problems.

17 references.
Hiltz, R H
134.
CORROSION OF
AND 1400 F.
Draley, Joseph
pp 63-80 of CONF-691007

The corrosion
contaminated a
gray surface
1200°F as a fur-
ner surface layer
metal. At 140
thought to be
occurred than
1200°F.

Hines, J G
135.
DEVELOPMENT OF
Corrosion Sci.

Direct-loaded,
Cr-Ni steels we
necessary for
specimens for
are comparable
specimens. The
period and a cr
no change in po
more important s
stress, and so w
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given specimen
d account for orca
The corrosion of Types 304 and 316 stainless steel in oxygen-contaminated sodium (> 30 ppM oxygen) was studied at 1200°F and 1400°F. A gray surface scale, identified as sodium chromite, formed at 1200°F as a function of time and oxygen concentration. It began as a surface layer but penetrated along grain boundaries into the base metal. At 1400°F a green thin surface layer formed which was thought to be made up of two components. Less internal penetration occurred than would occur at an equivalent time and oxygen level at 1200°F.

Deborah, J G

DEVELOPMENT OF STRESS CORROSION CRACKS IN AUSTENITIC CR-NI STEELS.


Direct-loaded, axially stressed specimens of a variety of austenitic Cr-Ni steels were exposed to boiling 42% MgCl₂ soln. The progress of cracking was followed by potential measurements and by removing specimens for exam. after suitable periods of exposure. The results are comparable with those earlier obtained on 0.051-in. diam. specimens. The life of a specimen can be divided into an induction period and a cracks remain fine during the 1st stage, during which no change in potential can be detected; this stage is relatively more important the larger the specimen and the lower the applied stress, and so was not recognized previously. The cracks open up and become branched during the 2nd stage, which is accompanied by a fall in potential. The relative duration of the induction period and the total period of crack propagation varies considerably with the exp. conditions, particularly the size and form of the specimen and the mode of stressing, but for fully softened, axially stressed, cylindrical specimens, the ratio of these periods is const. for a given specimen diam. Sufficient corrosion current is available to account for crack formation by purely electrochemical processes.
Hines, J G; Jones, E R W.
SOME EFFECTS OF ALLOYS COMPOSITION ON THE STRESS CORROSION BEHAVIOUR OF AUSTENITIC Cr-Ni STEELS.

Hoar, T P
STRESS CORROSION CRACKING.

Plenary lecture. Stress corrosion cracking facts and figures are reviewed. Cracking propagation requires ductility, not brittleness, in the metal under attack. For rapid stress corrosion cracking the supply of corrosive reagent from the environment is a critical factor. Stress corrosion cracking can only occur when the metal has very special properties and the soln. a very special compn.
84 references.

Hochmann, J; Bourretat, J.
STRESS CORROSION CRACKING OF 18/10 STAINLESS STEEL.
Compt. Rend. 255, 3416-17; 1962.

A series of 5 steels of ≤ 0.02%C-18 Cr-14 Ni were made with 0-4.1% Si. They were tested after (a) holding at 450° and air cooling and (b) with 20% cold work after (a). The simple surfaces were polished mech. and subjected to stress in boiling 42% MgCl\textsubscript{2}. Steels with 3.3% Si lasted 2000 hrs., when the test was stopped. The samples with only 0.03% Si lasted only 155-500 hrs. after testing treatment (a) and 5-43 hrs. after (b).

Hochmann, J; Bourretat, J.
STRESS CORROSION OF AUSTENITIC STAINLESS STEELS. (In French)

After a review of the basic phenomena and the theory of stress corrosion of austenitic stainless steels, preventive measures to be taken are discussed. Surface prepns. changes in chem. analysis of the steel are most successful in preventing stress corrosion. The investigation comprised particularly the influence of Ni and Si addns. and the influence of the austenitic-ferritic structure.
140. Ito, G

STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS. (In Japanese)
Kagaku To Kogyo (Tokyo) 18:2, 264-71; 1965.
A review with 13 references.

141. Ito, G

STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS, I. AUSTENITIC STAINLESS STEELS. (In Japanese)
Nippon Kinzoku Gakai Kaiho 8:10, 708-16; 1969.
The effect of elements, such as Ni, Cr, Mo, Si, Cu, N and C contained in austenitic stainless steels on the stress corrosion cracking (acc) of the steels, formation and growing of acc, and mechanism of the anticracking effect of alloy elements, are reviewed. 50 references.

142. Ito, G

STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS, III. STAINLESS STEELS IN HIGH TEMPERATURE WATER. (In Japanese)
Nippon Kinzoku Gakai Kaiho 8:10, 721-7; 1969.
The effect of Cl ion concn., dissolved O, pH, temp., and stress on the corrosion cracking of stainless steels in water, the effect of steel compn. on the stress corrosion cracking susceptibility of austenitic stainless steels, cracking of Ferrite stainless steels, particle segregation in Ni alloys, and anticracking treatment of steels in high temp., water, are reviewed. 64 references.

143. Ito, G et al

CORROSION OF AUSTENITIC STAINLESS STEEL IN HIGH-TEMPERATURE FLOWING WATER. (In Japanese)
Bosoku Gijutsu 17:10/11, 440-8; 1968.
Studies were conducted on SUS 27, a type 304 austenitic stainless steel, at 320° and at flow rates up to 12 m./sec. The corrosion product film formed on the surface of the steel under these conditions was composed of magnetite only in contrast to the coexistence of magnetite and hematite formed in static tests.

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Contd...
The effects of purity, amount of dissolved O₂, and the flow rate of H₂O on the corrosion rate of stainless steel were related to one another. The corrosion was severest when the cond. of the test H₂O was >6 x 10⁻⁴ mho/cm. and the amount of dissolved O₂ was <0.3 ppm. In test H₂O's of higher O₂ content, ~2-3 ppm, the corrosion was milder. The corrosion rate was reduced to the lowest value when the purity of H₂O was kept high. The effect of flow rate of H₂O on the corrosion rate was noticed only in low purity H₂O.

144. Ito, G et al

EFFECTS OF ADDITIONAL ELEMENTS ON THE SUSCEPTIBILITY OF AUSTENITIC STAINLESS STEELS TO STRESS CORROSION CRACKING IN HIGH-TEMPERATURE WATER CONTAINING CHLORIDE.


The ability of the alloying elements N, Ni, Si, V, Mo, Re, and Al to reduce the susceptibility of vacuum-melted austenitic stainless steels to stress corrosion cracking in high-temperature water containing 600 ppm of chloride ion was investigated. The majority of alloys examined exhibited a reduced tendency to cracking compared with commercial 304, 304L, 316, and 347 steels. The 18-8 Cr-Ni alloys containing <0.05% N were, however, highly susceptible to cracking. Increasing the amount of Ni in the 18% Cr alloys from 8 to 20% decreased the tendency to cracking.

145. Ito, G et al

EFFECTS OF IMPURITIES ON THE SUSCEPTIBILITY OF AUSTENITIC STAINLESS STEELS TO STRESS CORROSION CRACKING IN HIGH-TEMPERATURE WATER CONTAINING CHLORIDE. (In Japanese)


The effects of C, Si, Mn, and P on the resistance to stress corrosion cracking of austenitic stainless steels were studied in pressurized, high-temperature water containing chloride. The tests were carried out at 300°C for 300 h in an autoclave containing a solution with 600 ppm Cl⁻ prepared from NaCl and pure water. The same alloys were also tested in boiling MgCl₂ solution. Alloys containing P < 0.03, C < 0.1, Si > 2 or Mn > 1.5 wt.% were highly susceptible to cracking in aqueous solutions of NaCl or MgCl₂. 9 references.
Three austenitic-ferritic and two austenitic steels, similar to 18-8 grades but with low Ni contents (3.60-6.28% Ni) were studied under constant stress in an indirect-stress tester, in a 42% solution of boiling magnesium chloride. At a stress of 30 kgf/mm², all specimens ruptured in less than 1 hr, exhibiting transgranular and intergranular corrosion. A Nb-stabilized steel (0.53% Nb, 4.85% Ni) withstood a stress of 20 kgf/mm² longer than any of the others (175 hr), showing a preponderance of transgranular corrosion over intergranular under the microscope. At 10 kgf/mm², the life of the specimens ranged from 155-590 hr. The steel containing the least Ni (3.60%, austenitic-ferritic structure) failed at 590 hr, but without cracking and showing no signs of corrosion. 7 references.

147. Jackson, R P

STRESS-CORROSION CRACKING OF 17-4 PH STAINLESS STEEL.

DP-779 (1962)

148. James, L et al

SPRAY BOND TEST EVALUATES STRESS CORROSION CRACKING BEHAVIOR OF AUSTENITIC STAINLESS STEEL AND OTHER MATERIALS.

Mater protect. 2:11, 18-22, 24, 26; 1963.

Stress corrosion cracking behavior of austenitic stainless steel and other materials wetted by chloride-contg. potable water was investigated. Details are given of the spray bend test procedure and app. Wrapping Al wire around pipe surfaces prevented cracking with certain limitations, c. steel was equally effective. Several materials, including com. grade Ti, were resistant to cracking in the test environment. Results are tabulated.
149. Kalichak, T N et al

FATIGUE AND CORROSION-FATIGUE STRENGTH OF SOME MARTENSITIC STAINLESS STEELS CONTAINING 12% CHROMIUM. (In Russian)


The effect of thermal treatment, alloying degree, and rerefining treatment of 12% Cr steels: 1Kh12N2VF, 1Kh2N2MVFBA, and 2Kh13 on their durability in various media was studied. All steels were melted in elec. furnaces, while steel 1Kh12N2MVFBA was addnl. melted by the electroslag method. Corrosion-fatigue cracks had transcryst. character. An atm. of moist air lowered the ultimate fatigue strength by 15-25% as compared to the same strength in normal lab. air. The ultimate fatigue strength of these steels increased monotonically together with increasing tensile strength within the ranges 95-135 daN/mm², while at the same time ultimate corrosion-fatigue did not change. The refining during electroslag melting increased the durability of steel 1Kh12N2MVFBA by 10%.

150. Kamachi, K et al

MECHANICAL BEHAVIOR OF AUSTENITIC STAINLESS STEELS IN THE PROCESS OF STRESS CORROSION TESTING. (In Japanese)

Nippon Kinzoku Gekkaishi 35:1, 64-70; 1971.

For the purpose of investigating the stress corrosion process in terms of material strength, several specimens subjected to stress corrosion testing were examd. by using x-ray diffraction methods, the dislocation ds. were measured by transmission electron microscopy. Plate specimens for tension tests were prep’d from 0.3 mm thick material of SUS 27 and were electrolytically polished. These specimens were tested by a tension type stress corrosion testing device in a 42% MgCl₂ soln. at 154° under stresses 13-30 kg/mm². At several stages in the testing process, the specimens were taken from the app. and the x-ray diffraction patterns were measured. These specimens were then thinned electrolytically and their dislocations were obsd. Many of the dislocations piled up at grain boundaries or had uniform distributions in grains including stacking fault formation. The dislocation d. reaches the value of 10⁶/cm² or over, when corrosion cracking takes place. The x-ray data of half-width ratio b/β vs. corrosion time T curves are analogous with the dislocation d. curves, and the results of lines profile anal. show the effect of strain broadening.
According to the experience of the authors with such cracking of conventional stainless steels containing ≤0.9% Si and ≤19.5% Cr + Mo, these failures could not be prevented with ≥40% Ni, which was too costly. Investigations of compositions containing 16-20% Ni showed that satisfactory resistance to such cracking could be obtained in them with higher Si and lower Cr and Mo. Test results are reported on specimens of various compositions stressed in tension at 25 and 35 kg/mm² respectively, in an aqueous solution of MgCl₂ boiling at 150°C, to show the effects of composition changes on the time for failure by cracking.

182. Kawamura, T; Oka, H

STRESS CORROSION CRACKING IN STAINLESS STEEL EQUIPMENT AND ITS PREVENTION. (In Japanese)


A review is given on stress corrosion cracking in chemical industries. 14 references.

153. Kazuo, H et al

ATMOSPHERIC STRESS CORROSION CRACKING OF LOW ALLOY HIGH STRENGTH STEELS AND STAINLESS STEELS. (In Japanese)

Zairyō 17:179, 720-8; 1968.

Experiments were conducted extending over 3 years in which low-alloy high-strength steels and stainless steels were exposed under static load to various types of atmosphere, i.e. industrial, marine, and rural. No cracking either in the welded or in the nonwelded specimens of low-alloy high-strength steels also did not show any cracking. Pitting and intergranular corrosion occurred, however, in the heat-affected zone of the welded stainless steels (SUS 50 (13% Cr) and SUS 24 (18% Cr)).
154. Kenneth, R W

METHOD OF PROTECTING AUSTENITIC STAINLESS STEEL SUBJECT TO STRESS CORROSION.


The resistance of austenitic stainless steel containing 6% Ni and 18% Cr to stress corrosion cracking in chloride and sulfide atm. is improved by partially coating the surface with Al and heat-treating at $1300^\circ$F, for 1 hr. In corrosion tests, partially Alcoated stainless steel horseshoes refluxed in 350 g, MgCl$_2$, 6H$_2$O and 40 ml, H$_2$O at 307$^\circ$F, failed in $\sim$38 days as compared to hrs. for unprotected specimens.

155. Kirkpatrick, H B et al

STRESS CORROSION.


Stress corrosion cracking has been identified as the cause of failure of low carbon steel in riveted boilers and pressure vessels in contact with hot alkali solutions, of brasses and other Cu alloys in environments containing ammonia, of steel landing gear struts and Al alloys fittings and of high strength steels and Ti alloys under high electrochemical potentials. Metals affected show sharply reduced tensile strength, reduced ductility and very little elongation to fracture. Time to failure depends on stress level and cracks tend to be narrow and extend deep into the metal. A table lists environments known to cause stress corrosion of Al, Cu, austenitic and ferritic stainless, carbon and low steel, high strength alloy steel, Mg, Ni and Ti. Design precautions include measures such as limiting tensile stresses, eliminating residual tensile stresses, eliminating corrodatnts in the service environment using cathodic protection and organic coatings. Several factors are considered as responsible for stress corrosion including an anodic shift, the presence of electrochemically susceptible paths, strain-accelerated transformation periodic electrochemical mechanical action layer rupture along weakened regions and H$_2$ reaction. 11 references.
EFFECT OF TEMPERATURE ON THE SUSCEPTIBILITY TO STRESS CORROSION CRACKING OF STAINLESS STEELS. (In Japanese)

Boshoku Gijutsu 17:9, 361-8; 1968.

Arrhenius plots were made using data on uniaxially stressed specimens of types 304, 303Se, 201 and 431 stainless steels immersed in 35% MgCl₂ soln. at various temps.; pH of which had been adjusted to 3 at 22° by adding HCl. The reciprocal of time to failure was taken as the rate of stress corrosion cracking. The results were in good agreement with the Arrhenius equation. Both the activation energy and logarithm of the rate coeff., i.e. the preexponential term, increased in direct proportion to the stress level applied, and the lines illustrating the above relations broke at a stress-level corresponding to 0.03% proof yield strength of types 304 and 303Se steels. As for the other steels such a break was not evidently observed. It is concluded that the rate of stress corrosion cracking increases with applied stress.

THE MECHANISM OF STRESS CORROSION EMBRITTLEMENT.


A brief summary on the present situation of a research program directed towards obtaining a better understanding of the mechanism of stress corrosion embrittlement of cracking in 2 systems, stainless steel/MgCl₂ and brass/ammoniacal soln., in presented and discussed, which comprises the following aspects of the problem; 1) cathodic reactant in MgCl₂ soln.; (2) apparent activation-energy; (3) delayed time to fracture; (4) delayed-fracture curve; (5) effect of solute atoms; (6) protective c.d.; (7) effect of cold work; (8) chloride-cracking of martensitic stainless steel; and (9) ammonia-cracking of brass. 45 references.
Stress corrosion tests were made by using austenitic stainless steels such as SUS 27, 28, and 33. The test specimens used for the constant-strain method and the constant-stress method were coated with flame-sprayed Al (99-99% Al, 0.1-0.2 mm thick) or Zn-rich paint (contg. 95% Zn, 0.1-0.2 mm thick) and tested in 42% MgCl₂ soln. at 154°. Surface-treated specimens were harder to crack than untreated ones. Natural electrode potential and cathodic polarization curves were measured in 20% NaCl + 1% Na₂Cr₂O₇ - 2H₂O soln. (pH 4.4) at 25 ± 1°. The natural electrode potential of specimens coated with Al or Zn showed almost the same value as that of Al or Zn alone.

Sulfide stress cracking causes failure of compressor components in refinery service.

Failures of centrifugal compressor components have occurred in refinery environments contg. H₂S. Wet, acidic refinery streams contg. H₂S can cause cracking of susceptible materials, but wet streams of H₂S contg. quantities of NH₃ resulting in alk., conditions do not. Low alloy constructional steels and pptm. hardening stainless steels with yield strengths above 100,000 psi, are highly susceptible to cracking. Steels properly heat treated to 90,000 psi max. are not susceptible, Ni base pptm. hardening alloys, Monel K-500 and Inconel X-750, are not susceptible to cracking. Fabrication procedures and heat treating practices for impellers operating in streams capable of causing sulfide stress cracking should be controlled to minimize plastic deformation, residual stresses, and damaging structures, particularly in welds.
162. Kowaka, M; Fujikawa, H

EFFECTS OF PHOSPHORUS AND NITROGEN ON STRESS CORROSION CRACKING OF
AUSTENITIC STAINLESS STEELS IN BOILING MgCl₂ SOLUTION. (In Japanese)


The influence of P and N on the stress corrosion cracking of 18-10 Cr-Ni
austenitic stainless steel in boiling MgCl₂ at 154°C was investigated
by the U-bend and tensile methods. The results showed the detrimental
effects of P and N, and the interaction between these elements, on the
sensitivity to stress corrosion cracking. The general corrosion rates
and potential/time relationships of these steels in boiling MgCl₂ at
154°C were also studied. The results are discussed in relation to
the dislocation structures of the materials. 13 references.

163. Kowaka, M; Fujikawa, H

THE EFFECTS OF SEVERAL ELEMENTS ON STRESS CORROSION CRACKING OF
AUSTENITIC STAINLESS STEELS IN BOILING MgCl₂ SOLUTION. (In Japanese)


The effect of several elements on the stress corrosion cracking of
18-10 Cr-Ni austenitic stainless steel was studied using boiling
MgCl₂ at 154°C. C, Si, and S (0.1 wt.%) were beneficial while Mo, Cu,
and Cr were detrimental. Mn in amounts up to wt. % had little effect
but in greater amounts became detrimental. C, S, Mo, and Cu increased
the resistance to general corrosion in the same solution. The relation
between stress corrosion and general corrosion is discussed.
12 references.

164. Koziol, J J; Christopher, S S

CORRELATION BETWEEN SENSITIZATION AND STRESS CORROSION CRACKING OF
300 STAINLESS STEELS.


The effect of preoxidation and variations in surface conditions on the
susceptibility to transgranular cracking of Types 304 and 347 stainless
steel were studied. Tubing with annealed, drawn, swaged and diffused
Ni surfaces was exposed to an aq. environment to evaluate the difference
in behavior of nonstabilized and stabilized types (304 & 347) of stainless
steels under identical test conditions. Tubes with swaged surfaces
(15% redn. in area) and surfaces contg. diffused Ni layers showed
improved resistance to transgranular cracking when compared with the
other samples evaluated in this program.
A trend toward increased susceptibility to transgranular cracking which was observed for proximized and sensitized Types 304 stainless steels, confirmed the possibility of interaction between grain boundary oxidation and transgranular cracking.

165. Koziol, J J; Christopher, S S

CORRELATIONS BETWEEN SENSITIZATION AND STRESS CORROSION CRACKING OF 300 SERIES STAINLESS STEELS. (Final Summary Report)

CEND-3256 82p , 1966.

166. Kuzyukov, A N et al

MECHANISM OF THE CORROSION CRACKING OF STAINLESS STEEL KH18N10T IN WATER CONTAINING CHLORINE IONS. (In Russian)


Examples of the effect of Cl ions on the corrosion of stainless steels are presented and some new tests on the corrosion cracking of KH18N10T Cr-Ni steel in water containing various concentrations of Cl ions are described. The mechanism underlying the development of cracks in steel samples immersed for prolonged periods in such solutions is discussed. The relative effects of stress and direct chemical interaction are considered. The propagation of in material affected by the form of the microstructure and the nature of the predominating structural constituent.

167. Lacombe, P

METALLURGICAL AND ELECTROCHEMICAL FACTORS OF CORROSION IN STAINLESS STEELS. (In Spanish)


The individual effects of the constituents of stainless steels on the corrosion resistance are reviewed and criteria for selecting steels for specific applications are discussed. The metallurgical structures of Fe-Ni-Cr alloys (e.g., Inconel) and the function of the more important add. elements are examd. Max. resistance to intergranular attack by HNO₃ is obtained when the C content is very low (0.02-0.04%). The presence of Si, N, and Mn affects the austenitic structure, and hence the resistance to acids and salt solns. The advantages of the Cr-Ni-Mo-Cu austenitic-ferritic steels for use in chlorides and caustic solns. under low stress conditions are pointed out. Examples are given of the electrochem. behavior of stainless steels in corrosive media. The uses of potential measurements and of the electron and optical microscope for studying intergranular pptn. are described.
Autoclave tests were conducted for an 8-month period to compare the corrosiveness and stress corrosion cracking inhibition qualities of alternate N Reactor steam generator secondary system water chemistry to that of the zero solids (hydrazine-morpholine) water treatment presently used. Seven tests with phosphate levels of 0-1000 ppm, sulfite levels of 0-100 ppm, hydrazine levels of 0-15 ppm, and morpholine levels of 2 ppm were conducted. Stress corrosion cracking of 304 stainless steel tubing obtained from an N Reactor steam generator occurred in both the liquid and vapor phases of solns. not containing phosphates, and in the vapor phase over solns. containing phosphate, but not on samples immersed in the liquid phase any soln. containing phosphate ion. Stress corrosion cracking did not occur on lots of unsensitized 304 stainless steel and 304 stainless steel heat-treated similarly to the steam generator tubing not did it occur on Inconel 600, Incoloy 800 or A212 CS. wt. losses on the stainless steel, Inconel, and Incoloy samples were negligible. Total penetration on the carbon steel after 8 months ranged from 0.02 to 0.3 mils in the various solns.

Stress corrosion cracking-in the Fe-Ni-Cr alloy system in aqueous media is reviewed. Special emphasis is given to austenitic alloys. Cracking of these alloys is reviewed critically as a function of metallurgical and-environmental variables. The various mechanisms of stress corrosion cracking are considered with respect to their applicability to this alloys system.
170. Lee, H H; Uhlig, H H

**EFFECT OF NICKEL IN Cr-Ni STAINLESS STEELS ON THE CRITICAL POTENTIAL FOR STRESS CORROSION CRACKING.**


Greater amounts of alloyed Ni in 20% Cr stainless steels improve the resistance to stress corrosion cracking in part by shifting the critical potentials to more noble values below which failures are not observed. When the critical potential for any alloy becomes more noble than the corresponding corrosion potential (> 26% Ni) the alloys are resistant to MgCl₂ at 130° for > 200 hr. Nevertheless, rapid failure of such alloys containing up to 35% Ni, and probably including 45% as well, can be induced by anodic polarization to a potential which is noble to the corresponding critical value. Gradual drift of corrosion potentials to more noble values, eventually exceeding the critical potentials, is the likely cause of stress corrosion cracking in < 45% Ni stainless steels. Above 45% Ni, structural factors at the surface or plastically deforming alloys become dominant, and failures do not occur regardless of the prevailing potential. Pure Ni is anodic to the 20% Cr-Ni stainless steels and can be used as a sacrificial anode to protect them cathodically against stress corrosion cracking. The data support the mechanism of failure based on stress sorption cracking.

171. Leistikow, S

**INVESTIGATION OF REACTOR MATERIALS AFTER CORROSION IN SUPERHEATED STEAM IN TEST CIRCUITS AND NUCLEAR REACTORS.** (In German)


In the presence of adhering or partly adhering oxide films the extent and the products of the corrosion of austenitic Cr-Ni steels and Ni-based alloys can be determined by planimetric evaluation of metallographic cross-sections after 1-200 X magnification. A complete analysis of corrosion with oxide losses should include determination of the concentration gradients of the alloy elements, e.g., by X-ray fluorescence analysis after stepwise electrolytic dissolution.

172. Logan, H L (Ed.)

**THE STRESS CORROSION OF METALS.**

INFLUENCE OF ALLOYING ELEMENTS ON THE STRESS CORROSION BEHAVIOR OF AUSTENITIC STAINLESS STEEL.


The effects of C, Mn, P, Si, Cu, Cr, Ni, Mo, Al, and N on the stress corrosion resistance of austenitic stainless steels were detd. in boiling MgCl₂ soln. P, Si, and Mo affected the stress corrosion resistance of cold-worked material, C and N the resistance of annealed material, and Ni the resistance of both. Increased amts. of C, Ni, and Si improved the stress corrosion resistance; increased amts. of Mo, P, and N decreased the resistance, and Mn, S, Cu, Cr, and Al had little or no effect. This study resulted in a steel contg. Cr 18%, Ni 18%, Si 2%, and C 0.06%, with low P and Mo contents. This steel was melted in an elec. furnace and its properties detd. Test results show that the new steel (USS 18-18-2 stainless steel) is much more resistant to stress corrosion cracking than currently available austenitic stainless steels. Also, the resistance of this steel is better than that of a Cr 20%, Ni 34% alloy that is marked for resistance to stress corrosion cracking.

AUSTENITIC STAINLESS STEELS RESISTANT TO STRESS CORROSION CRACKING.

U.S. 2,276,864 1966 (Patent)

Such steels that can be stressed safely for long periods in chloride-type environments contain only sufficient C for stable austenitic to insure good cold-forming, and low N, preferred compns. being C 0.075-0.09%, Mn 1.4-1.6, P 0.02-0.03%, S 0.01-0.02%, Si 0.4-0.6%, Ni 8-12%, Cr 17-18%, and N 0.01-0.015%. A steel contg. C 0.075%, Mn 1.5%, P 0.028%, S 0.012%, Si 0.5%, Ni 8%, Cr 17.7%, and N 0.005% quenched from 1950°F., was stressed to 75% of its yield strength in boiling 42% MgCl₂ soln. for 4500 hrs. without failure, while other Steels of similar comp. except for slightly higher Ni and Cr and 0.029-0.04% N, failed by stress corrosion cracking in 4-5 hrs. when tested similarly.

STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEEL. (Status Report - Sept. 1, 1964)

DP-957
176. Mackawa, T; Kagawa, M

EFFECT OF TEMPERATURE ON THE STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS IN HIGH TEMPERATURE SODIUM CHLORIDE SOLUTIONS.
(In Japanese)


The stress corrosion cracking of austenitic stainless steels, such as SUS 27, 28, 32 and 43, in high temp. NaCl solns. was carried out to det. the effects of temp., Cl concn. and dissolved O contents on the susceptibility. Test temp. of NaCl were 100, 150, 200, 250, 300, 325, and 350° and the concns. of Cl were 10, 50, 100, and 500 ppm. Stainless steels were dipped for 300 hrs. in the NaCl solns. under a bending stress of 20 kg./mm.². In deoxygenated solns. (~ 0.01 ppm.), no corrosion cracking was detected in any case. In oxygenated solns., pronounced cracking on SUS 27, 28, and 43 steels was detected at 150-300°, but none at 350°. The soln.-treated SUS 32 indicated no cracking in any case.

177. Mackawa, T et al

CORROSION OF STAINLESS STEELS IN HIGH-TEMPERATURE BORIC ACID SOLUTIONS. (In Japanese)

Boshoku Gijutsu 17:5, 114-19; 1968.

The corrosion behavior of austenitic stainless steels in high temp. boric acid soln. was studied. The general corrosion rate for 10,000 hrs. was 2 mg./dm.²/month at 300°. The stress corrosion cracking in NaCl soln. was diminished by the addn. of boric acid. The general corrosion rate and the stress corrosion cracking were suppressed by the addn. of a small amt. of KOH.

178. Mamcdov, E M et al

EFFECT OF HIGH-TEMPERATURE THERMOMECHANICAL TREATMENT ON THE STRUCTURE, CORROSION, AND MECHANICAL PROPERTIES OF STAINLESS STEEL, 1Kh21N3T.
(In Russian)


In a 1Kh21N3T grade stainless steel (C 0.1, Ti0.46, Cr 20.31, N 0.021, Ni 5.9%) high-temp. deformation followed by rapid quenching produces an increase in the yield strength and a better resistance to boiling 50% HNO₃.
Strip lengths, 8 mm thick, have been hot-rolled at 900, 1000, and 1100° with 10, 20, 30, and 40% redn. in area and quenched, along with specimens heated to the same temp. but not deformed. At 900 and 1000° the thermomech. treatment with a 40% deformation gives an increase of 22 and 11%, resp., in the yield strength, at 1100° in the same conditions the tensile strength rises by 17% and the yield point by 45%. Even without deformation, quenching produces high ductility: for 1100°, elongation 35% and redn. 74%. A certain improvement obsd. in the results of a 24-hr corrosion test in boiling 50% HNO₃ is connected with a more uniform Cr distribution after the thermomech. treatment, as found by electron probe anal.

179. Mannheimer, W A; Paxton, H W

SOME EFFECTS OF NITROGEN ON THE RESISTANCE TO STRESS CORROSION CRACKING OF TYPE 304 STAINLESS STEEL WIRES.


The stress corrosion cracking of nitrided 304 stainless steel was evaluated in boiling MgCl₂ environments. A significant increase in specimen lifetime is produced by nitriding in the 500-950°C range. Electrochemical measurements suggest that the mechanism for improvement due to nitriding probably results from a cathodic protection effect. 16 references.

180. Marek, M; Hochman, R F

STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEEL.

Corrosion, 26:1, 5-6; 1970.

Stress corrosion characteristics and the acidity of the solution inside a crack on 304 austenitic stainless steel were studied in boiling magnesium chloride at 154°C. Fracture surfaces were also studied by electron microscopy using replica techniques and in the scanning microscope at magnifications up to 2600 X. Results show high acidity near the crack tip and the existence of both transcrystalline and intercrystalline fractures.
181. Marshall, R P

ANALYSIS OF FAILED 17-4 PH BOLTS FROM THE HWCTR.


Analysis of five bolts of 17-4 PH stainless steel from the Heavy Water Components Test Reactor that had failed in service showed that the failures were initiated by stress corrosion. In all but one of the failed bolts, an unstable crack size was reached after very little stress corrosion causing fast crack propagation and complete failure. In one bolt, the stress corrosion crack had stopped growing. Many of the bolts, including all those that failed, were found to have been improperly heat treated to approximately the H925 condition, instead of the specified H1100 condition. The harder H925 condition is conducive to stress corrosion cracking in the alloy. No evidence for failure by fatigue was found.

182. Marshall, C W et al

CRACK PROPAGATION AT STRESSES BELOW THE FATIGUE LIMIT.


Data are given for AM-350 stainless steel and for a Ti-8Al-1Mo-IV alloy to demonstrate that an assessment of cumulative damage in fatigue must evaluate both initiation and propagation of cracks. Cracks will propagate at finite rates alternating stress levels well below those required to initiate a crack.

183. Masaki, W; Yoshihiko, M

STRESS CORROSION CRACKING OF AUSTENIC STAINLESS STEELS. II. ELECTROCHEMICAL EFFECT ON STRESS CORROSION.


Stress corrosion cracking of stainless steels under tensile stress in a boiling soln. of 42% MgCl₂ can be arrested by contact of less noble metals (Al, Fe, Cu) of suitable surface area.
184. Matsushima, I

STRESS CORROSION CRACKING FROM AN ELECTROCHEMICAL STANDPOINT.
(In Japanese).


The effects of contaminants on the corrosion cracking of metals, segregation in alloys under stress, formation of anode by corrosion reaction, electrodeposition and corrosion processes, potential change during corrosion cracking, and electrochem. studies of stress corrosion cracking are reviewed. 43 references.

185. Matsushima, I. et al

STRESS-CORROSION AND HYDROGEN CRACKING OF 17:7 (CHROMIUM-NICKEL) STAINLESS STEEL.


Stress corrosion results for 17:7 stainless steel, which although austenitic may transform to ferrite on cold rolling, indicate the importance of crystallographic structure on mode of failure. In the annealed condition 17:7 is resistant to H-cracking but susceptible to MgCl₂ test environments; after cold reduction by 20% it fails in both although only partially transformed to ferrite. In MgCl₂ soln. cracking times may be prolonged by cathodic polarization, indicating a stress corrosion mechanism. 10 references.

186. May, M.J. et al

SUBCRITICAL FLAW GROWTH.

Iron Steel Inst. (London), Publ. 114, 177-87; 1968.

The application of linear elastic fracture mechanics to the study of subcritical flaw growth by stress corrosion cracking and fatigue were studied. The factor controlling crack propagation is the stress intensity at the tip of the crack. The benefits of the fracture mechanics approach over the more conventional qual. approaches are discussed and examples are given of the effect of environment and metallurgical factors on the stress corrosion cracking limit, KISC. An indication is given of the application of this approach to design considerations involving subcrit. flaw growth. Under such conditions the crit. properties are crack-propagation characteristics of materials. Development of improved materials should be directed towards the plane strain fracture toughness, K₁C, values and lower crack growth rates.
187. McCollough, I S; Scully, J C

PITTING ATTACK ON AN AUSTENITIC STAINLESS STEEL IN SULPHURIC ACID.


A letter. The implications of 'tunnel' corrosion with regard to the propagation of stress corrosion cracks and in other situations, are considered. Simple interrupted charging experiments (H charging of stainless steel) on bulk specimens indicate that a small amount of attack is cumulative and eventually gross pitting is observed. It is suggested that funnel initiation may be a characteristic of certain metals and alloys. Electron micrographs of a thin foil of H-changed 304 steel showing pitting are illustrated and the relevance of pit formation to tunnel and crack formation is discussed. 12 references.

188. Medovar, B I et al

THE STABILITY OF AUSTENITIC, CHROMIUM-MANGANESE STEELS AND ALLOYS AGAINST CORROSION CRACKING IN CHLORIDE SOLUTIONS. (In Russian)


Specimens from steel of the type Kh14G30 contg. Ni 1-23 wt. % were tested for corrosion cracking under stress by boiling at 154° in a 42 wt. % MnCl₂. The tested steels were alloyed variously with Mo 2.5-3.35, Ti 0.23-0.3, were alloyed variously with Mo 2.5-3.35, Ti 0.23-0.3, Al 0.25-0.38, or B 0.23-0.4 wt. %. The austenitic steel 1Kh18Ni10T was used as a standard. All these metals were preliminarily heated for 1 hr. at 1100° and cooled in air. With steel 1Kh18Ni10T the cracks appeared after 24 hrs., while steels of the type Kh14-G30 contg. 8-23% Ni showed cracks after < 24 hrs. At Ni 3.66 wt. % the cracks appeared after 169 hrs., while at Ni 2.0% or Ti 0.26 and Al 0.30 wt. % improved resistance to general corrosion; however, it increased the tendency to corrosion cracking. Steel contg. < 2% Ni had an increased resistance to corrosion cracking, and the addn. of B (0.23-0.40 wt. %) made this steel still more resistant provided Mo was present (2.51 wt. %).

189. McLaughlin, B D

COMPUTER SIMULATION OF STRESS CORROSION CRACKING.

Corrosion 27:2, 84-90; 1971.


-68- Contd...
By assuming that the electrochem. oxidn. mechanism of crack propagation is not supplemented by mech. fracture or plastic deformation during the early stages of crack growth and that the equil. rate of a charge transfer half-reaction, occurring at the interface between 2 phases, is dependent upon the local surface tension at the point of reaction, it is possible to satisfactorily account for the following general aspects of stress corrosion cracking such as the existence of an incubation period, the existence of a threshold stress, the variation of incubation time with applied stress, and the variation of incubation time with overpotential.

190. Mizuno, M; Suzuki, T

STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS. III. STAINLESS STEELS IN HIGH TEMPERATURE WATER. (In Japanese)


The effect of ferrite on the stress corrosion cracking susceptibility of austenitic stainless steels, and stress corrosion cracking resistant austenitic ferrite 2 phase stainless steels, are reviewed. 18 references.

191. Moller, G E

UNDERSTANDING STRESS CORROSION CRACKING.


Stress corrosion cracking is discussed as an educational background for metallurgical and design engineers. Stress corrosion cracking is defined and its mechanism, the practical aspects, its environmental effects, its effects on various alloy metals, and preventive measures are discussed. Emphasis is placed on austenitic stainless steels.

192. Montuelle, J

STAINLESS STEELS OF HIGH PURITY. (In French)


The structure of 18-8 high purity stainless steel, prepared from zone-refined Fe and Ni, at ordinary temp. is reviewed with significant hardening by tempering. The effects of this on the corrosion behavior of the steel is reviewed with respect to stress.

- 69 -
193. Morita, S

STRESS CORROSION CRACKING OF COLD-ROLLED AUSTENITIC STAINLESS STEELS IN NaCl SOLUTION.


The effect of cold working on the stress-corrosion crack sensitivity in boiling NaCl with or without an additional oxidising agent was studied in 18-8 and 18-12 Mo steel. The transgranular corrosion cracking appeared in the specimen immersed in NaCl solutions, provided that the solution had suitable composition for cracking. Comparing 18-8 with 18-12 Mo in its crack susceptibility, in most of these solutions, the latter, containing Mo, was more resistant to the corrosion cracking, which does not occur with MgCl₂ solution. The preferential attack of locally transformed ferrite phase was not so predominant in MgCl₂ solution. The condition of corrosion environment which is apt to cause cracking in stainless steel depends on steel, as was shown in the case of pitting corrosion. In addition, the mechanism of crack initiation was discussed.

194. Morita, S

STRESS CORROSION CRACKING OF HEAT-TREATED, AUSTENITIC STAINLESS STEELS.

Nippon Kinzoku Gakkaishi 25, 675-9; 1961.

The effect of heat-treatment temp. on the susceptibility of stress corrosion cracking was studied by using a direct load app. The quant. relation between applied stress and the time to failure was obtained on annealed 18-8 in boiling 42% MgCl₂. At 400-800°, the effect of heating temp. on the susceptibility of stress corrosion was studied in boiling 42% MgCl₂ and NaCl solution. In MgCl₂ solution, the effect of heating temp. was very small and the crack occurring in this solution was always transgranular. In NaCl solution, on the contrary, the susceptibility was definitely increased by heating at 500 to 800°, and in this temp. range, the path of cracks was mainly intergranular. In NaCl solution, intergranular corrosion was scarcely observed on the surface of sensitized unloaded specimen; though the specimen under tensile stress failed by intergranular cracking. In acidified copper sulfate solution, which was known to attack sensitized specimens intergranularly without any tensile stress, the propagation of intergranular crack in the stresses specimen was much more serious than the penetration of ordinary intergranular corrosion through the surface of the specimen. The conditions causing intergranular cracking were discussed.
195. Morita, S

STRESS CORROSION CRACKING OF SENSITIZED AUSTENITIC STAINLESS STEELS.


The effect of sensitizing heat treatment on the susceptibility to cracking and crack propagation in austenitic stainless steels was studied by using U-bend specimens. In general, the stress corrosion cracks of austenitic stainless steel in chloride solution are of transcrystalline nature. However, some intergranular cracks were found in sensitized steel. In 42% MgCl₂ cracks were always transcrystalline in the sensitized specimen as well as in the annealed one, and the crack sensitivity of the steel did not increase by sensitizing treatment. Intergranular cracks appeared in some of the sensitized specimens in NaCl solution. In this case, steels were more sensitive to the stress-corrosion cracking in sensitized state than in annealed state. In extra-low-C or stabilized steels, however, the cracks were always transcrystalline regardless of the pretreatment of the specimen, and the crack sensitivity of these steels did not increase by sensitizing treatment. The c.d.-potential curves in chloride solution were observed on these steels, and the relation between the anodic polarizability of steels and the susceptibility and the path of stress corrosion was discussed. The conditions causing intergranular cracking were also discussed.

196. Nadkarni, V M

CORROSION RESISTANCE OF AUSTENITIC STAINLESS STEELS.

Bombay Technol, 18, 56-62; 1968.

A review of the resistance to corrosion of austenitic stainless steels, containing Cr-Ni ratio of 1:8. 15 references.

197. Namio, O; Terukuni, I

ON THE RELATION BETWEEN STRESS CORROSION CRACKING AND CRYSTALLOGRAPHIC ORIENTATION IN 18:8 STAINLESS STEEL. (In Japanese)


The stress corrosion behavior of 18:8 stainless steel was investigated in a 42% MgCl₂ solution. The crystallographic orientation of various in the specimen was examined. The observed cracks were classified into four groups: (i) pit-type cracks along (111) or (100) planes; (ii) Lomer-Cottrell-type cracks along the (110) plane; (iii) dislocation pile-up type cracks near grain boundaries; and (iv) cracks which were mixtures of (i), (ii), and (iii). 10 references.
198. Haumann, F K; Spies, F

FAILURE EXAMINATION: INTERCRYSTALLINE STRESS CORROSION (CAUSTIC EMBRITTLEMENT). (In German and English)


The nature of the cracks developing around rivet holes in steam boilers or brine evaporators is discussed in the light of experience gained with a variety of types of steel over a long period. Such cracks are directly associated with intercrystalline stress corrosion and this is readily confirmed by a study of their tracks after initial etching. Increasing the Al content of the steels employed aids crack resistance.

199. Nielsen, N A

STRESS CORROSION MECHANISMS.

J. Mater. 5:4, 794-892; 1970.

A review with 49 references of phenomenological stress corrosion failures in stainless steels-aq. chloride systems, the role of H as an embrittling agent, and the most recent theories of stress corrosion mechanisms.

200. Ohtani, N

CORROSION OF STAINLESS STEELS. (In Japanese)

Denki Seiko 40:2, 106-17; 1968.

A review with 19 references on the mechanism of passive state formation on stainless steels, the relation between the corrosion and the structure of metals, the role of oxide film in the passive state, intergranular corrosion, pitting corrosion, and stress corrosion cracking of stainless steels.

201. Ohtani, N; Iba, T

RELATION BETWEEN STRESS CORROSION CRACKING AND CRYSTALLOGRAPHIC ORIENTATION IN 18-8 STAINLESS STEEL. (In Japanese)


Stress corrosion cracking test of 18-8 stainless steel was carried out in a 43% MgCl₂ soln. The crystallographic orientation of various cracks in the specimen was esp. examd.

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The cracks observed are classified into 4 groups; pit type cracks along (111) or (100) planes, LC type cracks along the (110) plane based on the Lomer Cottrell barrier, dislocation pile up type cracks near grain boundaries, and mixed type cracks. At the initial stage of the test, there seem to be many pit type cracks which are related to the corrosion of grain boundaries and slip lines. On the contrary, all the types of cracks are observed in large quantities at the end of the test. Although the effect of applied stress on fracture becomes remarkable at the final stage of the test, it requires a further study as to which is more important to fracture, the tunnel formation effect by corrosion pits or the destructive effect of applied stress.

202. Okada, H et al

FORMATION OF CRACKS IN AUSTENITIC STAINLESS STEELS CATHODICALLY CHARGED WITH HYDROGEN.

Corrosion, 26:7, 183-86; 1970.

Type 304 stainless steel and vacuum-melted 20Cr-22Ni-Fe alloy were heat-treated at 1230° for 8 hr in vacuum. After cooling and electrolytic polishing, the specimens were charged with H cathodically evolved from 5% H2SO4 with 10 g Na2AsO3/l. at a c.d. of 0.5 A/cm2. Austenitic stainless steel is hardened and fine surface cracks are formed by cathodic charging. The cracks due to H form parallel to slip lines. Time-to-fracture of austenitic stainless steels is prolonged by cathodic polarization; hence stress-corrosion cracking of austenitic stainless steels is not directly attributable to H.

203. Okada, H et al

FORMATION OF TRACKS IN AUSTENITIC STAINLESS STEELS CATHODICALLY CHARGED WITH HYDROGEN.

Corrosion, 26:7, 183-86; 1970.

Experimental results indicate that austenitic stainless steel is hardened and fine cracks are formed on its surface by cathodic charging. It should be noted that the cracks due to H form lines parallel to slip. The slip planes of f.c.c. metals and alloys are (111) planes and a slip line is considered to be the trace of a slide of metal on a slip plane. Consequently, the observations were interpreted to mean that the cracks follow (111) planes. The reason why the cracks form and propagate along (111) planes is not clear. 10 references.
Recently, austenitic stainless steels are generally used to build up at. reactors. These steels can suffer stress corrosion cracking under certain conditions of stress and corrosive environment. On the other hand, the occurrence of some troubles by the stress-corrosion cracking of austenitics stainless steels under unusual conditions was reported. Exp. marine at. reactors are in danger of accelerating the occurrence of stress corrosion cracking that results from the repetition of wetting and drying of the reactor wall by cooling water which moves with the rolling of a ship. Various autoclave tests were carried out, with the following results: (1) Wetting and drying of specimens accelerates the occurrence of stress corrosion cracking. (2) Addns. of Nb and soln. treatment reduce the corrosion rate. (3) The dissolved O, chloride ions of \( \sim 5 \) ppm. in water, and surface contamination of the specimen augment the stress corrosion cracking.

The conditions of stress corrosion of austenitic stainless steels in marine atomic reactors were investigated. Various autoclave tests were carried out. Wetting and drying the specimens accelerated the occurrence of stress corrosion. Addn. of Nb and soln. heat-treatment reduced the corrosion rate, but dissolved O, chloride ions (\( \sim 5 \) ppm), and surface contamination of the specimen all increased stress corrosion.

MECHANISM FOR STRESS CORROSION CRACKING OF STAINLESS STEEL IN REACTOR SYSTEMS.

A mechanism for chloride stress corrosion cracking of Type 304 stainless steel that has been sensitised, pickled and dry ground involves the chloride-bearing $\text{Al}_2\text{O}_3$ present in the moderator-coolant system of Savannah River reactors. Chloride is absorbed by the $\text{Al}_2\text{O}_3$ during its formation on hot fuel cladding; Fe, an impurity in the cladding, greatly enhances chloride absorption. $\text{Al}_2\text{O}_3$ spalls and is transported by the coolant to the stainless steel surfaces. Chloride is released from the $\text{Al}_2\text{O}_3$ by the acidic reaction at anodic sites on the steel. The chloride ion is attracted to the positive anodic site and initiates stress corrosion cracking. Cracking of susceptible stainless steel by this mechanism can be reduced by controlling coolant pH (pD) between 5.0 and 5.2 to prevent general release of chloride, and by avoiding addn. of chlorides and chlorinated hydrocarbons to the reactor, and by blocking abodic sites by inhibitors or by changing the potential of the stainless steel.

208. Onishi, S et al

STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEEL IN HIGH TEMPERATURE WATER. (In Japanese)


Recently, austenitic stainless steel is generally used to build at. reactors. It has been reported that troubles occur from the stress corrosion cracking of austenitic stainless steel under some conditions. Specifically, in marine at. reactors there is fear that acceleration of stress corrosion cracking will result from wetting and drying of the reactor wall by cooling water according to the rolling of ships. Expts. were made on the following waters; effects of the wetting and drying of specimens; effects of the chem. compn., welding, and heat treatment of materials; and effects of the purity of water and the surface contamination of specimens.
209. Orman, S

RAPID TEST FOR STRESS CORROSION CRACKING.

Corros. Sci. 9, 849-51; 1969.

210. Overman, R F

USING RADIOACTIVE TRACERS TO STUDY CHLORIDE STRESS CORROSION CRACKING OF STAINLESS STEELS.


Radioactive-tracer techniques indicate the presence of charged areas on the surface of steel which may be created by a high concn. of small sulphide inclusions. In one charged area $7 \times 10^9$ g Cl was sufficient to initiate corrosion, and hence cracking, on a stainless steel surface stressed by grinding. 16 references.

211. Ozdemirel, N

INTERGRANULAR CORROSION IN AUSTENITIC STAINLESS STEELS AND HOW IT CAN BE AVOIDED.

Demir Celik 17:8, 256-61; 1968.

A review is presented on the mechanism of intergranular corrosion and its prevention. 3 references.

212. Phelps, E H; Mears, R B

THE EFFECT OF COMPOSITION AND STRUCTURE OF STAINLESS STEELS ON RESISTANCE TO STRESS CORROSION CRACKING.


In a study of the stress corrosion behavior of austenitic and ferritic steels in a no. of corrosive environments and including the effects of anodic and cathodic polarization, $12\%$ Cr steel with Mo and $W$ and type 410 martensitic steels and types $302$ and $304$ austenitic steels were tested; tests were effected in boiling $42\%$ MgCl$_2$ and room-temp. tests were made in a no. of Na salts aerated with air, in $3\%$ NaCl aerated with O$_2$, in $10\%$ NaCl with H$_2$O, in $10\%$ FeCl$_3$, in $3\%$ NaCl satd. with H$_2$S, and in $3\%$ NaCl with $0.5\%$ $H_2OH$ and satd. with H$_2$S during 1700 hrs. The $12\%$ Cr steel was very susceptible to cracking in a no. of the media in which the tempered 410 and annealed 304 steels were quite stable, a substantial no. of anions other than $Cl^-$ appeared capable of effecting cracking in the former steel, often in a time shorter than that required by $Cl^-$ soln. solns. near neutral of slightly acid were more prone to cause cracking.

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Polarization tests on type 302 steel appeared consistent with corrosion along an active path through the steel, while at cathodic currents 0.5 ma./in.² a H embrittlement mechanism appeared to apply; with the 12% Cr steel the results were inconclusive.

213. Poboril, P et al

STRESS CORROSION CRACKING RESISTANT AUSTENITIC STEELS. (In Czech)


In the tests carried out under const. load, stress corrosion cracking resistance is detd. in the soln. of MgCl₂ 42 and CaCl₂ 40 at 105-110°. Two 18/8 Cr Ni steels (one of them stabrillized with Ti), one Cr-Mn steel, contg. Mn 16.5, Cr 19.2, and N 0.47%, as well as 3 Mn-Cr austenitic heat-resisting steels contg. Mn 16.7-19.4 and Cr 7.5-11.1% are examd. Typical failure in the stress corrosion resistance is shown by the tests of both Cr-Ni steels. Low corrosion resistance is found in the Cr-Mn steel with the addn. of N. All Mn-Cr steels exhibit in the given condition high stress-corrosion cracking resistance. 36 references.

214. Podobaev, N I

THE MECHANISM OF DELAYING STRESS CORROSION CRACKING BY CORROSION INHIBITORS.


215. Pogodin, V P et al

INTERCEANULAR CORROSION AND CORROSION CRACKING OF STAINLESS STEELS IN AQUEOUS MEDIA. (In Russian)


Intergranular corrosion and stress corrosion behavior are reported for austenitic, ferritic and martensitic stainless steels in pure water, steam and solutions of salts, acids and alkalis. The corrosion-testing conditions include those prevailing in the water- and steam-cooled reactors, power stations and in the chemical industry. Behavior, such as media composition, composition and structure of steels, heat treatment, stresses and radiation effects. Corrosion preventive methods are reviewed, including alloying the steels with elements such as C, Ti, Nb, Ta, Cr, Ni, Mn, Mo, Si, W, V, Mn and B.
216. Pouillard, M

CORROSION OF AUSTENITIC STAINLESS STEELS UNDER TENSION.

Corrosion Anti-Corrosion II, 264-7; 1963.

The corrosion of austenitic stainless steel under tension in the presence of chlorides, Na₂S, HgS, alkalis, and pure H₂O was considered. The corrosion attack in chloride-contg. soln. is esp. strong, for which reason the temp. is kept as low as possible, and tension which reach the elastic limit of the steel must be avoided. The use of steels with 20-22% Ni and 2% Si is recommended when the action of chlorides is to be reckoned with, as well as autenitic steel with a few percent ferrite.

217. Pourbaix, M de; Huebner, W

STRESS CORROSION OF TWO STAINLESS POTENTIAL PRESSURE VESSEL STEELS WITH MIXED PHASE STRUCTURE.


218. Prazhak, M et al

THE ROLE OF ANION ADSORPTION IN THE PITTING AND CORROSION CRACKING OF METALS. (In Russian)


Potentiodynamic polarization of 99.95% Ni in 0.4N-K₂SO₄, and in NaOH solutions contg. various additions of Cl⁻ ions, was used to obtain values of the pitting potential, Eₚ. The ability of a solution to cause pitting corrosion is primarily determined by the surface concentration of the activating ion (Cl⁻) and this depends not only on its analytical concentration in the solution but also on the adsorption equilibria of all the components of the solution. The effect of the activating and passivating ions on Eₚ can be described by the use of the freundich. similar relationships cab be obtained between the concentration of passivating ions, CrO₄²⁻, and activating ions, Cl⁻ (as FeCl₃), in the pitting of 1819 Cr-Ni stainless steel. Preliminary results on the corrosion cracking of this steel in MgCl₂, and of Al-Mg alloys in NaCl of various pH values, indicate that competitive adsorption effects also have an effect in the first stage of the process. 19 references.
219. Procter, R P M; Paxton, H W

STRESS CORROSION CRACK INITIATION IN 7075-T6 SHEET IN ORGANIC LIQUIDS.


Stress corrosion failures occurred in 7075-T6 alloy U-bend specimens exposed to dry ethanol environments for up to 361 days. However, no signs of stress corrosion cracking were visible on specimens exposed to carbon tetrachloride after about 750 days.

220. Pugh, E N

THE MECHANISM (s) OF STRESS CORROSION CRACKING.


The major theories of stress corrosion are reviewed. It is concluded that a single generalized theory can be ruled out. The characteristics of stress corrosion cracking in several materials including Al alloys, brasses, mild and austenitic stainless steel, and Mg and forth.

In Al alloys the failure is considered to be mech.; brass is thought to fail in certain ammoniacal environments by the continuous formation and rupture of a brittle tarnish layer. In the latter system a second mechanism is also operative, probably mostly chem. in nature.

86 references.

221. Rhodes, P R

MECHANISM OF CHLORIDE STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS.


Electrochem. studies were made in aq. LiCl, MgCl₂, and MgBr₂ solns. and in ZnCl₂/KCl molten salt to clarify the corrosion reactions related to stress corrosion cracking (SCC) of austenitic stainless steel and better to define environmental variables crit. to chloride SCC. Type 304 stainless steel electrodes were used, and complementary SCC was ob. in concd. MgBr₂ solns. H₂O must be present in the electrolyte; SCC did not occur in dry molten ZnCl₂/KCl. H evolution from corroding specimens may be facilitated by anodic polarization. Present studies do not support a model equating crack propagation with stress-assisted anodic dissoln. H evolution occurs at the crack tip and this is a crit. precursor to crack initiation and propagation. A model of SCC requiring H evolution at the crack tip is proposed, with emphasis on the effect of anodic reactions within the crack in maintaining high acidity near the crack tip. Recent publications suggest that the role of evolved H in SCC may be related to formation of H induced martensitic platelets along paths of crack propagation.
222. Rideout, S. P.

STRESS CORROSION CRACKING OF TYPE 304 (18-8) STAINLESS STEEL IN HIGH-PURITY HEAVY WATER.


Laboratory tests, duplicating heavy-water reactor moderator experience with stainless steel outlet nozzles, demonstrated that Type 304, 18-8 Cr-Ni, stainless steel sensitized and pickled in HNO₃-HF is extremely susceptible to stress-corrosion cracking in water with a very low Cl-ion concn. Stress corrosion cracking may be caused, if grain-boundary pickling crevices are present, at concn. of Cl⁻ below the ppm level though the time to initiation may be years. 37 references.

223. Robinson, J. D; Crackrell, A

AVOIDANCE OF STRESS CORROSION CRACKING IN HEAT EXCHANGERS.

Brit. 1,132,014 1968 (Patent)

The formation of gas or vapor bubbles and thus stress corrosion cracking in heat exchangers made of austenitic stainless steel coupon Ni ≤ 45 and other elements 20-8% is eliminated by submitting the coolant to a pressure higher than its vapor pressure at the highest operating temp. The concn. of the corrodant impurities esp. Cl⁻ and NaOH should be ≤ 10 ppm./impurity. The corrosion inhibitor concn. (Na₃PO₄) should be ~5 times the coolant ion concn. Stress corrosion cracking of British Standard Specification 3605 14 steel is prevented for long periods by submitting the cooling H₂O contg. 30 ppm. Na₃PO₄ and operating at 120-150° to a pressure of 400 psig.

224. Ronquist, A

THE EFFECT OF ORDERING AND STACKING-FAULT ENERGY ON THE SENSITIVITY TO STRESS-CORROSION CRACKING.


The correlation between susceptibility to stress corrosion cracking and properties of the metal such as stacking-fault energy and ordering are discussed. Detailed consideration is given to problems associated with the measured of the stacking-fault energy using the node technique. Results show that there is a great uncertainty in node measurements and therefore considerable doubt as to the significance of correlations among alloys.
The suggestion is made that correlations of stress corrosion susceptibility only with facts associated with deformation processes may be insufficient to specify the cracking susceptibility. Special attention should be given to the combined effects of complex forming tendencies of the environment together with factors affecting deformation processes. 29 references.

225. Ronnquist, A

STRESS CORROSION IN METAL ALLOYS. (In Sweden)
A review of exptl. techniques and proposed theories. 51 references.

226. Roy, A et al

CORROSION CRACKING OF STAINLESS STEEL VESSELS OF AN AIR LIQUEFACTION PLANT.
Technology 5:1, 45-9; 1968.
Investigations were made by x-ray diffraction, thermomagnetic and electron microscopic techniques on samples collected from the leakage points of an air liquefaction plant. In each case the following three regions were chosen for examn.: weldmet, material adjacent to the weld, and parent metal far away from the weld. The x-ray diffraction photographs of the parent metal far away from the weld, of all samples, showed austenite as the only crystal phase. But, the diffraction photographs of filing dusts collected from the material adjacent to the weld and weldmets revealed small amounts of ferrite along with the austenite. The photographs also indicated lattice strain which was increasing from the parent metal towards the weldmets. Thermomagnetic anal. corroborated the findings of the x-ray diffraction anal. Results showed that cracking of stainless steel vessels was due to stress corrosion caused by residual stresses and chloride environments.

227. Royuela, J J

STRESS CORROSION (In Spanish)
The factors involved in the chem. and electrochem. corrosion of steel reinforcement and the resulting effects on structures are discussed.
Portland and alumina cements behave differently in this respect. The addition of CaCl₂ as a hardening accelerator increases the probability of attack. Cases of corrosion resulting from design and construction faults are also described. The difficulties of establishing standards and methods of test are examined, and practical recommendations are made. Direct protection is afforded by coatings or inhibitors. Indirect protection is obtained by good practice ensuring that the concrete is uniform and homogeneous. CaCl₂ should not be used, and the mixing water should be free from sal. salts.

228. Royuela, J J

THE EFFECT OF ELECTROCHEMICAL POTENTIAL ON THE STRESS CORROSION OF IRON-NICKEL-CHROMIUM ALLOYS. (In Spanish)


15 Commercial stainless steels and 50 high-purity Fe-Ni-Cr alloys were stressed in boiling MgCl₂ solution and potential/time curves obtained. In some tests a constant potential was applied. Pure alloys were found to be more resistant than the equivalent commercial alloys; Ni improved corrosion resistance but Mn, Cr, Mo, Nb and C had an adverse effect. Conditions for the cathodic protection of different alloys were established. 23 references.

229. Royuela, J J

STRESS CORROSION OF IRON NICKEL CHROMIUM ALLOYS AND VARIATION AND INFLUENCE OF ELECTROCHEMICAL POTENTIAL ON THESE TESTS. (In Spanish)


A stress corrosion study was made of a series of stainless steels and alloys (Fe and Ni 5-65%; Fe-5Cr; Fe, Ni 5-30%, and 5-40% Cr). The tests were made in 4% boiling MgCl₂. The variation and effect of the electrochemical potential were measured. Special alloys were more corrosion resistant than commercial ones of similar Ni and Cr contents. The detrimental effects of C, Mn, and Nb was noted in the 18/8 steel. Ni increases the stress corrosion resistance while Cr reduces it. In alloys where Ni was wholly or partially substituted by Mn the time to failure was considerably less. Time and type of failure were derived from the initial part of the potential-time curves. These can be used also for considering the possibility of cathodic protection for the material.
230. Ryabchenkov, A V; Gerasimov, V I

THE EFFECTS OF NITROGEN, PHOSPHORUS, AND SULPHUR ON THE RESISTANCE OF CHROMIUM-NICKEL-AUSTENITIC STEELS TO CORROSION CRACKING. (In Russian)

Zashchita Metallov, 6:2, 134-144; 1970.

The austenitic Cr-Ni-Fc alloys of type Kh20N46B have a high resistance to corrosion cracking in various environments; with a view to using steels of lower Ni content, the effect of N, P, and S on the resistance to this form of attack was studied in steels of lower Ni content e.g. in 0Kh20N35B prepared by open-hearth or vacuum methods. Tests were made in (i) boiling 42% MgCl₂ (154°C), (ii) 25% NaCl-0.5% K₂Cr₂O₇ at 200°C and 16 atm. in autoclaves, and (iii) aqueous solutions contg.) Cl 200-0 0.3-6. 0 mg/l. at 320°C and 115 atm. in autoclaves. The tendency of this 35% Ni steel to corrosion cracking is increased by N, and particularly P, and these should < 0.03 and < 0.01%, resp., with N + P < 0.035% for open-hearth and < 0.05% for vacuum steels. Steels contg. Ni < 30% are susceptible to corrosion cracking even with very low N + P contents. S has little effect on the susceptibility to corrosion cracking and the usual industrial permitted level of S 0.02% does not intensity the attack irrespective of the Ni content with either stabilized or unstabilized steels. The effects of N and P on the resistance to stress corrosion are apparently connected with ordering which leads to changes in the dislocation structure and to the appearance of electrochemical heterogeneities that promote the initiation and development of corrosion crack nuclei.

231. Ryabchenkov, A V; Gerasimov, V I

THE EFFECT OF ALLOYING ON THE RESISTANCE OF AUSTENITIC STEELS TO CORROSION CRACKING IN CONCENTRATED SOLUTIONS OF CHLORIDES. (In Russian)

Zashchita Metallov, 1 (1), 48-54; 1965.

Tests were made in a soln. of 25% NaCl + 0.5% K₂Cr₂O₇ at 200°C and 16 atm. and in boiling 42% MgCl₂. After 2.5, 15, 25, 50, 100, 150, 200, 300, and 500 hrs., observations were made with a loupe (7 X); the criterion was the appearance of cracks. The resistance of Cr-Ni and Cr-Ni-Mn steels to corrosion cracking increases with increasing Ni content; at ~ 45% Ni the steel is not prone to corrosion cracking. Mn and Mo show a neg. effect on the resistance of high-Ni steels. Under a tension of 53.7-55.0 kg/mm², obtain stability in the long run (500 hrs.) in boiling 42% MgCl₂ solns. Steels with lower Ni content show nearly the same limit for the long-run resistance as steel.
The effect of preliminary corrosion under stress in a boiling 42% MgCl₂ soln. on the fatigue strength of Kh18Ni10T and Kh18N45B steels (in the open) was investigated. In the case of Kh18Ni10T, the preliminary corrosion, under these conditions, leads, after 1-5 hrs., to a marked decrease in the steel fatigue strength owing to the formation of submicroscopic corrosion slots and corrosion microfissures. This effect was not observed with Kh18N45B due to its remarkable resistance to stress corrosion cracking.

Experiments with three types of austenitic steels (Kh18N9Ti and 15-13-3Ti) of different susceptibilities to stress corrosion, showed that the effect of stress destroys the protective oxide film and causes electrode potentials to become less noble by 30-80 mv. In stress corrosion, a stable potential difference between separate micro-areas is set up and is the main cause of corrosion cracking. The role of stresses in corrosion cracking is discussed and defined.
235. Sandoz, G et al

SOLUTION CHEMISTRY WITHIN STRESS CORROSION CRACKS IN ALLOY STEELS.


Measurements were made of pH and metal ion concns. in the soln. within stress corrosion cracks in various research steels including 0.45% C, 0.29% C + 5.8% Ni, 0.28% C + 11.6% Ni, 0.32% C + 5.5% Mn, and 0.31% C + 1.9% Mo steels and com. steels including AISI type 4340, 17-4 PH, 13 Cr-8 Ni-Mo, 9 Ni-4 Co-0.2 C, 12 Ni-5 Cr-3 Mo, and 18 Ni, the latter 2 being of the maraging type. Cracking was effected by stressing under 3.5% NaCl, pH 6.0, and 25°. In addn. to the use of indicator-impregnated filter paper for estg. pH and detecting Fe2+ and Fe3+ ions, quant. chem. techniques were developed to det. the wt. and hence the proportion of metal ions in soln. All steels tested developed a pH of 3.7 in the soln. near the stress corrosion crack tip; Fe2+ and Fe3+ ions were in doubt due to access of O2 during anal. processing; the other data suggests a very low Fe3+ concn. within the crack. Alloying elements in the steels were found in the soln. near the crack tip in approx. the same proportions as in the original steel compn. Preferential dissoln. of Mn was found due to the crack tending to run through Mn-rich areas. The data suggest a predominant role of hydrolysis of Fe ions in detg. the acidity of the soln. in the crack with alloying elements having little effect. Active metallic surface in the crack is anodic. Crack acidity appeared independent of bulk pH.

236. Santis, R De; Casarini, G

THE CORROSION OF AUSTENITIC STAINLESS STEELS. (In Italian)


Details are given of corrosion failures of stainless steels in different environments. Examples include: intercrystalline corrosion in the heat-affected zones near welds and the selection of materials and heat treatments to minimise this; pitting corrosion in the presence of Cl, Br, and S2O5, and the beneficial effects of Mo additions in relation to pitting corrosion; and stress corrosion in tubes and pressings and the improvement of stress corrosion-resistance obtainable with increased Nb content. 22 references.
237. Saxena, M N

MECHANISM OF STRESS CORROSION CRACKING IN AUSTENITIC STAINLESS STEELS.


238. Saxena, M N; Dodd, R A

TRANSGRANULAR STRESS CORROSION CRACKING MECHANISMS IN HIGH-PURITY AUSTENITIC STAINLESS STEELS.


A study of small quantities of quaternary alloying materials on transgranular stress corrosion cracking of high-purity 20% Cr-20% Ni austenitic stainless steel has been made. Of particular effectiveness in promoting stress corrosion is Mo with a max. effect at a concn. of \( \approx 1.5\% \). It has a similar but less marked effect. On the other hand the addn. of 20% Cu markedly diminishes cracking susceptibility. It is thought that Mo will reduce diffusion rates while Cu will enhance diffusion rates and promote rapid recession at stress corrosion sites. The addn. of Cu some what counteracts the crack inducing tendency of Mo. Ultrapure alloys were induction-melted in magnesia crucibles in a He atm. More impure C-bearing compn. were arc-melted. Samples were rolled into sheets and cut into strips homogenized in sealed Vycorcapsules at 1000\(^\circ\)C, and water quenched. They were then exposed to boiling MgCl\(_2\) (42%) in the absence of cathodic protection while strained in tension to 3% extension. Time to complete fracture was recorded. 50 references.

239. Saxena, M N; Mishra, M S

STRESS CORROSION CRACKING.


Stress corrosion cracking is briefly reviewed and crack initiation and propagation are discussed in outline. 10 references.
240. Scully, J C

ELECTROCHEMICAL PARAMETERS OF STRESS CORROSION CRACKING.


Detailed considerations is given to the effect of failure to passivate at a slip step produced at the tip of a transgranular stress corrosion crack in relation to the effect of selective demudation of the protective species in the environment around the step; the speed of slip step formation is assumed const. and the arguments apply to an alloy with a propagating crack of a certain depth and width at a fixed temp. and for a given grain size. Aspects discussed in detail include repassivation, ionic strength, anodic polarization, addn. of solute elements, etc.; reference is made to austenitic stainless steels in halide media, to Ti in Cl\textsuperscript{-} media, etc.

Repassivation considerations can be useful and tunnel corrosion in susceptible alloys is also significant, particularly as regards the role of the anion; in the latter case, solute segregation within the slip plane along which attack proceeds is important. The environment provides an active surface by preventing repassivation and by causing film breakdown initially. Tunnel corrosion can appear in SO\textsubscript{2}\textsuperscript{-} solns. with cathodically charged foils of 18 Cr-8% Ni stainless steel, allowed subsequently to repassivate by switching off the charging current; under stress-corrosion conditions, tunnel corrosion will not be found in SO\textsubscript{2}\textsuperscript{-} solns. because repassivation occurs on the emergent step too rapidly. Addnl. factors of importance include metallurgical condition, local galvanic couples, pptn. of inoel. Cl\textsuperscript{-} salts, cathodic depolarizers acting at morepoble potentials than the O electrode, plating out of noble cations, etc.; these may all promote cracking in dil. Cl\textsuperscript{-} media which might otherwise be considered safe. In other media, these factors may also be detrimental. 38 references.

241. Scully, J C

THE ROLE OF YIELDING IN STRESS CORROSION CRACKING.


Electron metallography shows that dislocations are preferentially attached during the stress-corrosion cracking of 18Cr-8Ni steels and Ti alloys. This highly localized attack is found only on alloys susceptible to cracking. On nonsusceptible alloys such attack is random and widespread. It is characteristic of susceptible alloys that dislocations form long planar arrays. The main effect of the corrosive medium is to release this pile-up and the subsequent rapid attack on dislocations moving along a slip plane represents the propagation of the stress corrosion crack.
The role of yielding in producing moving dislocations of such pronounced chem. reactivity is considered in detail. Yielding in alloys that do not readily cross slip causes considerable shear strain which prevents the formation of a protective film at the tip of a crack, promotes electrochem. reactions by reacting turbulent conditions near the tip and by causing segregational effects within the alloy lattice, and it may also increase the aggressiveness of the corrodent through preferential adsorption on newly created slip steps. 16 references.

242. Shimose, T et al

STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS IN CHLORIDE SOLUTIONS.


An investigation was carried out on the effects of stress, chloride concn., temp., and O on the stress corrosion cracking behavior of 18-8 and 18-13 Mo steels. Tests were made in the autoclave with chloride ion concn. varying from zero to 300,000 ppm. at 130° to 250°. The susceptibility for stress corrosion cracking increased with the increase in chloride concn. and (or) temp. The addn. of O to the autoclave promoted the tendency to stress corrosion cracking, at 180° the 18-8 steel cracked at 300 ppm. chloride ion concn. in the liquid phase and at 10 ppm. in the vapor phase. These results suggest the presence of definite threshold stresses for the stress corrosion cracking which depend on the chem. compn. and corrosion environments, such as temp., and chloride ion and 0 concns. In dil. chloride solns. all cracks originated in pits formed in both the vapor and the liquid phases. Complete exclusion of O eliminated the occurrence of stress corrosion cracking as well as pitting corrosion.

243. Shively, J H et al

CREEP UNDER HIGH HEAT PLUX AND STRESS RUPTURE PROPERTIES OF AUSTENITIC STAINLESS STEELS IN ELEVATED-TEMPERATURE SODIUM?

ANL-7520 (Pt.1) pp. 74-92.
244. Shreir, L L

REVIEW OF ELECTROCHEMICAL METHODS FOR STUDYING HYDROGEN EMBRITTLEMENT AND STRESS CORROSION CRACKING. (In German)


The features common to or different for both the H embrittlement and stress corrosion cracking, the electrochem. methods for studying H embrittlement, the methods for studying the contents and the states of H in the metals, and the internal stresses due to H are reviewed. The H absorption is regarded as a side reaction accompanying the overall reaction. Stress corrosion cracking is the joint action of mech. and chem. processes.

245. Shreir, L L

REVIEW OF ELECTROCHEMICAL METHODS OF STUDYING HYDROGEN EMBRITTLEMENT AND STRESS CORROSION CRACKING. (In German)


Apparatus and methods for the study of these processes are described. The similar and dissimilar features of the two types of failure are discussed. H absorption can be regarded as a side reaction, the reaction conditions and the structure of the metal are the main factors. Methods for investigating the amounts and state of H and internal stresses which are developed are reviewed. Stress corrosion cracking results from a combination of chemical and mechanical processes in the case of martensitic steels. 73 references.

246. Shustova, Z F et al

TENDENCY OF HIGH STRENGTH CHROMIUM NICKEL STAINLESS STEEL 1Kh16N4B (EF 56) (Weida) TOWARDS CORROSION CRACKING. (In Russian)


The tendency of welds in high-strength Cr-Ni steel 1Kh16N4B to suffer corrosion cracking was studied in relation to the form of heat treatment applied and the other mechanical characteristics of the original material. Welds in samples tempered at 300-600°C (UTS 100 kg/mm²) suffered no stress corrosion. Welds in samples tempered at lower temp. or not tempered at all (UTS 120 kg/mm²) suffered severe stress corrosion although this effect was reduced on heat-treating at 600°C.
247. Shuvalov, V A et al

EFFECT OF THE SURFACE TREATMENT OF AUSTENITIC STAINLESS STEEL Khi8N10T ON ITS RESISTANCE TO CORROSION CRACKING. (In Russian)


The effect of surface treatment (shot or sand blasting) on the resistance of austenitic stainless steel Khi8N10T to corrosion-cracking in a boiling solution of MgCl₂-FeCl₃ was studied. Surface treatment increased the corrosion-cracking resistance of all samples, whether in the stressed state or otherwise; the best effect was obtained by using a jet of fine sand (grain size 0.01-0.1 mm). Subsequent working of the samples tended to reduce this beneficial effect. 8 references.

248. Shuvalov, V A et al

EFFECT OF THE SURFACE TREATMENT OF AUSTENITIC STAINLESS STEEL Khi8N10T ON ITS RESISTANCE TO STRESS CORROSION CRACKING. (In Russian)


Austenitic steel type 18-8 is widely used but under certain conditions it suffers from corrosion cracking. A study was made of the effect of surface treatment of this steel on its resistance to corrosion cracking; as the quality of surface finish improves the rate of corrosion decreases, both for preliminary cold formed and stressed specimens. Best results were obtained with fine sand (0.015-0.15). Deformation of the sand-blasted metal sharply reduces the corrosion cracking resistance which is attributed to disturbance of the process continuity. The film obtained during heat treatment (stabilizing annealing at 870° for 3 hrs.) of steel 18-8 has a marked effect on the resistance. Data shown indicate that films developed on these steels when stabilizing in any of the media investigated, except air, increase the time before cracking.

249. Shuvalov, V A; Gerasimov, V V

STRESS CORROSION OF STAINLESS STEELS IN AERATED STEAM.

EFFECT OF HEAT TREATMENT ON THE RESISTANCE TO CORROSION CRACKING OF PIPES MADE OF STEEL 1Kh18N12M2T.


Seamless and welded pipes of stainless steels 1Kh18N9T and Kh18N12М2Т, which are subject to considerable tensile stresses in use, are very susceptible to corrosion cracking in chloride solns. In alk. media (concs. NaOH) they are less susceptible. Cracking is transcryst Stabilizing annealing of seamless 1Kh18N9T and Kh18N12М2Т pipes and welded 1Kh18N9T pipes at 920° for > 2 hrs. followed by cooling in the air prevents corrosion cracking in 42% MgCl₂ and concd. NaOH at 200°. Use of pipes made of these steels in chloride solns. is not recommended since, after a stabilizing anneal, they are subject to considerable local corrosion and corrosion cracking in these solns. Stabilizing annealing at 920° and quenching of seamless pipes of these steels is recommended for most corrosive media, esp. media causing corrosion cracking of stressed metal. From Ref. Zh., Khim. Abstr. No.6(20). 1963.

THE INFLUENCE OF THE CHEMICAL COMPOSITION AND STRUCTURE OF STAINLESS STEELS ON THEIR CORROSION RESISTANCE IN AGGRESSIVE MEDIA.


Studies of the conditions leading to intercrystalline structural-selective corrosion and corrosion cracking of austenitic, austenitic-ferritic, and austenitic-martensitic stainless steels, are discussed with ref. to these corrosion modes. All three types of steel are susceptible to intercrystalline corrosion under certain conditions; the ferritic stainless steels are most subject to structural selective corrosion and are also susceptible to corrosion cracking. Examples of corrosion cracking of high-alloy Cr-Ni steel in H₂SO₄ solutions are reported. 10 references.
252. Shvarts, C L et al

EFFECTS OF THE CHEMICAL COMPOSITION AND STRUCTURE OF STAINLESS STEELS ON THEIR CORROSION RESISTANCE IN AGGRESSIVE MEDIA. (in Russian)


The intercryst. and structure-selective corrosion as well as the corrosion cracks of austenitic, austenitic-ferritic, and austenitic-martensitic steels are discussed. Austenitic-ferritic steels are most often affected by the structure-selective corrosion. Contrary to literature data, the corrosive cracking of austenitic-ferritic steel was noted in 42% MgCl₂ at 132° and in boiling ZnCl₂ soln. (sp. gr. 1.04) in the presence of stresses corresponding to both the elastic and plastic deformation. Metallographic studies revealed that the fissures run between the austenite and ferrite grains as well as through them. Austenitic-martensitic steels are more crack-resistant. In Kh18N10T steel the cracks appear after 100-200 hrs. of testing in 42% MgCl₂, while in Kh15N9Yu steel, the cracks do not appear, even after 4000 hrs. of testing. The resistance of Cr-Ni steels corrosion cracking increases with increase of the Ni content in the steel. In 42% MgCl₂ at 142°, the cracks formed in 0Kh23N28M3DT steel only after 2250 hrs.

253. Sidorov, V P; Ryabchenkov, A V

EFFECT OF CERTAIN FACTORS ON CORROSION CRACKING OF AUSTENITIC BOILER STEELS.


254. Slunder, C J

STRESS CORROSION CRACKING OF HIGH STRENGTH STAINLESS STEELS IN ATMOSPHERIC ENVIRONMENTS.


The stainless steels include the cold-rolled austenitics (USS 12 MoY), the martensitic grades (17-4pH and stainless W), the martensitic pph-hardenable grades (17-4pH, pH 15-7 Mo, AM 350 and 355), and the semi-austenitic pph-hardenable grades (AISI 301, 201, and 202, USS Tenelon, and USS 17-5). Exposure were in the marine atm. at Kure Beach, outdoors at several semi-industrial locations, and in several lab. test environment and mech. properties of the test materials are included.
Intergranular stress corrosion cracking of austenitic Cr-Ni steels is described, and effect of the steel compn. and structure, surface prepn., soln. compn., electrode potentials, and stresses on this phenomenon are discussed. Mechanism of the cracking is outlined. 12 references.

256. Smith, H R et al

STUDY OF STRESS CORROSION CRACKING BY WEDGE-FORCE LOADING.


257. Smith, T J; Stachle, R W

MICROTOPOLOGY OF STRESS CORROSION CRACKING (OF IRON-NICKEL-CHROMIUM ALLOYS).

COO-1319-36, 14p.

Fe-Ni-Cr alloy thin films were examined in the electron microscope before and after exposure to boiling MgCl₂. Alloy compns. were Fe-15% Ni-20% Cr; Fe-15% Ni-20% Cr-0.1% Si; Fe-15% Ni-20% Cr-0.1% N; and Fe-45% Ni-20% Cr (all at.-%). Each alloy was treated to obtain structures in the annealed, strained and aged condition. Examination of specimens exposed to boiling MgCl₂ showed that stress exerts an important influence on the mode of cracking. In the absence of stress, attack tended to take the form of pitting. With stress, the attack was highly oriented with the pitting aligned in parallel crystallographic directions. The alloy compr. P exhibited pitting with definite geometric shapes. Defect structure in the thin film appeared to have little correlation with established trends in cracking susceptibility or with the mode of dissoln. of thin films. 14 references.
Thin films of austenitic steels containing at. % Fe+15 + 20 Cr, Fe + 15 Ni + 1.5 Si, Fe +15 Ni + 20 Cr + 0.1 P, and Fe +15 Ni + 20 Cr were examined by electron microscopy. The samples were subjected to various treatments: annealed at 1090° for 2 min., annealed and 5% strained, annealed, strained, and aged at 870° during 1 hr. Following microscopic observations, the samples were exposed to corrosion in conventional boiling 42% MgCl₂ sols., and reexamined. The structure of all alloys containing 15% Ni was similar, regardless of the presence or absence of P and Si. The micrographs of the alloys after annealing, straining, aging, and corrosion testing are juxtaposed. Stress alters the dissolution pattern: random pitting is transformed to highly oriented arrays. The presence or absence of dislocations owing to different pretreatments affects dissolution only slightly. Dissolution activity of the P-containing alloy was much more intense, whereas all other steels corroded more or less in a similar way. The possible mechanism of stress-corrosion cracking is considered in view of the experimental evidence. Evidence for a Bond-type mechanism requiring the propagation of cracks in a strained metal through alternating embrittlement and destruction effects rather poor. No similar patterns were observed. A mechanism involving passive film breakdown, followed by rapid metal dissolution, explains better the experimental facts and is in agreement with previous concepts. The mechanism may be applicable, but experimental evidence is still inadequate. The corrosion pattern is in agreement with a tunnel model which presumes that the highly oriented arrays of pits correspond to linearly aligned tunnels. The origin and propagation mechanism of these tunnels is not yet clarified. Dislocations, however, are not responsible, and the existence of an unknown dissolution process is presumed. Electrochemical criteria offer a better explanation of stress-corrosion cracking than a stack fault approach.

Stress corrosion experiments were carried out on the Nb stabilized austenitic steel X 10 CrNiNb 18 9, in various conditions of MgCl₂ at various temps. with externally applied current, potentiostatically at the "rube" potential by anodic polarization, and mech. tests such as expansion measurements, creep curves, and metallographic investigations. Transcryst. stress corrosion cracking in chloride.
is a more unequal, weak, localized kind of corrosion as compared with the transcryst. fatigue corrosion of the same steel under passifying action in chloride-free reducing action. In fatigue corrosion, in a wide range of expth. conditions, only a single crack occurs, at the place where cyclic stresses cause slip of sufficient height to break through the surface. The mechanism of stress corrosion cracking in the range of and above the 0.2% elastic limit differs in the occurrence of spreading slip plane slipage, with increasing difficulty in restoring the passive slip by a redox reaction. Chloride ions penetrate to the slip plane, making repassivation of the surfaces even more difficult. These displacements lead to nearby slip plane displacement and the formation of submicroscopic notches, which finally reach macroscopic size. Pits are formed, and cracks radiate from the surface of the pit. These displacements do not occur when the stresses are clearly under the 0.2% elastic limit or when the austenitic steel is cold hardened.

260. Stachlé, R W

CIRCULATING AUTOCLAVE SYSTEM FOR STRESS CORROSION CRACKING STUDIES.


A circulating autoclave system was constructed and operated in which time to breaking can be detd. exactly at 700°F., pressure 5000 psi., a wide range of stresses, various concns. of dissolved gases and ionic species, and for a large no. of specimens exposed simultaneously. Com. and specially melted Fe-Ni-Cr alloys were studied in preliminary expts. Results confirmed established trends for the effects of environment and alloy compn. at 500°F.

261. Stachlé, R W

COMMENTS ON THE HISTORY, ENGINEERING AND SCIENCE OF STRESS CORROSION CRACKING.


Some of the critical issues in the engineering implications of stress corrosion cracking include: incorporation of stress corrosion data in mechanical design, terminology and nomenclature, correlations with liquid-metal embrittlement, testing and general education. Important concepts in mechanistic considerations are reviewed. The possibility of evolving a general mechanism is discounted. 35 references.
262. Staehle, R W

EFFECTS OF FABRICATION AND PROCESSING ON STRESS CORROSION CRACKING OF IRON-NICKEL-CHROMIUM ALLOYS.


Stress corrosion cracking of austenitic Fe-Ni-Cr alloys is reviewed with respect to the effects of fabrication and processing on the incidence of failure. Various alloy-environment systems in which cracking occurs are summarized. Features of the phys. environment are considered in relation to their tendency to accelerated stress corrosion cracking. The effects of manuf. processes, e.g., cold deformation, surface roughness, tamination, heat treatment, and welding are considered.

263. Staehle, R W

MONTAGE OF PROCESSES OPERATING DURING STRESS CORROSION CRACKING.


A chart is shown for the processes operating in environment and within metal which are significant in the mechanistic interpretation of stress-corrosion cracking. This chart does not show all possible phenomena. Certain process may be more important during initiation than during propagation. This figure should indicate the questionable basis for interpretations based on only a single method of analysis such as activation energy 'plots', nucleation and growth, incubation times, propagation rates, observation of phenomena in thin foils by the electron microscope, or electrochem., evaluation of relatively large surface areas. Several of these methods must be used in concert.

264. Staehle, R W

STEEL IN THE CHEMICAL INDUSTRY: FOURTH ECSC CONGRESS. II.-CURRENT STATUS OF STRESS CORROSION CRACKING OF SINGLE PHASE IRON-CHROMIUM-NICKEL ALLOYS.


The various environments which are particularly likely to cause cracking in Fe-Cr-Ni alloys are discussed. The phenomenological aspects of cracking are outlined including dislocation coalescence, lattice disarray, adsorption-induced crack propagation, film rupture, slit-step enrichment, and intergranular mechanisms.

- 96 -
The austenitic Fe-Ni-Cr alloys are characterized by a high toughness, a stress strain curve with no yield point and very high strength after cold working. They are susceptible to stress corrosion cracking, as shown by a stainless steel bellows exposed to steam containing chloride and O₂ in the environment, the pressure of impurities such as N₂, P, Pt elements, C, Si and Al and the existence of a two-phase structure of austenite plus ferrite. The essential feature of the stress corrosion mechanism appears to involve a slip-slip dissolution mechanism.

Stress corrosion cracking experiments are reported in dilute chloride environments at 500°F and in boiling MgCl₂ environments. Data are reported in terms of % unbroken vs time. Studies show that various surface preparations greatly affect mean cracking times and can cause significant differences in data scatter. A study of the effect of alloy composition on annealing twin frequency was completed and final results show generally that increasing the Ni and Cr increases the frequency of annealing twins. Results are reported from a study of tensile properties as a function of temperature and alloy composition. A potentiokinetic polarization study was completed for the ternary Fe-Cr-Ni alloy system and results are summarized graphically. Figures presenting concepts in the theory of stress corrosion cracking are included.
268. Staehle, R.W


Reported are results from circulating autoclave studies, optical metallography, polarization studies in boiling MgCl₂, true stress true-strain studies, and dynamic straining experiments conducted in solution at selected potentials. A significant result from the circulating autoclave studies shows that the cracking rate of stainless steel below 150°F is greatly reduced.

269. Staehle, R.W


Additional analysis of effects of surface preparation on time-to-cracking in boiling MgCl₂ shows that the average time-to-breaking can be directly correlated with the potential-time behavior as measured on open circuit. Other analysis of the same data shows that the data fit log-normal distribution. Transient dissolution studies show that the breakdown of passivity by mechanically produced slip steps does not repassivate nearly as rapidly as chemically (addition of high chloride) broken passivity. Stress-strain studies of nickel single crystals showed that dissolution occurring simultaneously with flow lowers the yield point significantly compared with a flow curve determined in air. Results of thin foil examination continued to show the formation of slip step dissolution patterns in a wide variety of compositions. An extensive strain hardening study was completed and calculated values for the strain hardening parameters are reported.

770. Staehle, R.W


271. Staehle, R W


272. Staehle, R W


Results of circulating autoclave tests are reported along with those from transient dissolution studies, and experiments define the effects of nitrogen addition on the stress corrosion cracking behavior. Circulating autoclave autoclave studies were conducted at 200°C in 10 ppm Cl⁻ + 10 ppm O₂. Specimens failed both by localized pitting depending on the alloy composition. A review of the literature on the subject of transient dissolution has been completed and is included. The applicability to the present state of the art is evaluated. Nitrogen additions are shown to promote the formation of protective film.

273. Staehle, R W et al

EFFECT OF ALLOY COMPOSITION ON STRESS CORROSION CRACKING OF Fe-Cr-Ni BASE ALLOYS.

Corrosion, 26:11, 451-86; 1970.

The behavior of Fe-Cr-Ni base alloys was studied in boiling MgCl₂ solutions. The primary experimental measurements were time-to-breaking of wire specimens, addition, polarization, potential-time, current decay, constant potential cracking and metallographic studies were conducted. Alloys with very substantial improvement in resistance to cracking were found. The most effective alloy additions were found to be Al, Be and O; Lowering Cr to the 10-15% range was also found to be very effective in preventing cracking. The results are discussed in terms of the slip-step dissolution model of stress corrosion cracking. 19 references.
Stress corrosion in stainless steels is caused by chlorides and the time-to-failure of an Fe-Ni-Cr wire in a boiling solution of 42% MgCl₂ illustrates this. The origin of Cl ions on the surface of the metal is discussed and the mechanism of stress corrosion cracking is briefly outlined. Important parameters are Cl-content, temp., composition of the alloy used, pH, etc. The results of stress corrosion tests on a number of different alloys including stainless steels contg. Ni 8 and 20% Incoloy 800, DS, and 825; Nimonic alloys; and Monel 400 are presented. Tests were made in NaCl and NaOH at 300°C. Alloys with high Ni content are the most resistant to various types of corrosion. Those particularly suitable are Incoloy 800 and 825.
278. Stier, H et al

EFFECT OF VARIOUS CONVENTIONAL HEAT TREATMENTS ON STRESS CORROSION RESISTANCE.

AD-293098, 10p. 1959.

The stress corrosion resistance of 0.032 and 0.040-in. thick Armco 17-7 pH stainless steel sheet was evaluated under a stress of 0.8 of the guaranteed 150,000 lb./in.² min. yield strength in the presence of Federal Standard No. 151A salt spray atm. Material conditioned by RH-1050, TH-1050, and RH-950 heat treatments and strain representative of fabricating steps were examined. Material treated by RH-1050, TH-1050, and RH-950 heat treatments possessed stress corrosion susceptibility inversely related to hardening temp. Double hardening treatments reduced the stress-corrosion susceptibility, but reduced strength below specified values.

279. Streicher, M A

EFFECT OF HEAT TREATMENT ON THE CORROSION OF 16% AND 25% CHROMIUM STAINLESS STEELS.


The present investigation was undertaken to relate the effect of heat treatment to microstructure, alloy compn. and forms of corrosion by using several new evaluation tests, and to det. whether heat treatment also affects corrosion in NaCl and MgCl₂ solns., with and without application of external stress. Test specimens were taken from 1 com. heat of AISI 430 (15.85% Cr) steel and 3 com. heats of AISI 440 (23-7% Cr) stainless steels. Heat treatments were made in an elec. furnace with Ar atm. On U-bend specimens in the soln.-annealed condition there is no intergranular attack on AISI 430 or 446 in either the solns. However, when heated 1 hr at 2200°F and water quenched both steels are subject to stress cracking in both solns. In the NaCl soln. cracking is intergranular while in the MgCl₂ soln. it is primarily transgranular. The 1st cracks appeared after ~500 hrs in the NaCl soln. and after only 25 hrs in the MgCl₂ soln.
280. Streicher, M A; Sweet, A J

APPARATUS FOR STRESS CORROSION TESTS IN BOILING MAGNESIUM CHLORIDE SOLUTIONS.


Time to failure in stress corrosion tests on stainless steels and related alloys depends on the temp. of the boiling MgCl₂ test soln. Small losses of water vapor, and condensate from solns. of 40-6 wt. % MgCl₂ lead to rapid increases in boiling temp. Components of a 3-part test app. (flask, condenser, and trap) have been designed to reduce losses of water vapor and condensate to negligible proportions. With this app. the temp. of the boiling MgCl₂ soln. can be held const. (as 155 ± 1°) for 100 days or more. This app. can also be useful for other solns. whose b.p.s. are significantly affected by such losses. Design details are given for a 1-l. modified Erlemeyer test flask, condenser, and vapor trap. Dimensions are also provided for 2 stress corrosion specimens, a U-bend and a bent beam, together with holders for these specimens which fit a 1-liter test app.

281. Subrahmanyan, D V; Stachle, R W


282. Suss, H

STRESS, CORROSION AND HYDROGEN EMBRITTLEMENT PROPERTIES OF 17-4 PH IN 600°F. WATERS.

KAPL-M-6580 64p. 1967

Stressed 17-4 PH specimens were exposed for 700 days to 600°F. H-ammoniated H₂O and to H-ammoniated and aerated H₂O. The susceptibility of the alloy aged at 900°F. to stress corrosion in 600°F. aerated H₂O was confirmed. No such susceptibility was evident in the H-ammoniated H₂O. The susceptibility of the 900°F. aged material to H embrittlement in both H₂O conditions was shown. This susceptibility was evident only with a high applied stress of 165,000 psi. for air-melt and 100,000 psi. for consumable-electrode-melt materials. No stress corrosion attack of the alloy aged at 1025 or 1100°F. in either environment was indicated. The one failure of each 1025°F aged and 1100°F aged, with applied stresses close to yield strength, has been attributed tentatively to H embrittlement.

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283. Suzuki, T et al

INFLUENCE OF STEEL COMPOSITION AND GASKET MATERIALS ON THE CREVICE CORROSION OF STAINLESS STEEL PIPING. (In Japanese)


The influence of steel composition and insulating gasket materials on the crevice corrosion of stainless steel piping was investigated by loop test and polarization measurements in 5% NaCl (pH = 3.0) at 50°C. The loop test showed that the crevice corrosion tendency was markedly varied with the composition of stainless steels and of gasket materials attached to the steel. For the stainless steel composition, the tendency decreased in the order: SUS 24, SUS 28, 33 and 18 Cr-16Ni-5Mo. For the gasket material, it decreased in the order; chrysotile asbestos, blue asbestos, SBR and Teflon. Polarization measurements were also made on the stainless steel specimen (crevice-free) and that coupled with gasket materials (crevice-containing). The current-density ratio-potential curves showed the same tendency obtained from the loop test. The larger the ratio in the potential range from passivation to pitting potential, the larger the crevice corrosion tendency of the couple of a stainless steel and a gasket material. The variation of the crevice corrosion tendency contributed by the gasket materials can be explained as being due mainly to the swelling nature when immersed in the environmental solution and on the adhesion wetting nature of the surface.

284. Suzuki, T et al

STRESS CORROSION-CRACKING RESISTANCE OF AUSTENITIC FERRITIC STAINLESS STEELS WITH HIGH CHROMIUM AND LOW NICKEL CONTENTS.
(In Japanese)

Nippon Kinzoku Gakkai-Si, 32-11, 1171-77; 1968.

Low-C, Fe-Cr-Ni alloys were studied in order to develop a two-phase steel, i.e. austenitic and ferrite, and the resistance to stress-corrosion cracking in a chloride environment was investigated. Martensitic hardening occurred when the (Cr + Ni) content was < 24% and the difference between the Cr and Ni contents was > 18%. Characteristic intergranular corrosion of the ferritic steel could be arrested when the austenitic phase was precipitated to > 10%. 10 references.
285. Takano, M; Shimodaira, S

ELECTRON MICROSCOPIC STUDY ON STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS. (In Japanese)


Effect of some alloying elements such as C, Ti, Mo, and N on the susceptibility of austenitic stainless steels to stress corrosion cracking was investigated by transmission electron microscopy with thin-foil specimens of these. Most susceptible of 18-8 stainless steels was that congn. 0.08% C. Dislocation arrangements were dependent on the relative contents of C and Ti, but addn. of Mo had no effect. The arrangement of dislocations was planar in N-cong. stainless steels. In 18-8, 18-20, and 25-20 stainless steels, N was effective on stress corrosion susceptibility. In 18-8 and 18-20 stainless steels, the dislocation distribution was dependent upon the relative contents of N and C. Stress corrosion initiated at slip steps and advanced into the interior of the steel by galvanic corrosion.

286. Takano, M; Shimodaira, S

MECHANISM FOR THE OCCURRENCE OF STRESS CORROSION CRACKING IN 18-8 AUSTENITIC STAINLESS STEELS. (In Japanese)


The effect of N on the stress corrosion cracking susceptibility of 18-8 austenitic stainless steels was investigated by transmission electron microscopy. It was confirmed from the observations that the stress corrosion cracking susceptibility of specimen B was augmented. These thin foil specimens were further exam. after exposure to solns. which cause stress corrosion cracking was discussed. The mechanism of the stress corrosion cracking may be considered as follows: When the restricted slip planes are continuously exposed to a corrosive environment during plastic deformation, the pitting is initiated at these fresh surfaces. The solute atoms are thus segregated to slip planes with the moving dislocations inside the specimen. There occurs a high concn. of solute atoms on the slip planes and in their vicinity. The stress corrosion cracking, once initiated at the fresh surface, would proceed in the specimen by an electrochem. process.
287. Takano, M; Shimodaira, S

MECHANISM OF STRESS CORROSION CRACKING OF FACE-CENTERED-CUBIC ALLOYS.

The stress corrosion behavior of austenitic stainless steels, Inconel, and a 70Zn alloy in corrosive environments was investigated with thin-foil and bulk specimens. To study the segregation of solute atoms in austenitic stainless steels, Instron tensile tests were carried out at 20°C and room temp. The mechanism of the nucleation of transgranular stress corrosion cracking of austenitic stainless steels in boiling 42% MgCl₂ soln. is different from that of the propagation. When conditions are satisfied, the transgranular stress corrosion cracking proceeds by electrochem. reaction along the segregated regions. The surface film has an important role in the intergranular stress corrosion cracking of brass in NH₄aq. solns. The initiation of micro pits (preferential dissoln. at the fresh slip steps) is not directly assocd. with the crack nucleation and its propagation. The grain boundaries contain dislocations and impurities in high d., and the disturbance increases with increasing absorption of dislocations under the presence of the surface films, so that the chem. reaction in the grain boundaries becomes more active, and corrosion is more accelerated. 17 references.

288. Takano, M; Shimodaira, S

MECHANISM FOR THE OCCURRENCE OF STRESS CORROSION CRACKING IN 18-8 AUSTENITIC STAINLESS STEELS. (In Japanese)
Nippon Kinzoku Gakkai-Si, 29:5, 553-557; 1965.

Transmission electron microscopy was used to study the effect of N on stress corrosion of 18-8 stainless steels. A planar arrangement of dislocations occurred when N was present, the arrangement being cellular in the absence of N. With specimens contg. N subjected to stress in boiling 42% MgCl₂ soln., pitting began at active slip planes and advanced along these planes. Chem. attack ceased if the stress was removed. In N-free specimens where cross-slip was possible, no pitting occurred. The mechanism of stress corrosion is discussed in terms of the dislocation configurations present in the specimen contg. N. 16 references.
STRESS CORROSION CRACKING IN AUSTENITIC STAINLESS STEEL UNDER CONSTANT STRAIN-RATE AND CONSTANT POLARIZATION.


The mechanism of stress corrosion cracking of an austenitic stainless steel in 42% aq. MgCl₂ solns., aerated and deaerated, was investigated under constant strain rates and constant polarization. From measurements of the stress strain curves and the observation of corrosion behaviors at slip steps produced during stress corrosion, it was found that the susceptibility of stress corrosion cracking depended largely on the dissolved O and the oxidizer in a corrosive medium and on the polarization of specimens, and also that the mechanism of stress corrosion cracking differed depending on the strain rates. The presence of surface films on the austenitic stainless steel which failed in air (electropolished surface) and in a 42% MgCl₂ aq. soln. was confirmed by a reflection electron diffraction technique, and the surface films were found to consist of varying mixts. of Fe-Cr-Ni spinel-type oxides, or α- or γ-Fe₂O₃, and (or) α-Fe₂O₃. The combined action of the repassivation of fresh slip steps produced in the alloy-corrosive system and the stress to produce the corrosion at particular slip steps play an important role in stress corrosion cracking.

A STUDY OF THE STRESS CORROSION CRACKING SUSCEPTIBILITY OF 18-8 STAINLESS STEEL BY ELECTRON MICROSCOPY. (In Japanese)


It is well known that 18-8 stainless steels are much more susceptible to stress corrosion cracking than Inconel in solns. contg. Cl ions. This work was attempted to find out whether the susceptibility to stress corrosion cracking of these metals depended on the kind of surface films on the alloys or on the dislocation distribution in 18-8 stainless steel was also investigated by transmission electron microscopy. The surface films formed on 18-8 stainless steel and Inconel, which were immersed in pure water or aq. MgCl₂ solution (Cl⁻, 500 ppm.) for 20 hrs. at 300°C, were investigated by relation electron diffraction and diffuse reflection spectra. The films formed on both 18-8 stainless steel and Inconel consisted on Ni(OH)₂. On the other hand, there was a remarkable difference in dislocation distribution on these metals; in 18-8 stainless steel, the dislocations were confined to slip planes and stacking faults were present, while in Inconel the slip was not restricted to particular direction and cross slip easily was allowed. The susceptibility to stress corrosion cracking of 18-8 stainless steel is closely related to stacking fault energy. The effect of addnl. elements on the dislocation distribution in 18-8 stainless steel is also discussed.
291. Tanaka, R et al

**INFLUENCE OF DISSOLVED OXYGEN ON THE STRESS CORROSION BEHAVIOR OF 18Cr-8Ni AUSTENITIC STAINLESS STEEL.** (In Japanese)

Tetsu To Hagane 56:2, 342-50; 1970.

In order to study the behavior of O (dissolved in corrosive agents), which has been reported to influence the stress corrosion cracking of austenitic stainless steels, the specimens of the steel were stressed and exposed to 42% MgCl₂ soln. or 40% FeCl₂ soln., under N or a normal atm and the change in ductility and hardness during corrosion, and fracture time were measured. In 42% MgCl₂ soln., without dissolved O, the stress corrosion cracking occurred with both the whole immersion specimen and the half immersion specimen. The dissolved O is necessary for pitting to occur in high temp. NaCl soln., but after the initial pit forms, the crack propagation may depend on H embrittlement which results from the nomenon that low pH FeCl₂ is formed in the pit by electrochem. reaction. The stress corrosion mechanism seems to be explained from the standpoint of crevice corrosion mechanism, and consequently it was not the O but the H that plays an important role in stress corrosion cracking processes.

292. Tanaka, R et al

**INFLUENCE OF HYDROGEN ON STRESS CORROSION BEHAVIOR OF AUSTENITIC STAINLESS STEEL.** (In Japanese)


In order to investigate the behaviors of H embrittlement and stress corrosion cracking in austenitic stainless steel, the change in ductility of 18Cr-8Ni steel under various environments was studied chiefly by means of 180° repetition bending test. The main results obtained are as follows: the H embrittlement in austenitic stainless steel was determined sensitively at the bending test after pickling and electrolysis. It was found that the steel also embrittled during stress corrosion testing in boiling 42% MgCl₂ solution in a manner similar to H embrittlement by pickling and electrolysis. The H occlusion owing to various environments occurred only near the surface layer. The recovery of ductility was limited at the initiation period of the embrittlement and the longer exposure time made more embrittlement. It was concluded that the H embrittlement plays an important role in the formation of the susceptible paths for the stress corrosion cracking of austenitic stainless steel. 60 references.
293. Tanaka, R; Hsu, T-K

STAINLESS STEEL FOR ANTI-STRESS CORROSION AND HIGH-TEMPERATURE SERVICE.


The stress corrosion fracture times (hr) in boiling 42% MgCl₂ solution under an applied stress of 30 kg/mm², the room-temp. tensile strengths (kg/mm²), elongation (%), 0.2% proof stress (Kg/mm²), and rupture times (hr) at 700° under an applied stress of 15 kg/mm², resp., are:

new stainless steel (Cr 17.19, Ni 10.27, C 0.15, Si 0.37, Mn 1.42, V 0.27, Nb 0.35, B 0.02, and (P+S) 0.004-0.25%) 1000, 71.0, 801, 27.5, 900; and com. 304 stainless steel (Cr 18.49, Ni 8.93, C 0.07, Si 0.74, Mn 1.65, N 0.027, P 0.036, and S 0.010), 1.62, 21.1, 80.1, 21.1, 10, resp. Although the corrosion of the new steel in 5% H₂SO₄ is 4-fold greater than that of 304 steel, the intergranular corrosion resistance, pit-corrosion resistance, and high-tem. oxid. resistance of the new-steel are better than those of 304. Pit-corrosion resistance is esp. good. The cost of the new steel is possibly only slightly higher than that of 304 steel.

294. Tedmon, C S Jr., et al

INTERGRANULAR CORROSION OF AUSTENITIC STAINLESS STEEL.


The wellknown susceptibility of sustenitic stainless steels to intergranular corrosion after heat treatment at 550-800° (i.e., "sensitization") has long been attributed to depletion of Cr from regions of the alloy matrix adjacent to grain boundaries in which Cr₃C₆ had pptd. Those regions of the steel in which the local Cr-comp. falls below ~12% have a diminished ability to form a passive film and hence corrode preferentially. Thermodynamic calcs. of the Cr-Cr₂₃C₆ equilibrium in and near grain boundaries were made to det. the Cr content in the vicinity of carbide particles. The equil. Cr content is a strong function of the temp. and of the C and alloy contents of the steel. Variations in the susceptibility to intergranular attack are detd. primarily by changes in the equil. Cr content near the carbides and not by changes in the no. and distribution of particles. Exptl. studies of rates of grain boundary attack as functions of temp. and compn. have confirmed the predictions of the anal. A further factor of less importance is the distribution of carbides in the grain boundary. Calcs. were made to det. the Cr concn. gradient within the boundary between carbide particles as a function of temp. and compn. as well as the Cr gradient normal to the boundary. These calcs. predict a strong interdependence between susceptibility to intergranular corrosion, carbide-particle spacing, and sensitizing temp. Exptl. results on thinned samples of sensitized material corroded in a Strauss soln. and examd. by electron microscopy are in good agreement with predicted effects.
295. Ternes, H

THE STRESS CORROSION CRACKING OF IRON ALLOYS, WITH SPECIAL REFERENCE TO STAINLESS AUSTENITIC STEELS.


The present state of knowledge of stress corrosion cracking of stainless steels is reviewed with emphasis on austenitic steels.

296. Thiruvengadam, A; Preiser, H S

CAVITATION DAMAGE IN LIQUID METALS.


This report summarizes the results of the investigation on the cavitation damage resistance, the high frequency fatigue and the stress corrosion behaviour of five metals in liquid Na up to 1500°F. The test duration is an important parameter in evaluating the relative cavitation damage resistance. Stellite 6B exhibits the greatest resistance as compared with Cb-132M, T-222, TZM, and 316 stainless steel. The rate of damage decreases with increasing temp. High frequency fatigue tests at ~35 ppm. and at ~100 ppm. oxide contamination in liquid Na up to 1500°F. show that the oxide content does not change the fatigue behaviour of TZM and 316 stainless steel. The fatigue of 316 stainless steel in 1500°F. Na at 14000 cycles/sec. is comparable with the results obtained at 1500°F. vac.:"m (3 x 10^-5 torr) at 4-5 cycles/sec. No stress corrosion cracking was observed on TZM and on 316 stainless steel over a 60-hr. test at 2 oxide levels (~35 and ~100 ppm.) in liquid Na at 1000°F. and 1500°F. up to 100% yield.

297. Thomas, K C; Allio, R J

MECHANISM OF STRESS CORROSION IN MATERIALS FOR NUCLEAR APPLICATIONS.


298. Thomas, K C et al

STRESS CORROSION SUSCEPTIBILITY AND THE DISLOCATION ARRANGEMENTS OF AUSTENITIC STAINLESS STEELS.

Corrosion Sci. 5:4, 71-9; 1965.

In considering stress corrosion sensitivity in relation to dislocation arrangements, a study was made of the effect of strain and temp. on dislocation arrangements in type 304 stainless steel...
and Incoloy 80S, the former sensitive and the latter resistant to stress corrosion in MgCl₂ soln. at 142°. Increased stain for a fixed temp. and increased temp. for a given strain increased dislocation d. in both materials; increasing temp. of Straining had little effect on dislocation arrangement. Dislocation arrays were planer, the stacking fault. energy being 10 ergs/cm.² for stainless steel and 30 ergs/cm.² < 1 hr., while Incolony 800 did not fail under similar conditions in 350 hrs.; the latter effect is attributed to a recording reaction occurring sufficiently quickly to destroy chem. reactive sites need. for crack initiation. 24 references.

299. Thomas, K C et al

STRESS CORROSION OF TYPE 304 STAINLESS STEEL IN CHLORIDE ENVIRONMENTS,


The difference in time to failure of Type 304 stainless steel in various chloride solution at cont. stress, temp., pH value, and Cl⁻ concn. are dependent. The time of failure increase in the order Mg²⁺, Ca²⁺, Li⁺. This may be due to adsorption effects which may be MgCl₂ soln. were made after different surface treatment of the stainless steel. Addn. of 3.5% of inhibits stress corrosion in annealed or work-hardened steel. Steel contg. 5.4% Si resisted the corrosion for 1000 hrs.

300. Tiller, W A; Schrieffer, R

HYDROGEN PUMP FOR STRESS CORROSION CRACKING.

Scr. Met. 4:1, 57-61; 1970.

The characteristics of stress corrosion cracking is math. analyzed on the basis of 2 approxms. for energy. The calcns. indicate that electrons flow into regions of highest tension making the cracked tip cathodic. The max.p.d. between the cracked tip and bulk metal is 0.8 V. Fluid at the tip of the crack is acids. H⁺ chemi-sorsbs on the metal surface and forms a covalent bond. The continuity of H⁺ pumping depends of (1) the discharge of H⁺ at the metal surface, (2) the migration rate of H⁺ into the metal, (3) the source concn. of H⁺ ions.
301. Troiano, A et al

HYDROGEN-PERMEABILITY AND STRESS CORROSION CRACKING IN STABILIZED AUSTENITIC STEEL.


By electroplating H on one surface of a thin membrane of 310 stainless steel and measuring the rate at which gas escapes from the other side, it was shown that the diffusivity of H is at least 3 orders of magnitude lower than in Fe, and it is rate determining. In H₂SO₄ solution a cathodically applied current is necessary to activate the surface to allow H to permeate the steel, but permeation continues and even increases when the potential is removed. Solutions of HCl and NaCl activate the surface spontaneously, corrosion pits providing an important means of hydrogenation even under anodic polarization. H plays a role in the nucleation and propagation of cracks in the stress corrosion cracking of f.c.c. austenitic steel.

302. Troiano, A et al

HYDROGEN INDUCED EMBRITTLEMENT AND INTERNAL FRICTION IN STABILIZED AUSTENITIC STEEL.


Stress corrosion cracking is attributed to stress induced diffusion of H to regions of high triaxial force, where it lowers the cohesive strength. Only H which is free to diffuse can influence cracking, and it is thus important to determine the nature of H-traps which may reported on type 310 austenitic steel at 170-270°C to observe the effects of straining and ageing on H-trapping and recovery. 7 references.

303. Trueb, L F

CORROSION AND STRESS CORROSION CRACKING OF EXPLOSIVELY SHOCKED AUSTENITIC STAINLESS STEELS AND EXPLOSION-BONDED STAINLESS STEEL-TO-STEEL CLADS.

Corrosion, 24:11, 355-58; 1968.

Corrosion rates and sensitivities to stress corrosion cracking of two types of austenitic stainless steel (304 and 310) were investigated after explosive shocking between 90 and 540 kbars. In boiling nitric acid as well as in ferric sulfate-sulfuric acid, the intergranular
corrosion of both 304 and 310 stainless steel was only mildly affected by explosive shocking in fully solution-annealed as well as in sensitized material. Explosive shocking at pressures below a critical threshold value did not increase the sensitivity of either type of stainless steel to stress corrosion cracking. Cracking due to shock-induced residual stresses occurred above 200 kbars in 304 stainless steel and above 300 kbars in 310. 19 references.

304. Truman, J E

METHODS AVAILABLE FOR AVOIDING STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS IN POTENTIALLY DANGEROUS ENVIRONMENTS.


Stress corrosion cracking of stainless steels is caused by environments that are quite specific, e.g. solutions of halides or of strongly caustic substances. The effects of Cl concentration, cation species, temp., O-concentration, and of the solution pH; the applied stress; and the composition and metallurgical condition of the steel; on chloride and caustic-induced cracking were investigated. Methods available to ensure that stress corrosion cracking does not occur in service are considered and possible techniques of improving stress corrosion cracking resistance are discussed. 9 references.

305. Truman, J E; Perry, R

NOTE ON THE EFFECT OF TESTING TEMPERATURE ON THE STRESS CORROSION CRACKING OF MARTENSITIC STAINLESS STEELS.


For 13% Cr martensitic stainless steels brittle fracture occurred at up to 300°C due to the presence of H although toughness increased with temp. The degree of embrittlement decreased with increase of temp. for a given H content.

306. Truman, J E; Perry, R

THE RESISTANCE TO STRESS CORROSION CRACKING OF SOME Cr-Ni-Fe AUSTENITIC STEELS AND ALLOYS.


A study was made of the effect of variations of Ni and Cr content of austenitic steel (Cr 10-25, Ni 15-45, Mo 0-5, and Cu0-4.0%)
on its susceptibility to stress corrosion and caustic cracking. Tensile tests were effected in 42% MgCl₂ at 150°, in 40% CuCl₂ at 110°, in 3% NaCl at 250° at 2000 psi, in 16% NaCl at 250° at 2000 psi, in 50% NaOH at 300° at 2000 psi, in a strong soln. of NaCl in steam at 300° at 1600 psi. Increasing Ni reduced stress corrosion cracking susceptibility in a Cl⁻ environment; some cracking was still found in 45% Ni. Cr had a reduced effect but a slight min. may exist at 15-20% in Cl⁻ media. In NaOH, the beneficial effect of Ni was not so strong but Cr increases to 20% were beneficial. Mo and Cu have little influence in a Cl⁻ medium. In addition, to restricted slip some other factor is required for cracking to proceed. Significant features requiring further study include the specific action of different halides, that of temp., the role of cation species, the effect of corroden. concn.; all these suggest a chem. control factor.

307. Truman, J E et al
THE NATURE OF STRESS CORROSION CRACK INITIATION WITH MARTENSITE STAINLESS STEELS.

For 13% Cr martensitic (170 tons/in²) stainless steels cracking was initiated at a late stage of exposure (80-90% of failure time) irrespective of total time to failure. Explanations based on H embrittlement concepts with initiation as a slower process than each stage of propagation are suggested.

308. Truman, J E et al
STRESS CORROSION CRACKING OF MARTENSITIC STAINLESS STEELS.

Twelve 12-13% Cr steels contg. 0.07-0.32% C were studied using 5/8-in-diam. test pieces loaded by a simple lever system by wts. in an opp. of the stress-rupture type. One compn. wasted in sheet form 10,018 in-thick). Four test environments were: 6% NaCl contg. 0.5% H₂O₂ and satd. with H₂S at 50°, cold 3% NaCl, boiling 3% NaCl, the polluted industrial atm. in the est. end of sheffield. Failure can be by corrosion along a narrow active path or because of H embrittlement with higher tempering temps. corrosion in the more important with lower temps. H embrittlement is the major cause. The H embrittlement type of failure is due to local rapid absorption at the crack tip rather than to general hydrogenation.

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Under acid conditions the strength of the materials is the major factor. Steels with max. stress values below 70 tons/sq.in. are relatively immune to cracking. It is doubtful whether any high-C martensitic stainless steel could be used safely under corrosive conditions if tempered between 250 and 650°. 29 references.

309. Tsekovich, K N; Gerasimov, V V

SECOND-ORDER STRESSES AND RESISTANCE OF SOME AUSTENITIC STAINLESS STEELS TO CORROSION CRACKING. (In Russian).


Investigations of 2nd-order stresses were made on steels: 1Kh18N9T, Kh23N18 (EI-417), 0Kh23N28M3D2T (EI-943), Kh25N20OS2 (EI-283), Kh20M4G2 (EI-211), and KhN50HT (EI-703), after similar plastic deformation as well as on the mechanism of the deformation and its relation to corrosion cracking. Results of x-ray analysis indicated that there is a relation between 2nd-order stress and resistance of steel to corrosion cracking. Higher stress upon similar plastic deformation corresponds to lower steel resistance to cracking in boiling 42% MgCl2 + 5% FeCl2 ag. solns. It is assumed that in the plastic deformation process of steels susceptible to corrosion cracking, local sections with higher stresses originate before the start of the corrosion crack, and are subject to faster dissolution. Studies on the deformation mechanism conducted with an electron microscope confirmed the results obtained by x-ray analysis. For steel 1Kh18N9T plastic deformation is achieved mainly by twinning and rough sliding. As resistance to corrosion cracking increases, elements of transverse sliding are observed, but twinning and initial sliding prevail. Twinning is seldom noted with the most resistant EI-703 steel. Deformation proceeds mainly owing to initial and transverse sliding.

310. Tsekovich, K N; Gerasimov, V V

STRESSES OF THE SECOND KIND AND RESISTANCE OF AUSTENITIC STAINLESS STEELS TO CORROSION CRACKING.


311. Uhlig, H H; Cook, E W Jr.,

MECHANISM OF INHIBITING STRESS CORROSION CRACKING OF 18-8 STAINLESS STEEL MgCl2 BY ACETATES AND NITRATES.

Modest additions of sodium acetate, nitrate, iodide, or benzoate to \( \text{MgCl}_2 \) test solution, boiling at 130°C, are found to increase resistance to or inhibit stress corrosion cracking of 18-8 stainless steel. The critical applied potential in \( \text{MgCl}_2 \) solution (-0.145V) above which, but not below, cracking occurs, is shifted in the noble direction by extraneous salt additions. When the shift exceeds the corrosion potential for 18-8 in the same solution, cracking is apparently inhibited. On the other hand, salt additions, \((\text{FeCl}_3)\) which shift the corrosion potential in the noble direction may induce or accelerate stress corrosion cracking. The critical potential is interpreted as that value, above which but not below, \( \text{Cl}^- \) ions 'adsorb' to cause imperfection sites of plastically deforming metal in an amount adequate to cause failure (stress sorption cracking). The present data do not support an electrochemical mechanism of stress corrosion cracking based on anodic dissolution of metal ions at the tip of a crack, nor the mechanism dependent on continuous cracking of a surface oxide film.

312. Uhlig, H H; Sava, J P

ORIGIN OF DELAY TIME IN STRESS CORROSION CRACKING OF AUSTENITIC (25:20 CHROMIUM-NICKEL) STAINLESS STEELS.


Stressed specimens of 25:20 Cr-Ni stainless steel were subjected to boiling \( \text{MgCl}_2 \) for various times. Oxide or passive films had little or no influence on time to crack initiation or on propagation rate. The important factor is the time for segregation of \( N \) and similar atoms to lattice defect sites. The segregation of \( N \) causes ageing and produces crack-sensitive paths.

313. Uhlig, H H; Sava, J P

ORIGIN OF DELAY TIME IN STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS.

Corrosion Sci. 5:4, 291-9; 1965.

In a study of factors affecting delay time in the stress corrosion cracking of stainless steel, tests were made on a Type 310 material (25 Cr, 20 Ni, 0.03 C, and 0.14% Mo), either cold rolled or annealed, in \( \text{MgCl}_2 \) soln. at 154°C; tests were made by an initial immersion for a definite period either just short of or greater than the induction time necessary for initial initiation of cracking followed by repickling for 5 min. and further \( \text{MgCl}_2 \) testing.

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The time to failure depended only on total previous exposure time of unstressed specimens at 154°, whether in MgCl₂ or air; cracking time was not altered by interrupting the test early or late, followed by repickling the stressed specimens and re-exposure to MgCl₂. The data are inconsistent with any supposed role of an oxide or passive film in detg. failure segregation at lattice imperfections and the associated time factor at 154°. N appears to be the significant impurity. A low-N 20Cr-19% Ni steel showed no quench-aging or stress-corrosion cracking sensitivity.

314. Uto, Y
STRESS CORROSION CRACKING OF STAINLESS STEELS BY SULFIDES. (In Japanese)
Stress corrosion cracking and methods for its study and prevention are reviewed. 13 references.

315. Vasilenko, I I et al
STRESS CORROSION CRACKING OF STAINLESS STEELS Kh17N2 AND KhN5M5 IN CHLORIDE SOLUTIONS. (In Russian)
Stress corrosion tests were made of ferritic-martensitic steel Kh17N2 and austenitic-martensitic steel Kh17N5M5 in 3% and 2% NaCl solns. at room temp. and at the b.ps. of the solns Kh17N2 was quenched and then tempered at 170-650°; Kh17N5M5 was normalized, cooled to-70°, and then tempered at 450° stresses were induced either by tension or by bending. None of the specimens tested at room temp. in 3% soln. showed any signs of cracking. Tests at the b.ps.; either by immersion or spray, showed that Kh17N2 was more resistant to stress corrosion cracking than Kh17N5M5. Steel Kh17N2 tempered at 170° and at γ460 (brittle range) was sensitive to cracking; after tempering at 340°, it resisted cracking. None of the specimens tempered at 650° cracked. In general, the results were markedly affected by test variables, such as aeration or alternate wet-dry condition.

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316. Vaughan, D A et al

RELATIONSHIP BETWEEN HYDROGEN PICK-UP AND SUSCEPTIBLE PATHS IN STRESS-CORROSION CRACKING OF TYPE 304 (18/8) STAINLESS STEEL.


The susceptible paths for stress corrosion cracking in 18/8 Cr-Ni, 0.08% C, stainless steel were identified by electron-microscope examination of thin sections before and after exposure in 42% MgCl₂. Difference in susceptibility to stress corrosion cracking were attributed to the solubility of H in the steel and the extent of diffusion under applied stress. In resistant steels the hydride phases precipitate rapidly and prevent diffusion of H to high-tensile-stress regions; in susceptible steels the ppt. does not form immediately. Electron and photomicrographs of the process are included.

317. Vaughan, D A et al

RELATION BETWEEN HYDROGEN PICKUP AND SUSCEPTIBLE PATHS IN STRESS-CORROSION CRACKING OF TYPE 304 STAINLESS STEEL.

Corrosion 19:9, 315t-326t; 1963.

The susceptible paths for stress-corrosion cracking in types 304 stainless steels were identified by electron-microscopic exam. of this sections before and after exposure to boiling 42% MgCl₂. These paths were generated by the corrosion reaction, esp. the cathodic part. Type 304 stainless steel reacted with H to form hydride phases which were attacked rapidly by the corrosion environment and would not be detected in the steel after stress-corrosion cracking failure. Differences in susceptibility of type 304 stainless steel were due to the solv. of H in the steel and the extent of diffusion under applied stress. In resistant steels the hydride phases ppt. rapidly and prevent diffusion of H to high-tensile-stress regions, while in susceptible steels the ppt. does not occur immediately. H in solids soln. diffuses through the austenite lattice under an applied load and forms a stress-oriented tranagrular ppt. phase distribution similar to the distribution of the cracks in stress corrosion-cracked specimens.
318. Veingarten, A M et al

RESISTANCE OF HIGH-STRENGTH DISPERSION-HARDENED STAINLESS STEELS TO STRESS CORROSION CRACKING. (In Russian)


The study on title resistance were carried out with austenitic-martensitic steels of different grades. As corrosion medium, a 42% soln. of MgCl₂, a synthetic sea water, and sea water from the Black Sea were used. Testing temps. were 60 and 100°; and the testing time was 100 hr for the 1st 2 mediums and 1000 hr for the sea water. During testing the time to failure in a given medium was detd. at stresses of 0.25 and 1.3 of the ultimate creep point of T. In addn., the tensile strength was detd. in air, in 42% MgCl₂, and in synthetic sea water at 60 and 100°, as well as after immersion in the corrosion media for 100 hr under stress of 1.0-1.2 of T. All tested steels showed a tendency to corrosion cracking in boiling 42% MgCl₂ and the degree of this tendency depended on chem. compn., heat treatment conditions, structure, and the level of applied stresses.

319. Verma, K M et al

CORROSION OF COLD BOX EQUIPMENT IN AN AMMONIA PLANT-A CASE HISTORY.

Technology 7:3, 176-8; 1970.

A case history of corrosion of cold box equipment in an NH₃ plant is discussed. Some stainless steel vessels in the air-sepn. and N-wash units were found damaged by corrosion at several places during installation. It was concluded after investigation that carbide pptn. coupled with corrosive environment esp. chloride from insulating materials were the main factor responsible for causing corrosion failure of the stainless steel vessels.

320. Wecker, G A

EFFECTS OF MARINE ENVIRONMENT ON HIGH STRENGTH STEELS.


General and stress corrosion cracking behavior of several classes of high strength steels in the marine environments are investigated. Eleven exptl. heats of maraging steel were evaluated for resistance to stress corrosion cracking in sea water. Alloys contg. 12 or 14% Ni were susceptible to pitting attack and stress corrosion cracking, while 18% Ni maraging steels were highly resistant to pitting attack.
The corrosion characteristics of 5Ni-Cr-Mo-V HY-130 steel were also investigated in sea water. The stress threshold stress for HY-130 was determined by using the criteria of no failure after 6 months of exposure in natural sea water under sustained stress in the precracked cantilever test. A study was made to determine if long-term continuous cathode protection of HY-130 in sea water would lead to eventual problems associated with H embrittlement. Work utilized precracked cantilever specimens, which were precharged with H at several high-c.d. levels and then step loaded to failure while still being cathodically protected. Cathodic protection tests were also carried out by using 2-point loaded bent-beam specimens stressed to 90% of the 0.2% yield strength which were cathodically protected at 15 and 150 ma./ft.2 c.d.s. for 1 protection on the low-cycle corrosion fatigue behavior of HY-130 was also determined. It was concluded that HY-130 steel has good resistance to stress corrosion cracking in sea water. HY-130 steel is insensitive to H embrittlement when cathodically overprotected in sea water and tested as either a precracked cantilever or bent beam specimen. Cathodic overprotection of HY-130 steel in sea water reduces the low-cycle corrosion-fatigue life of the alloy at any given reversed pseudoelastic stress level.

321. Warren, E B

SOME FACTS ABOUT STRESS CORROSION OF AUSTENITIC STAINLESS STEELS IN REACTOR SYSTEMS.

Reactor Mater. 7:1, 1-13; 1964.

322. Watanabe, M; Mukai, Y

EFFECT OF COLD WORKING ON STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEELS AND THEIR WELDED JOINTS.


The stress corrosion of several austenitic stainless steels in boiling 42% MgCl₂ solution was investigated under constant load using a testing machine in which direct metallographic observations could be made during testing. The effects of prior cold working in the temp. range-196 to + 100°C on the time to failure, the quantity of martensite, the initiation time and propagation time of stress corrosion cracks and the effect of heat treatment on the time to failure of cold-worked material were studied. The effect of cold working before and after welding on the stress corrosion behavior of welded joints was also examined. 12 references.
In the first stage of the research on stress corrosion cracking under
dynamic load, the tested material was AISI 304 stainless steel and the
corrosion medium was a boiling soln. of 42% MgCl₂ (b.154°). The
app. was a const. tensile loading type, the load time and the no-
load time of which can be changed arbitrarily. The damage due to
stress corrosion cracking under pulsating trapezoid load is not equal
to the accumulated value of static damage. This damage is not only
influenced by the dynamic effect due to the pulsating load but also
by the length of no-load time. The propagation time can be presumed
under the following assumption: the total sum of the damages due to
load time, no-load time, and dynamic effect is equal to the damage
under static load. In the case of the ratio of load time to no-load.
In the case of the ratio of load time to no-load time being const.,
the crack propagation time is prolonged by the prolongation of the
loading period.

The mechanism of stress corrosion cracking during the so-called
"induction period" before cracks initiated was studied by using
the method of preimmersion. During the induction period, the
corrosion potential of the test piece rose more and more independently
of the load value, until at last it reached the necessary value
causing the occurrence of "micro-pitting" which was believed to be the
initial stage of stress corrosion cracking. If the necessary value
of stress was applied at the time, cracks immediately started. The
stress is not necessary until the potential of specimen reaches the
necessary value described above. The material was not attacked by the
corrosion agent and it became brittle during the induction period.
The values of the threshold stress for crack initiation and for
crack propagation were obtained and generally, the latter had a lower
value than the former.
The relation between corrosion potential and the so-called "induction period" of austenitic stainless steels subjected to stress corrosion cracking tests under cathodic or anodic electrolysis is discussed. For cathodic electrolysis, the corrosion potential of the test piece was lowered. Consequently, it took a longer time until the corrosion potential reached the necessary value for crack initiation. Therefore, the induction period was also lengthened. When the c.d.e. of cathodic electrolysis increased sufficiently, no stress corrosion crack occurred during the test time. In this case the corrosion potential did not reach the necessary value for crack initiation. This is the mechanism of preventing stress corrosion cracking by cathodic electrolysis. Next, a cathodic current was applied to the restrained welded plate under stress corrosion test. Cathodic electrolysis was effective for preventing stress corrosion cracking. The propagation of stress corrosion cracking can also be controlled by the corrosion potential of the test piece.

The effects of cold working on the stress corrosion cracking of austenitic stainless steels in the boiling 42% MgCl₂ soln. were studied. For an 18-8 stainless steel which is transformed partially into quasi-martensite by cold working, both induction period and crack propagation time are changed by cold working. Especially, the crack propagation time is very much lengthened by heavy cold working. For other stainless steels, both induction period and crack propagation time are hardly changed by cold working. As a result of the quasi-martensite obstructing the advance of the cracking, the crack propagation time is lengthened and this effect is generally called the "Keying effect." The electrochemical potential of a test piece indicated at the crack-piece after cold-working indicates a slightly lower potential than the original test piece, but when the test piece is cold-worked heavily it indicates a slightly higher potential than the original one. The slip bands occurring at the time of cold-working are never attached during the stress corrosion applied test load are gradually attacked during the stress corrosion test.
When a slip band occurs, its fault plane has no protective film. If this unprotected fault plane appears in the MgCl₂ soln., it is attacked. If it appears in the atm., its area is suddenly oxidized and goes into a passive state. The higher the applied stress, the greater the no. of cracks which appear on the surface of tested specimen. When the test piece is cold worked, this relation is shifted toward higher stress followed by increasing yield point.

327. Welinsky, I H et al

FINAL EVALUATION OF SHIPPIINGPORT POWER STATION'S STAINLESS STEEL GENERATOR AFTER FIVE YEARS.


The steam generators were tubed with type 304 steel. Leaks developed in the IB unit after only a short period of operation. The unit has now been subjected to a complete destructive examination. Describes the condition of the unit and reviews the boiler water control used. Widespread cracking was found in the tubes. The cracks were intergranular in the sensitized sections and transgranular in the annealed sections. Although the cracking could be attributed to either chloride or caustic stress corrosion, the evidence points to caustic as the more probable cause. Most of the cracking apparently occurred during the initial 150 hr of operation when the boiler water contained free caustic. Seventeen of 31 typical tubes from the IB unit showed perforations. Trisodium and monosodium phosphate were used to adjust pH rather than caustic soda; disodium phosphate was substituted for sodium pyrophosphate and phosphate concentration was increased. 7 references.

328. Wendelbo, A H

POTENTIOSTATIC DETERMINATION OF STRESS CORROSION SUSCEPTIBILITY IN 431 STAINLESS STEEL.


The presence of Cr carbides in the martensitic matrix of 431 stainless steel parts can be detected by means of a simple galvanic nondestructive test procedure. The test is based on the large difference in small anodic current flows, for acceptable and unacceptable parts. The reliability of the method was verified by salt spray exposure to failure of stressed parts, which had been previously examined by the galvanic test. Initial expts. were done on rapidly and slowly quenched materials as well as on parts that had failed in service.

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Contd...
Characteristic current-voltage relations for the various samples were obtained over a voltage range of -0.3 to +0.5 V, by using a\n\nWenking potentiostat. The electrolyte was 0.2N NaCl. Voltages were\n\nreferred to a SCE, using a well-agitated KCl-saturated salt brine and a Pt\ncounter electrode. The electrolyte was stirred with a vibrating\nagitator. When current-voltage data were plotted, 2 distinctly\ndifferent curves were obtained. The semilog plot of c.d.v.s, applied\nvoltage for the properly quenched material exhibited a very low\nc.d. over a relatively broad range of applied voltage, while the\nmaterial having intergranular Cr carbides exhibited passivity over an\nextremely narrow voltage range. The large difference in c.d.\nbetween the 2 curves showed that this could form the basis of the\ndesired nondestructive test.

326. West, J M

MECHANISM OF STRESS CORROSION CRACKING.

Corrosion Sci. 1, 178-9; 1961.

Consideration of the data on stress-corrosion cracking in specific\nsystem suggests that both metal deformation and ionic solvation\nshould be considered. The metal structure may also be involved, in\nso far as the electronic configuration of both the metal and its\nsolvated cation may affect the activation energy of the solvation\nprocess. The atoms in surface steps have a very low coordination\nand dissolve following from yielding.

330. West, J M

STRESS CORROSION CRACKING.


The stress corrosion cracking of light alloys, caustic cracking of\nmild steel, seasonal cracking of brass, and chloride cracking of\naustenitic steels are reviewed. 29 references.

331. West, J M; Fairman, L

PROPAGATION OF STRESS CORROSION CRACKS IN AUSTENITIC STAINLESS STEEL.


In a study of propagation of cracking in stress corrosion of Cr 18,\nNi 10, Mo 2.5%, and 0 0.05% stainless steel in 42% MgCl$_2$ at 140°-\n54° with and without 5% FeCl$_3$, extension of direct-loaded wires was\nmade to an accuracy of better than 50 A.
No discontinuities were found during crack propagation and a
continuous mech.-chem. propagation of transgranular cracks appears
to be involved. Striations shown by fractography in the
transgranular stress corrosion fracture occurred on a scale of
0.1-0.7 μm; a model of crack propagation is proposed on the basis
of a dynamic equil. between dislocations movement to the surface
and electrochem. dissoln. A series of monot. "ledges" form when
slip is coarse and this gives an increase in exchange c.d.
29 references.

332. Westwood, A R

POSSIBLE ROLE OF ADSORBED STEP POISONS IN STRESS CORROSION CRACKING.
Corrosion Sci. 5:8, 381-4; 1966.

With relation to the possibility of adsorbed species affecting
stress corrosion effects, attention is paid to the influence of
step-poisons on the dissoln. behavior particularly as it might
influence tunnelling of pitting around the inclusion sites. Expts.
were carried out with \( \gamma \)-irradiated LiF single crystals irradiated
to \( 1.5 \times 10^6 \) r, dosage to show that "tunnelling" can be extremely
deleterious in terms of mech. properties of notch-brittle
materials; stearic acid was used at the step poison in this case.
Step-poisons capable of changing dissoln. from general to specific
will probably be significant in the future development of very high
strength, but notch brittle, materials used structurally. This
effect can be reduced by (1) use of inhibitor-ions which screen or
breakdown troublesome complex species in soln. and (2) altering the
compo. of the solid. 16 references.

333. Westwood, A R et al

ADSORPTION, EMBrittLEMENT, AND STRESS CORROSION CRACKING.
Phil. Mag. 10:104, 545-7; 1964.

Annealed and chem. polished polycryst. AgCl was immersed in 6N eq.
NaCl and the time-to-failure under a const. tensile load was detd. and
compared with that in air. There was a marked drop in stress to
cause failure in the salt soln. Also, when the AgCl was tested under
a const. tensile load in eq. AgCl solns., which had been presbd., with
complex ions by agitating with AgCl powder for 16 hrs., the time to
failure was substantially reduced from that obtained in unpresbd.
so1ns. These results suggest the assoc. of embrittlement with
adsorption and support the view that several environmentally
induced embrittlement phenomena may possess an essentially simi-
lar mechanism.

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334. Wilde, B E

TECHNIQUE FOR STUDYING THE KINETICS OF INTERGRANULAR CRACK NUCLEATION ON AISI TYPE 304 STAINLESS STEEL IN OXYGENATED WATER AT 289 C.


335. Wilde, B E; Armijo, J S

INFLUENCE OF SILICON AND MANGANESE ON CORROSION BEHAVIOR OF AUSTENITIC STAINLESS STEELS.

Corrosion 24:12, 393-402; 1966.

The effect of Si and Mg on the electrochem. and corrosion behavior of a high-purity austenitic 14Cr/14 Ni, balance Fe, alloy had been studied. Over the compn. range 50.41-500 ppm. Si, no effect was observed on the kinetics of the anodic or cathodic partial processes. Addn. of Mg over the range 5.26-300 ppm. accelerated the anodic dissolution kinetics in the active range of potentials and also the steady-state corrosion rate in N H2SO4, owing to its influence on the kinetics of the cathodic partial process. The nature of this effect was analyzed according to electrode kinetic concepts which showed that Mg changes value of the electrode process transmission coeff. Alloys contg. Mg and Si over large concn. ranges are extremely resistant to stress corrosion cracking in boiling 42 wt. % MgCl2.

336. Wilde, B E; Weber, J E

INTERGRANULAR STRESS CORROSION RESISTANCE OF AUSTENITIC STAINLESS STEELS IN WATER/OXYGEN ENVIRONMENTS: ACCELERATED TEST PROCEDURE.


A study was made to distinguish between the influence of gross plastic deformation and heat treatment on the intergranular stress corrosion cracking (I.G.S.C.) behavior of a variety of austenitic stainless steels tested under uniaxial tension in water at 289° with 100 ppm. dissolved O as an accelerator. The materials studied were 18Cr-6% Ni, 18Cr-14% Ni, and 18Cr-10% Ni and 20Cr-5% Ni with Si as a variable in the range 0.49-4.29%. Sohe, annealed material with no plastic deformation other than that assoc. with stressing to the yield point showed no evidence of cracking after exposure under the given conditions.
The presence of oxidizing cations, e.g., Cr<sup>6+</sup>, do not promote cracking of annealed type-304 stainless steel stressed to yield in water under the given conditions. Sensitized austenitic materials with C equal to or greater than 0.03 wt.% exhibited cracking even in the presence of high Si content; C and not Si and P controls the cracking behavior of the above materials. Duplex alloys contg. ferrite plus austenite appeared to be immune to cracking even after a heat treatment corresponding to sensitization in austenitic materials. This immunity is independent of the nature of the ferrite stabilizer employed. Thick welded sections of type-304-L steel are susceptible to cracking in the given conditions in the same manner as a fully sensitized material. Type-304-L steel may be welded without any deleterious results as regards its cracking resistance to water in the given conditions.

337. Wiegand, H et al

STRESS CORROSION CRACKING OF AUSTENITIC CHROMIUM-NICKEL STEELS IN A MAGNESIUM CHLORIDE SOLUTION AT VARIOUS CONCENTRATIONS UNDER DEFINED ELECTROCHEMICAL CONDITIONS. (In German)


Stress corrosion cracking tests in aq. MgCl<sub>2</sub> solns. of concns. up to 45% at various temps. and varying aeration were performed with X-12, CrNi 18-8, X 5 CrNi 18-9, X 2 CrNi 18-10 to det. the influence of sample pretreatment, O supply at the sample surface, type of steels. The effects of lowering the MgCl<sub>2</sub> concn., of defined present potentials, and of impressed currents on the reproducibility of the results and the c.i. vs. potential curves in various MgCl<sub>2</sub> solns. were studied.

338. Wiegand, H et al

STRESS CORROSION IN AUSTENITIC STEELS WITH STATIC AND PULSATING LOAPS. (In German)

A characteristic is defined for the comparison of different steels from the standpoint of stress-corrosion behavior, based on the mech. properties at the test temp. by employing the 500-hr. or 1000-hr. 0.01% max. elongation, obtained from the long term test at the particular temp. Dil. MgCl<sub>2</sub> solns. at lower temps. are recommended for approximating the test conditions to actual conditions.
339. Wiegand, H et al

STRESS CORROSION CRACKING TESTS OF RUST-AND ACID-RESISTANT AUSTENITIC STEELS IN ALKALINE EARTH HALIDE SOLUTIONS. (In German)


Stress corrosion cracking tests, both potentiostatic and without impressed current, were carried out on austenitic steels X1CrNi1810, X10CrNi5Mo189, and X2CrNi51810 in concd. MgCl₂, CaCl₂, and CaBr₂ solns. Preliminary boiling resulted in the formation of a protective layer and all specimens were treated in boiling soln for 3 hrs, prior to the measurements. During the tests, static tensile and superimposed low-frequency dynamic loads were applied, and the resistance to stress corrosion cracking detd. as a function of pH and salt concn. Read of the natural pH of the soln. by addn. of HCl or HBr gave improved resistance. The formation of a protective insol. silicate layer was proved, and cracks occurred at faults in this layer. Tests in fluoride solns. did not produce cracks because the silicates were sol. in H₂O.

340. Wiegand, H et al

THE SUPERPOSITION OF INTERCRYSTALLINE CORROSION AND CORROSION-FATIGUE CRACKING AND ITS ACTION ON THE CREEP BEHAVIOUR OF AUSTENITIC STEELS. (In German)


In order to investigate the interaction of corrosive attack and simultaneous mechanical cyclic-stressing on austenitic steels, and determine the degree of participation of intergranular corrosion in corrosion fatigue cracking, rotating-beam bend tests were carried out on 18/8, austenitic stainless steels, with and without Nb stabilization, in air and caustic acid solutions. The steels were tested in the solution-annealed and sensitized states. Under these conditions the grain boundaries were attacked preferentially by intercrystalline corrosion, and became the starting points for the initiation of fatigue cracks; hence these cracks originated in the intercrystalline, but then propagated in the transcrysalline mode. The intercrysalline crack formation was reinforced by mechanical stresses. 14 references.
STRESS CORROSION OF AN AUSTENITIC STAINLESS STEEL SCREEN. (In Port)

The failure is attributed to residual chloride content of the filter clay on the steel screen (AISI 304 wire) used for edible oil filtering. These chlorides (28-44 ppm) are washed out and dissolved by the steam which is blown through the filter every 5.5 hrs. in order to clean the filter aid and to remove residual oil from the filter layer. Repair soldering by using chloride-content flux may contribute to corrosion as well. In order to remedy the situation it is recommended to use a stainless steel screen free from residual stress or a ferritic type steel which, in addition, to being less susceptible to stress corrosion cracking, can be stress-relieved more easily than austenitic steels.

Yuki, N

CORROSION OF STAINLESS STEEL. (In Japanese)

The corrosion of JIS AISI type 304 and 304L stainless steels was investigated in high-purity water at 300° and under a pressure of 85 kg/cm² as a function of chemical composition, heat treatment, and surface prep. The change in 0 content between 0.01% and 0.07% and heat treatment, such as cold treatment and sensitization, did not appreciably affect the corrosion resistance of the stainless steels. Surface finish had a significant effect on the corrosion in high temp. water, pickled specimens showed better corrosion resistance than abraded ones. The specimens which showed a higher corrosion rate by the boiling 40% HNO₃ test specified by JIS also showed a higher corrosion rate under the conditions of the present expr.

Zakharev, D. V. et al

EFFECT OF HEAT TREATMENT ON THE TIME PROCEEDING FAILURE OF SOME STEELS IN CORRODING MEDIA. (In Russian)

The title study was carried out with stainless steels 3H18, Kh18N9T, and Kh15N6T,.
As a control similar testing was done with steel Kh18N10T (after austenitization at 1050°). The chem. compns. of these steels were given. The testing for corrosion cracking was done with ring specimens having a cross section 2.5 x 2.3 mm, whereby well-defined stresses were created as follows: for studied steels 30-50 kg./mm², while for the control Kh18N10T 10, 15, 20, and 25 kg./mm². The corrosion medium consisted either (1) of a boiling soln. of MgCl₂ with the addn. of 5% Fe chloride, or 2) of a steam-air mixt. at 100-105°. In the latter case the surface of specimens was previously coated with NaCl. Steels 2Kh13 and 3Kh13 had no tendency to corrosion cracking in MgCl₂ contg. soln.; however, they disintegrated rapidly owing to general corrosion. Because of this these steels were tested only in the steam-air mixt. Steel 2Kh13 showed corrosion cracking only after hardening and tempering at 500°; while steel 3Kh13 similarly corroded only after hardening and tempering at 150 and 500 corroded only after hardening and tempering at 150 and 500. Steel Kn35TYu showed corrosion cracking only after certain defined heat treatment conditions and only in the boiling MgCl₂ contg. soln. while steel Kh12N20TiR was more sensitive to corrosion cracking in MgCl₂ contg. soln., rather than in air-steam mixt. In general the more thermodynamically stable was the structure of a steel the less was this steel subject to corrosion cracking.

344. Zamiryakin, L K; Chikanov, V K
CORROSION RESISTANCE OF AUSTENITIC STEEL WELDS IN NITRATE SOLUTIONS.

345. Zamiryakin, L K.
EFFECT OF HIGH TEMPERATURE PLASTIC DEFORMATION ON THE SUSCEPTIBILITY OF TYPE KH18N10T AUSTENITIC STEELS TO STRESS CORROSION CRACKING.

STRESS CORROSION CRACKING OF WELD JOINTS OF KH18N10T STEEL.
(A in Russian)
Izvestiya Sibirsk. Otd. 5:6, 24-5; 1968.
347. Tensile tests were made in a tension testing machine for uniaxial extension of specimens rolling 42% MgCl₂ soln. and 300 g. NaOH/kg.
Austenitic Stainless Steels Resistant to Stress Corrosion Cracking and Having High Flow-Resistance. 

Sumitomo Metal Industries, Ltd.
Fr. 1,576,038 15p. 1969. (Patent)

The present invention is concerned with steels in the comp. ranges: C 0.05-0.12, Ni 7-15, Cr 15-20, Mn 0.1-5.0, Si 0.1-3.5, P 0.005-0.01, Mo 0.01-0.04, As 0.005-0.01, and N 0.04-0.2.

Mechanical Properties of Steels.


Work performed under United States-Burman Joint Research and Development Program.

Entrainment tests with and without stress, creep tests, and stress-corr. stress tests were conducted to study the influence of austenite-ferrite and austenitic steels. The stress-creep tests were made in solutions of NaCl, H2SO4, HCl, and HNO3. The results showed that these steels can withstand the following: 1. Creep rupture strength: 2. Stress corrosion cracking: 3. Fracture toughness: 4. Etc.
MECHANISM OF STRESS CORROSION IN STAINLESS STEELS:


The stress corrosion of austenitic stainless steel in a large number of aqueous and non-aqueous media has been studied, with the conclusion that no specific ion, compound, or solvent is essential to the cracking process. Evidence gathered from potential-time curves, acoustic observations, and loading rate studies supports the theory that the crack propagation mechanisms is electrochemical in nature. Furthermore, direct examination of the surface of a stress-corroding specimen by the electrochemical mapping technique revealed that anodic zones coincide with crack sites. It is concluded that investigation of the pre-cracking period of exposure is the most promising area for further study.

NEW STAINLESS STEEL TO RESIST STRESS CORROSION CRACKING.


A high-Cr ferritic steel with good resistance to stress corrosion cracking has been developed. A typical steel contains C 0.03, Si 0.5, Mn 0.6, Cr 15.7, Ni 2.5, Mo 1.0, and Nb 0.5%. Mechanical properties at room and elevated temp. were determined, and welding characteristics studied. Studies of corrosion resistance and stress corrosion cracking in various media are reported briefly.

SOME PHYSICAL CHARACTERISTICS OF AISI TYPE 304 CONTAINING NITROGEN. (Report 438-B.) THE RELATIONSHIP OF NITROGEN CONTENT OF AUSTENITIC STAINLESS STEELS TO STRESS CORROSION.


A STAINLESS STEEL TO RESIST STRESS CORROSION CRACKING.

Engineer, 225:5860, 777; 1968.

Austenitic stainless steels fail by stress corrosion in hot strong solutions of chlorides and acidic substances, especially in heat exchangers where hot gases or liquids are cooled by water. Ferritic steels are resistant to stress corrosion, but ordinary corrosion resistance is limited and post-weld heat treatment is needed.
A ferritic steel F.V. 702 has been developed which is free from the above limitations. Chemical composition is C 0.03, Si 0.5, Mn 0.6, Cr 15.7, Ni 2.5 Mo 1.0, and Nb 0.5%. The Cr, Ni, and Mo contents confer general resistance to corrosion and the Nb and control of C ensure resistance to weld decay. The structure remains ferrite. Tensile properties at room temp. on sheet 0.128 in. thick are UTS 44.5 tonf/in² (70 kgf/mm²), 0.2% FS 38 9 tonf/in² (60 kgf/mm²), elongation, 15% on 2 in. after soaking and at 850°C for 1 h; on a 3/4 in. bar, properties were at 20°C, UTS 45.5 tonf/in² (71 kgt/mm²), 0.2% FS 32.5 tonf/in² (51 kgt/mm²) and at 500°C UTS 31.4 tonf/in² (49 kgt/mm²), 0.2% FS 24.9 tonf/in² (39 kgt/mm²). Elongation (5D) was 22% at both temp. At room temp. the impact strength is limited being 11 ft/1bf (1.52 kgtf/m). Details of welding and corrosion tests are given.

353. **(FV 702) STAINLESS STEEL (VERSUS) STRESS CORROSION.**


A steel FV 702 produced by Firth-Vickers for service in conditions where stress corrosion is a possibility is described. Typical composition is C 0.03, Si 0.5, Cr 16.0, Ni 2.5, Mo 1.0, and Nb 0.5%. The steel is essentially ferritic; it remained uncracked after 500 h in boiling 42% MgCl₂ under 20 ton in⁻² stress, and also after 500 h in 3% NaCl at 225°C, at 10 tons in⁻² stress under 0 at 1500 lbs in⁻².

354. **STRESS CORROSION CRACKING OF Fe-Cr-Ni ALLOYS IN CAUSTIC ENVIRONMENTS.**


355. **STRESS CORROSION CRACKING OF Fe-Cr-Ni ALLOYS IN CAUSTIC ENVIRONMENTS.**


356. **A STUDY OF THE STRESS CORROSION BEHAVIOR OF STAINLESS STEELS.**


EURATOM Joint Research and Development program, 36 p.

EURAEC-1509
A STUDY ON THE STRESS CORROSION OF STAINLESS STEELS IN CHLORIDE SOLUTIONS. (Final Report.)


Work performed under United States-Euratom Joint Research and Development Program.

Tests were performed on eight grades of stainless steel, four with an austenitic structure and four with an austenoferritic structure. Testing devices used for the study are described. Sample preparations are summarized. Tests in boiling concentrated solutions of magnesium chloride to 44% at 153°C, calcium chloride to 62% at 150°C, and sodium chloride (5N) at 107°C were performed. Results are given. Stress corrosion tests in chlorinated water at 150°C were carried out at various pH in low-pressure autoclaves. At 200°C, tests were performed at pH of 2.6, 6.5, and 10. Experimental data are tabulated and results discussed and compared to previous results.
ADDENDUM

350. Balezin, B A et al

INVESTIGATION OF THE EFFECT OF CORROSION INHIBITORS ON THE CRACK CORROSION OF STEEL IX18H9 IN MAGNESIUM CHLORIDE SOLUTION BOILING AT 153°C.


The degree to which inhibitors designated PB-5, PB-8, BA-13 (a condensation product of benzylamine and paraffin), and KI prevented crack corrosion of a steel containing 18.44% Cr, 9.91% Ni, 1.39% Mn, 0.86% Si, and 0.05% C in a saturated MgCl₂ solution boiling at 153°C was studied on specimens kept under a stress of 30 kg/mm². It was found that addition of 0.1 volume% of HCl to the solution increased crack corrosion by a factor of 1.2 and the general corrosion by a factor of 1.5. The primary layer formed on the metal surface which initially localized the attack and protected the surface was slowly dissolved and replaced by a secondary film formed from the hydrolysis products. Addition of PB-5 and of BA-13 together with KI protected the steel against stress corrosion while PB-8, BA-12, and KI alone allowed the corrosive attack without preventing it completely. Cathodic polarization at a current density of 0.005 milliamp/cm² resulted in the complete protection against attack by boiling MgCl₂ containing 0.164% KI. Anodic polarization on the other hand reduced the protective action. The electrochemical behavior of the stressed specimens was determined. Addition of iron salts negated the beneficial effect of PB-5, but had little influence on the behavior of BA-12. Abstractor's note: Russian steel designation 1Cr18Ni9. However, X and H are not element names but initials only, transliterated Kh and N.

359. Birchen, D; Booth, G C.

STRESS CORROSION CRACKING OF SOME AUSTENITIC STAINLESS STEELS AS AFFECTED BY SURFACE TREATMENT AND WATER COMPOSITION.

CONF-28-3


A simple static autoclave test was developed for studying the stress corrosion cracking of austenitic and stainless steels in high-temperature and high-pressure water of relatively high purity. Chloride contents varying from 0.2 ppm upwards in water initially saturated with air can cause cracking under these conditions. A threshold strain was observed below which rounded pits occur and no cracks develop. Above this strain cracking is preceded by the formation of angular pits. The threshold strain is reduced by pickling. Emphasis is given to the need to avoid cold work on stainless steels that are to be exposed to a pressurized-water environment.
360. Clarke, P E; Ristaino, A J.

INVESTIGATION OF CHEMICAL INHIBITORS FOR STRESS CORROSION CRACKING OF STAINLESS STEEL. (Summary Report for January 1964 to June 1957.)

Since recommending coordinated phosphate-pH control for the STR boiler in 1950, numerous laboratory tests, experimental boiler tests, and actual service tests have been made of this treatment with and without supplementary chemical inhibitors, to determine its merit in maintaining proper waterside conditions and particularly in preventing stress corrosion cracking. It has been determined that the treatment originally recommended affords adequate protection for both mild steel and stainless steel surfaces completely submerged in boiler water. However, stainless steel parts exposed intermittently to the boiler water and its vapor are not protected against stress corrosion cracking if both dissolved oxygen (or certain oxidizing agents) and chloride ion are present. There is evidence that caustic alone will cause cracking under the same conditions. This damage has been prevented by supplementary treatment with sodium sulfite oxygen scavenger. A more practicable inhibitor for the stress corrosion problem still is being sought.

361. Coleman, E G et al

ON A SURFACE ENERGY MECHANISM FOR STRESS CORROSION CRACKING. A MECHANISM FOR STRESS CORROSION EMBRITTLEMENT.

ARP-2152-10 1960.

It has been demonstrated that stress corrosion cracks can be initiated on continuous loading in a suitable medium. Results are shown for stainless steel immersed in boiling MgCl₂ solution and for a Mg-6% Al alloy in aqueous NaCl-K₂Cr₂O₇ solution at room temperature. This behavior has been used to analyze the stress corrosion cracking process in terms of the dislocation theory of brittle fracture. It is proposed that the mechanism of cracking originates from a condition of reduced surface energy brought about by adsorption of some ion species from the surrounding medium. An analysis of the grain size dependence of the fracture initiation stress in the stress corrosion media leads to estimates of reduced surface energies of the order of 10⁰ to 200 ergs/cm².
362. Corinou, H et al
50215 SENSITIVITY TO STRESS-CORROSION AND INTERGRANULAR ATTACK OF HIGH-NICKEL AUSTENITIC ALLOYS.

363. Gulbransen, E A
UNUSUAL CRYSTAL GROWTHS OBSERVED IN THE HIGH-TEMPERATURE CORROSION OF 304 STAINLESS STEEL AND IRON. (Research Report 6-94602-1-R5.)
NR-7699 19p. 1957.
Electron microscope and electron diffraction studies were made on the corrosion products formed on 304 stainless steel and iron in dry air and oxygen, oxygen saturated at 25°C with water vapor, and oxygen saturated at 25°C with H₂O vapor plus a few parts per million of HCl vapor. In addition to the formation of the normal layer type of oxide film, many fine oxide whiskers were formed on from at 500°C in wet and dry oxygen atmospheres. These whiskers grow nearly perpendicular to the surface and were 300 to 1000 angstroms thick and up to 470,000 angstroms long. The density of whiskers was 10⁷ to 10⁹ per cm². The oxide was α-Fe₂O₃. With stainless steel, oxide whiskers of Cr₂O₃ were formed 100 to 500 angstroms thick and up to 50,000 angstroms in length. Some areas of the specimen were free from whiskers while other areas contain up to 10⁸ whiskers per cm². In atmospheres containing HCl vapor at 600°C, fan shaped single crystals of Cr₂O₃ were formed. These grow nearly perpendicular to the surface and were about 100 angstroms thick, 10,000 to 5,000 angstroms in height and 100,000 angstroms long. These crystals appear in parallel layers. Pre-straining of the specimens with stress levels greater than the yield point greatly accelerates the growth of the fan shaped crystals. It was proposed that this crystal habit may be important in determining whether a given alloy is susceptible to stress corrosion cracking.

364. English, J J; Griess, J C
STRESS CORROSION CRACKING OF AUSTENITIC STAINLESS STEEL IN URANYL SULFATE SOLUTIONS.
Corrosion, 20: 138t-44t; 1964.
The effects of a number of variables on the stress corrosion cracking behavior of two different heats of Type 347 stainless steel were examined in simulated aqueous homogeneous reactor fuel solution containing low concentrations of chloride ions.

Contd...
The fuel solution consisted of uranyl sulfate, sulfuric acid, and copper sulfate. Tests were conducted in the temperature range of 50 to 101°C. Although the two heats of stainless steel were nearly identical in composition, specimens from one heat were consistently more susceptible to cracking than specimens from the second heat. Chloride concentrations of 25 to 500 ppm were equally effective in producing cracks. The higher the dissolved oxygen content in solution, the more numerous and intensive were the cracks. Cracking was still observed, however, in the absence of oxygen. Uranyl sulfate concentration was an important variable; at concentrations of 0.40M and greater, no cracking took place with chloride present. Sodium dichromate was found to be an effective cracking inhibitor. Pretreatment of specimens in chloride free fuel solution either before or after stressing greatly reduced cracking susceptibility during subsequent exposure in the fuel solution containing added chloride.

Bent and bolted austenitic Cr-Ni steel specimens about 1/8 in. thick, "considerably" stressed while suspended in boiling 42% MgCl₂ solns. at 154°C in flasks having reflux condensers, resist cracking for at least 20 days if the Ni content is > 19, Cr 16-25, P < 0.018, Co 0.07-0.1, Si ≤ 1.6, N ≤ 0.045 with P + N ≤ 0.085, Mn ≤ 0.2, Cu ≤ 0.1, Bi, As, and Sb each ≤ 0.015, Mo ≤ 0.05, and Al either below 0.05 or above 0.06%. Ti and Nb are undesirable because of lowering the effective C content. Forged, cold-rolled, annealed, and sensitized specimens of 30 compns. were tested to derive these conclusions, which were approx. the same irrespective of such treatments. The cracking was generally more rapid as the divergence of the compn. from the stated limits increased. Vacuum melting is not required for resistance to this type of failure, but 0.12% P of more such as improves high-temp. strength must be avoided. The Ni content need not be over 35%. The Ni, C, and P limits are all especially crit. U.S. 3,159,479; 5pp. With higher Si, the C limits are not crit., the permissible compn. limits for no cracking in the same test for 20 days being as given in the previous patent with the exceptions of Si 1.7-2.5% and C up to 0.04%. The conditions of testing were the same, and results from 23 compns., mostly contg. <1.7% Si, are reported and discussed. The Ni, Si, and P limits are here considered esp. crit.

365. Copas, H R; Lang, F S

STAINLESS STEELS RESISTANT TO STRESS CORROSION CRACKING,

An extensive study was conducted on the susceptibility of Type 347 stainless steel to stress-corrosion cracking in high temperature water over wide ranges of chloride concentration, temperature, oxygen concentration, and pH. No cracking was observed at a chloride concentration of 5 ppm, but cracks were observed at 10 ppm and higher at temperatures of 100°C and above. Maximum susceptibility was found between 150 and 250°C, but no cracking was found below 100°C. No pH effect was noted. Various heat treatments and surface preparations showed no appreciable effect. Nickel plating, even with only partial covering of the surface, was found to inhibit stress-corrosion cracking completely, while chromate and phosphate in solution were effective only at high concentrations. Five other austenitic stainless steels were similar in behavior to Type 347 stainless steel, and three ferritic stainless steels exhibited only slightly better resistance to cracking. Of five high nickel, high chromium alloys tested, only Inconel exhibited complete immunity to stress-corrosion cracking. Cast chromium-nickel stainless steels were found to be extremely resistant to stress-corrosion cracking as long as they were not subjected to cold working or plastic deformation.
Once stressed above the yield the resistance to cracking could not be regained by annealing. A number of the alloys tested in high temperature water were also tested in boiling 42% MgCl₂. It was found that the susceptibility of an alloy to stress corrosion cracking in boiling 42% MgCl₂ solution is not necessarily a measure of its susceptibility in high temperature water containing relatively small concentrations of chloride ion.

369. Pashoa, T J

STAINLESS STEEL FAILURE INVESTIGATION PROGRAM. (First Quarterly Progress Report, February 15–June 30, 1965.)

GEAP-4915 1965.

A number of type 304 stainless steel clad fuel rods operating in boiling water reactor environments have failed due to intergranular cracking. Factors that may affect intergranular cracking of austenitic stainless steels are discussed and the research program proposed is described. The program consists of the investigation of the effects of material composition, coolant environment, irradiation damages, and operating stresses on clad cracking. In preliminary corrosion tests, high purity stainless steels proved more corrosion resistant than type 304 stainless steel. Intergranular attack was produced by boiling HNO₃ +Cr⁺ solutions, transgranular attack by boiling MgCl₂ solutions, and either transgranular or intergranular in FeCl₃ solutions at 343°C depending on test variables. A cladding specimen section through a region of localized strain revealed an incipient intergranular crack starting on the outside surface and extending 0.6 mils across the 14 mil cladding thickness. Eighty-four references on intergranular cracking in austenitic stainless steel are included.

370. Pennington, R T

NUCLEAR SUPERHEAT PROJECT ELEVENTH QUARTERLY REPORT, JANUARY–MARCH 1962.


Result of a study concerning the optimum type or types of superheat elements are presented. A seven-rod fuel element appears to be the most promising design for nuclear superheaters. It is recommended that the combination-type element with internal coolant channels be investigated. Physics work during period was devoted to the core for a 600-MW(e) reactor.
Results of analysis of flooding effects on reactivity are presented along with data on effects of moderator temperature and control rod worth. Examination of fuel element 8H-5A after irradiation at 750-845°F for 1000 hr. revealed small cracks in the cladding of intergranular nature. A description of the NUSU irradiation operation is included. Data are included on the ESH-1 and ESH-2 fuel design. Data are included which show that the stainless steel tubing rejection rate is about 10%. Development of welding parameters for 10- and 20-mil.-thick inconel, Hastelloy X, Hastelloy N, Ni-0-NeI, and stainless steel is reported. It was found that end plunges involving these alloys can be welded without undue preparation. Test work done on type 304 stainless steel stress corrosion is summarized along with results of a 1000-hr check on stress corrosion of Inconel and Incoloy. Results are also included on the effects of 1100°F steam on Hastelloy N and Inconel, and on the SH-5A and NuSu tests. In mechanical development efforts during the period were devoted to procurement of a plastic shroud for air-water testing and to a series of steam-water tests. A design and irradiation summary for SADE fuel elements is given. Work on the E-SADE is about 70% complete. Information is included on design of the 75-Mw(e) Mixed Spectrum plant along with data information of the Mixed Spectrum Superheater Critical Experiment.

The response characteristics of three chromel-alumel thermocouples to a ramp function change in temperature in the Bettis Foater Flow tube with the Core-I core cluster were determined. Experiments to obtain information of film boiling at elevated pressures in a forced-convection system were performed. The water parameters covered were: water inlet temperature 500 and 600°F, pressure 2000 psig, and mass flow rates 0.4 x 10^6 to 1.5 x 10^6 lb/hr-sq ft. Stress corrosion cracking of 304 stainless steel pipe by exposure to chloride-bearing water is being investigated. Fission product release and zirconium-water explosion hazards in core meltdown were evaluated by melting two zirconium-uranium subassemblies in a steam atmosphere.
372. Posey, W J (ed.)

PROGRESS REPORT NO. 50 FOR DECEMBER 1958 AND JANUARY 1959.
MSA Research Corp., Callery, Penna.

Film boiling runs made in tubes containing water showed considerable axial variation around the heat exchanger. Heat balance at low JaK flows was off by about 30%. Loop modifications were made, and tests will continue. Studies of chloride stress corrosion on stainless steel and Inconel pipe were conducted. The stainless steel stress corroded in one to four days depending on thermal cycling temperature. No coating was found which would provide extended protection. Coating with water glass prevented cracking in one 100-hour cycling test. Inconel did not stress corrode; however, pitting occurred in a 5-week thermal cycling test. Seventeen protective coatings were tested, four of which appeared to offer the best protection. These include coating 9 (Mn base), coating 5 (Ni base), coating 10 (Al base), and coating 6 (Zn base).

373. Turner, F; Richardson, H K

INVESTIGATION OF CRACKS IN AN 18/13/1 STAINLESS-STEEL AUTOCLAVE.

A stainless steel autoclave used in the corrosion testing of metals in water failed by stress corrosion in the vicinity of a weld. Welding had been by metallic arc using flux-coated electrodes and a slag deposit was found at the weld root in the failed area. The flux and resultant slag deposit were proved to contain significant amounts of chloride. The slag deposit was connected with the autoclave interior via the interface between the base plug and wall. This provided the corroding medium which in the presence of water residual plus operating stresses caused failure by stress corrosion cracking. Recommendations are made for the avoidance of this type of failure.

374. Waber J T; Waber, S

ACCELERATED CORROSION TEST OF STEELS;

General tests have been made on materials being considered for duct work in the new CMR laboratories in an effort to determine which would be most satisfactory. Materials tested were "A" Nickel, "B" Monel, Inconel, Inconel B, and Types 316, 316 LEC, and 318 stainless steel.
General accelerated corrosion tests were run in a simulated hood with the metals in contact with the fumes of six solutions—five concentrated acids and one alkali. The saw kerfs in each specimen were examined for stress corrosion. Welded specimens of the metals were also tested for stress corrosion cracking and for intergranular attack of the heat-affected areas. The stainless steels and inconel showed the best resistance to general chemical attack. Inconel offers the additional feature of being free from stress corrosion susceptibility and pitting. Hence, it is preferable by more than a slight margin. In general, the results of these corrosion tests agree quite well with general commercial experience. The use of inconel is recommended for the duct work because, of the freedom iron stress corrosion and pitting. Stress corrosion tests were run on seamless and welded stainless-steel tubing in the standard magnesium chloride reagent. The samples cracked abundantly after a few hundred hours. Considerable protection was afforded by heat-treating the tubing at 1950°F for one-half hour and then air-cooling. Where stainless tubing is used for drains, the 1950°F heat-treatment is recommended. It is also desirable that the steel be pickled before being passivated.

375. Wanklyn, J N et al

THE CORROSION OF AUSTENITIC STAINLESS STEELS UNDER HEAT TRANSFER IN HIGH-TEMPERATURE WATER.


The corrosion of two 18-8 austenitic stainless steels under stress and boiling heat transfer in oxygen-free water at pH 11 and 280°C has been studied. On plane surfaces, heat transfer does not significantly increases corrosion in times up to 1000 hours. In crevices where heat transfer causes superheating and concentration of solutions, stress corrosion cracking occurs. This is due to the caustic alkali (60 ppm) required to raise the pH to 11; by comparison, a chloride concentration of 0.5 ppm in the bulk water has a negligible effect. Unlike the previously reported stress corrosion by caustic alkali, the cracking is wholly intercrystalline. The minimum superheat and caustic concentration required to produce it are about 25 to 35°C and 40 to 50 wt. % KOH, respectively. The better-known transcrystalline cracking appears to require higher concentrations than this. In the appropriate solutions intercrystalline corrosion is possible in virtually unatressed metal, but mechanical failure is more rapid at stresses of the order of 20,000 psi (1400 kg/cm²).
Stress Corrosion Screening Tests of Materials for Steam Generator Tubing in Nuclear Power Plants.

Corrosion 16, 320t-41; 1980.

Nuclear power plant steam generator tubing materials were tested for their susceptibility to chloride stress corrosion cracking. Stressed U-bend specimens were exposed for 24 hours in a tilting autoclave to both the liquid and vapor phases of a high pH synthetic boiler water solution containing oxygen, phosphate, and 500 ppm of chloride ion. The results indicate that AISI Type 347 stainless steel, the control material, and Carpenter TMo are about equally susceptible to stress corrosion cracking in this test environment. Carpenter 20Cb and Type 304 having low carbon and nitrogen content displayed improved resistance. Inconel, Monel, nickel, and titanium displayed complete resistance. Ferritic steels were crack resistant but they did suffer pitting attack.

Mechanisms and Some Theoretical Aspects of Stress Corrosion Cracking of Austenitic Stainless Steels.


After reviewing briefly the generally accepted causes of stress corrosion cracking of stainless steels, design of heat exchangers intended for use with chloride containing waters is considered. Conditions causing stress corrosion cracking make tube-side cooling better than shell-side, favor designs eliminating stagnation and make mandatory operation resulting in full water boxes. Velocity in excess of 5 fps is recommended. Insulation containing chlorides should be protected from moisture and water temperatures kept as low as possible. Good aeration is necessary and recirculating waters should contain no chromates or other oxidizing compounds. While pH is not critical, this does not mean that pH in concentration cell anolytes is not important. Theoretical considerations involved in the stress corrosion cracking phenomenon are considered. Plastic deformation, which results in the accumulation of stresses at barriers along a slip plane, is viewed as a precedent to cracking. Nickel, among alloy constituents, is seen as beneficial in preventing cracking, and the reasons for this are suggested as an avenue of fruitful investigation. The nature of the corrosion phenomenon, involving such complex factors as films, adsorption effects, and electrical double layers are mentioned as areas where more study would be rewarding. Possibility of thermal or electrochemical concentration of chlorides must be designed out, cleaned out, cleaned out, or kept out of industrial cooling water systems.
A fifth test of the HRT core-pressure-vessel flanges and transition mockup was made. No leakage occurred. Metallographic examination has shown the occurrence of stress corrosion cracks on the outside of a straight section of type 347 stainless steel pipe exposed to a tap and demineralized water spray. A hydride phase was found metallographically in a Ti-75A sample holder exposed to UO₂F₂ and in a Ti insert exposed to CO₂-free UO₂SO₄. It was shown that SO₃/4 inhibits corrosion of stainless steel in UO₂SO₄ at 250°C. The initial run in the new all-Ti loop, loop H, gave low corrosion rates on pretreated stainless steel coupons. The second run gave higher corrosion rates which may be due to a difference in pretreatment of coupons. Films formed on stressed type 347 stainless steel by exposure in boiling and aerated chloride-free UO₂SO₄ solution were found to provide at least some protection to the alloy from stress corrosion cracking when exposed in a similar solution containing chloride ions. A number of alloys of Zr were tested in simulated HRT fuel solution.
382. Gries, J C, et al
CORROSION BY SOLUTIONS.
ORNL-5262(P-90-8)

383. Cochran, R W; Stachle, R W
EFFECTS OF SURFACE PREPARATION IN THE STRESS CORROSION CRACKING OF STAINLESS STEEL.
C00-1319-40 117p. 1966.

The effect of surface preparation on the incidence of stress corrosion cracking of Type 310 stainless steel was investigated. Wire specimens were used and exposed to boiling MoO3. Surfaces were prepared by mechanical polishing at three levels of roughness, chemical polishing, vacuum annealing, and electrochemical polishing. A wide range of mean times to cracking was noted. Mean times differed by about a factor of five. Distribution of cracking times also varied about the mean values. Mechanically polished specimens cracked in shorter times than those chemically polished or vacuum annealed. The data were rationalized in the terms of probability of forming chemically active slip steps.

384. Stachle, R W
INVESTIGATION OF CRACKING IN STAINLESS STEEL FUEL ELEMENTS. (Period Covered December 1964–August 1965.)
C00-1319-30 82p. 1965.

An investigation was undertaken to elucidate the nature of cracking mechanism near by a number of stainless steel clad fuel element failed in experimental assemblies in the VENR. The experimental investigation included optical metallography, microhardness, Huey tests, anodic polarization, chemical analysis and electron microscope fractography. An attempt was made to rationalize observation on the basis of cracking mechanism which was either entirely mechanical or chemical mechanical. Such an approach was desirable in order to assess whether the cracking was applicable only to the specific experiment or to a broad range of reactor types and materials. Because of the lack of physical information, no definite conclusion regarding either mechanism was obtained. While the evidence available at this time seems to favour a chemical mechanical or stress corrosion cracking type of mechanism, it is believed that a sufficiently good case exists for the mechanical idea that it cannot be discounted. Recommendations are given regarding specific experiments which should be performed to reach a credible conclusion.
MATERIALS PROBLEMS AND SELECTIONS IN THE ENRICO FERMI FAST BREEDER REACTOR.

The basic structural material is the primary sodium system of the Enrico Fermi Fast Breeder Reactor (EFFBR) is austenitic stainless steel. Where strength properties permit, type 304 stainless steel has been used. For components requiring higher strengths, types 316, 321 and 347 have been used. The intermediate heat exchangers and basic piping of the secondary system is also of type 304 stainless steel. The steam generators are made of a 2 1/4% Mo low-alloy steel. Stress corrosion cracking of the steam generator tubing has been observed and has been related to the cleaning procedure used. Austenitic stainless steel is susceptible to self-welding and galling when in intimate contact with itself. This is particularly so in a sodium environment. As a result, considerable effort has been devoted to evaluation of various surface treatments or coatings that can be applied to the stainless steels to prevent galling in both inert atmospheres and in sodium. In general, it was found that the harder materials such as chromium plate, nitrided surfaces, and hard-face coatings gave superior resistance to galling under most conditions. Nitriding of the stainless steel has been used more extensively with good success. The one exception has been on the application to dummy subassembly nozzles. Here, it is believed that the nitriding was substandard with respect to processing and that higher-than-anticipated loads were encountered during non-nuclear testing; as a result, the nitride layer was subject to galling. In all other applications, the nitride was found to be adherent.

BONUS BOILING WATER NUCLEAR SUPERHEAT REACTOR PROJECT. TASK FORCE REPORT ON CHLORIDE STRESS CORROSION OF AUSTENETIC STAINLESS STEEL.

TIS-16888 34p. 1962.

COOLANT CHEMISTRY AND CORROSION.

SAW-5603 (p. 90-123)

The elimination of hydrogen and oxygen in high-pressure, high-temperature steam from a boiling-water reactor using commercial catalysis is discussed. Water chemistry measurements and a catalytic recombination experiment for borax are reported. The Pathfinder chemistry and stress corrosion programs are discussed. Stress corrosion studies of Fe-Ch-Al alloys in superheated environments are reported.
Incoloy 800 fuel cladding corrosion and localized corrosion of type-304 SS and nickel-base alloys in superheated steam were studied. Oxidation products distributions during exposure to superheated steam were studied for 300-series SS and nickel-base alloys with and without heat transfer. The development of a digital readout programmed dissolved gas analyzer is reported. The EVESR chemistry programs are described.
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