PROGRAMA DEL SEMINARIO

Febrero 26, 1999

8:00-8:30	**Registro de Asistentes**
8:30-8:45	**Bienvenida** Ing. Alejandro Villalobos Hiriart IMP **Inauguración del evento** Ing. Rafael Vega Monter PEMEX
9:00-9:15	**Introducción** Dr. Charles Smith –MMS
9:15-10:45	**Fundamentos de Soldadura Húmeda** Dr. Stephen Liu – CSM
10:45-12:15	**Casos Prácticos** Tom Reynolds– Global
12:15-12:30	**Receso**
12:30-14:00	**Diseño de Soldadura Húmeda** Rodger Holdsworth – RRS Engineering
14:00-16:00	**Receso**
16:00-17:00	**Regulación** Tommy Laurendine– MMS
17:00-17:15	**Receso**
17:15-18:15	**Certificación y Aseguramiento de Calidad** Bill Hanzalek – ABS
18:15-18:45	**Necesidades de PEMEX** Roberto Ortega, Faustino Pérez – IMP
18:45-19:15	**Panel preguntas y respuestas**
19:15-19:30	**Clausura** Ing. José B. De León Pérez PEMEX

CONTENIDO

INTRODUCCION

Las instalaciones marinas de Petróleos Mexicanos, particularmente las plataformas, están expuestas a varios riesgos de origen ambiental y operacional que pueden dañar los componentes estructurales o poner en riesgo la integridad de dichas instalaciones.

PEMEX ha venido efectuando inspecciones submarinas a las plataformas desde 1982, aplicando una filosofía desarrollada en el Instituto Mexicano del Petróleo (IMP) con asistencia técnica de la compañía Det Norske Veritas (DNV). Como resultado de dichas inspecciones se han detectado una gran variedad de daños, causados por las actividades de operación que en las plataformas se realizan y por efectos del oleaje de operación y de huracanes. Algunos de los daños han sido reparados, a otros únicamente se les ha monitoreado su crecimiento y el resto se han considerado sin importancia por sus dimensiones.

Por la ubicación de los daños, su costo y sus limitaciones, las alternativas de reparación existentes son pocas, entre ellas tenemos:

- Abrazaderas cementadas
- Abrazaderas mecánicas
- Remoción de grietas por esmerilado
- Soldadura hiperbárica
- Soldadura húmeda

Esta última ha sido empleada con éxito en la sustitución de elementos estructurales de plataformas del Golfo de México y del Mar del Norte, de acuerdo con la literatura técnica existente. Sin embargo, en México ha tenido poca aplicación, en donde se ha aplicado no se han obtenido los resultados esperados, por ello el IMP con PEMEX Exploración y Producción Región Marina Noreste realizan un proyecto para identificar el estado del arte de la Soldadura Submarina, las instituciones y compañías que emplean esta tecnología, los requerimientos, etc., de tal manera que PEMEX pueda adquirir y aplicar la tecnología en la reparación de daños en elementos estructurales de plataformas.

Con el propósito de conocer el estado del arte de la soldadura húmeda y difundirlo entre personal de PEMEX y del IMP, el IMP conjuntamente con la Escuela de Minas de Colorado (CSM) organizaron el Seminario de Soldadura Húmeda, el cual fue patrocinado por PEMEX Exploración y Producción Región Marina Noreste y por el Minerals Management Service (MMS) de los Estados Unidos.

CHARLES E. SMITH

Nació el 11 de Octubre de 1942 en Waynesville Carolina del Norte.

Curso la carrera de Ingeniero Civil en el Instituto Militar de Virginia en 1965.

Cuenta con dos maestrías la primera en Ingeniería de Estructuras cursada en el Instituto de Tecnología de Georgia en 1967 y la segunda en Mecánica Aplicada cursada en la Universidad de Virginia en 1972.

Realizó sus estudios de Doctorado en Estructuras y Dinámica en la Universidad George Washington en 1994.

Actualmente es Gerente de Programas de Investigación del área de Ingeniería e Investigación en el Minerals Management Service Department of the Interior.

El Dr. Smith se incorporó al Minerals Management Service (MMS) (antiguamente la División de Conservación, Prospección Geológica de los Estados Unidos), en 1991 fue colaborador del Gerente del Programa de Investigación y Desarrollo, en las Operaciones de Minerales Costafuera, en 1993 el Dr. Smith asumió el cargo de Gerente de Programas de Investigación del Programa de Evaluación de Tecnología e Investigación el cual realiza estudios generales con universidades, compañías privadas y laboratorios gubernamentales para evaluar la integridad estructural de plataformas y líneas costafuera, métodos de monitoreo adecuados, factores humanos y administrativos y contención de derrames de aceite y procedimientos de limpieza total para asegurar las operaciones libres de contaminantes.

Antes de incorporarse al MMS el Dr. Smith fue Capitán de la Sección de Ingeniería (División de Ingeniería Civil) de los Cuarteles Generales de la Guardia Costera de los Estados Unidos (USCG), donde trabajo como asesor y consejero del personal de la USCG en cuestiones técnicas relacionadas a problemas de Ingeniería Civil y Estructuras. Sus principales áreas de interés fueron en análisis y diseño de torres atirantadas, ingeniería en sismo y viento, plataformas costafuera y ayuda para resistir el hielo en la navegación.

Esta registrado como Ingeniero Profesional y es miembro de muchas sociedades profesionales, particularmente del Instituto Americano del Concreto (ACI) donde fue el presidente anterior del Comité 301 (Especificaciones para Concreto Estructural), de la Sociedad Americana de Ingenieros Civiles (ASCE) donde es miembro del comité en confiabilidad de estructuras costafuera y del consejo técnico de Ingeniería en las regiones frías, del comité de diseño y construcción. El Dr. Smith es miembro de honor de la sociedad Thu Beta Pi y ha publicado muchos artículos técnicos relacionados a estructuras costafuera.

DR. STEPHEN LIU

El Dr. Liu se recibió como Ingeniero Químico Industrial en 1971, de la Escuela Técnica Federal de Minas Gerais en Brasil. Mientras colaboraba como Químico Analista y catedrático obtuvo el grado de Ingeniero en Metalurgia en 1976 en la Escuela de Ingeniería de la Universidad Federal de Minas Gerais.

Trabajó varios años como investigador en metalurgia con la compañía Acesita Specialty Steels Corporation. Durante el mismo periodo recibió el grado de Maestro en Ciencias en Metalurgia en la misma universidad.

En 1984, el Dr. Liu completó su Doctorado en Ingeniería Metalúrgica en la Escuela de Minas de Colorado, y se incorporó al Departamento de Ingeniería Industrial de la Universidad Estatal de Pennsylvania, como Asistente de Profesor en Manufactura y Procesos de Fabricación

Regresó a la Escuela de Minas de Colorado en 1987, en donde actualmente es Profesor Asociado y Profesor de Ingeniería Metalúrgica y de Materiales. El Dr. Liu ha enseñado y conducido áreas de investigación en metalurgia de los aceros, soldadura y recubrimientos.

Dr. Liu es Autor y Coautor de más de 170 publicaciones técnicas. Ha recibido varios reconocimientos de la Sociedad Americana de Soldadura (AWS), entre los que están el Premio McKay-Helm (1986), Adams Memorial Membership (1988), Miembro Distinguido (1993), Robert L. Peaslee (1994), District Meritorious (1994), y Miembro Honorario (1996). Dr. Liu fue elegido miembro del AWS en 1996. Por su trabajo de investigación en consumibles de soldadura humeda la prestigiada Engineering New-Record seleccionó al Dr. Liu como uno de los 25 más novedosos en la industria de la construcción en 1996. También recibió el premio al desempeño que otorga ASME-OMAE en 1991 y el premio SAE Teetor (1986). El Dr. Liu es actualmente Jefe de Editores de la revista Offshore Mechanics and Arctic Engineering de la Sociedad Americana de Ingenieros Mecánicos ASME.

Activo en varias sociedades profesionales entre las que estan la Sociedad Americana de la Soldadura (AWS), ASM Internacional, Sociedad de Metalurgia y Materiales, Sociedad Americana de Ingenieros Mecánicos, Sociedad de Soldadura de Japón, y del Instituto de Materiales (Miembro Profesional). El Dr. Liu también es un Ingeniero Profesional Registrado ante el Consejo de Ingeniería del Reino Unido.

RODGER D. HOLDSWORTH
Director of Management Systems
RRS Engineering

Rodger Holdsworth es Director de Sistemas Administrativos de la Compañía RRS Engineering, localizada en Nueva Orleans, Louisiana

Tiene mas de 27 años de experiencia en la solución de problemas, toma de decisiones en el manejo de proyectos, programas y sistemas sirviendo a la industria costafuera y terrestre, incluyendo los 4 años anteriores en la administración del proceso de seguridad y certificación.

Ha ocupado varias posiciones de administración técnica y de negocios relacionadas con la revisión de diseño de equipo, integración de sistemas mecánicos, construcción costafuera, sistemas de calidad y desarrollo de administración PSM.

Además de servir como un auditor dirigente y calificado de ISO 9000 y PSM y líder de grupo de trabajo para la certificación de Integridad mecánica. Rodger Holdworth ha fungido como jefe de proyecto en varios proyectos que requirieron el desarrollo de sistemas de manejo independiente de integridad mecánica, programas para identificación de riesgos, análisis de confiabilidad y riesgo para instalaciones terrestres y marinas.

Proporciona también capacitación para manejo de software, servicios de consultoría en auditorías PSM, análisis de procesos de riesgo, Integridad mecánica PSM, RPM y desarrollo de sistemas de calidad y su implantación.

Antes de integrarse a RRS Engineering, Rodger Holdsworth colaboró con Primatech Inc., como gerente de servicios de consultoría y con American Bureau of Shipping (ABS) en el grupo de Verificación Industrial como gerente de distrito de los estados del Golfo, sus responsabilidades incluían manejo de servicios técnicos para la industria relacionados con calidad, seguridad, riesgo, inspección y certificación de equipo y sistemas de ingeniería

El Sr. Holdsworth es miembro de ASQC, TC 207 (ISO 14000) en manejo de sistemas y funcionamiento, preside el comité D3 de Soldadura en la Construcción Marina, y el D3b. para Soldadura Húmeda, y miembro del Comité Técnico del AWS.

THOMAS T. LAURENDINE, P.E.

Curso la carrera de Ingeniero Civil y una Maestría en Ciencias en la Universidad de Nueva Orleans

Por lo que Respecta a su experiencia profesional, desde septiembre de 1996 trabaja como Ingeniero Estructural en el Minerals Management Service (MMS) en Nueva Orleans.

Es responsable de las modificaciones, reparaciones e inspecciones de las plataformas localizadas en la Placa Continental del Golfo de México

Está registrado como Ingeniero Civil en el Estado de Louisiana

Es miembro de la Sociedad Americana de Ingenieros Civiles (ASCE)

En 1998 recibió el premio MOISSEIFF de la Sociedad Americana de Ingenieros Civiles (ASCE) por el artículo titulado "Efecto de la Presión Externa en la Resistencia de Miembros Tubulares Cortos"

ROBERTO ORTEGA R.

Curso la Carrera de Ingeniero Civil y es candidato a Maestro en Ciencias de la Escuela Superior de Ingeniería y Arquitectura del Instituto Politécnico Nacional.

Actualmente es Jefe de la División de Plataformas Marinas del Instituto Mexicano del Pétroleo y Coordinador de Proyectos de Diseños Especiales.

Tiene más de 23 años de experiencia en el área de plataformas marinas y fue profesor de estructuras de la Escuela Superior de Ingeniería y Arquitectura.

FAUSTINO PEREZ G.

Curso la Carrera de Ingeniero Civil en la Escuela Superior de Ingeniería y Arquitectura del Instituto Politécnico Nacional.

Actualmente es Jefe del Departamento de Inspección y Mantenimiento de Plataformas del Instituto Mexicano del Pétroleo y Coordinador de Proyectos de Inspección de Plataformas Marinas.

Ha participado en un proyecto de fatiga en aceros de alta resistencia en la Universidad de Londres.

Tiene más de 11 años de experiencia en el área de plataformas marinas.

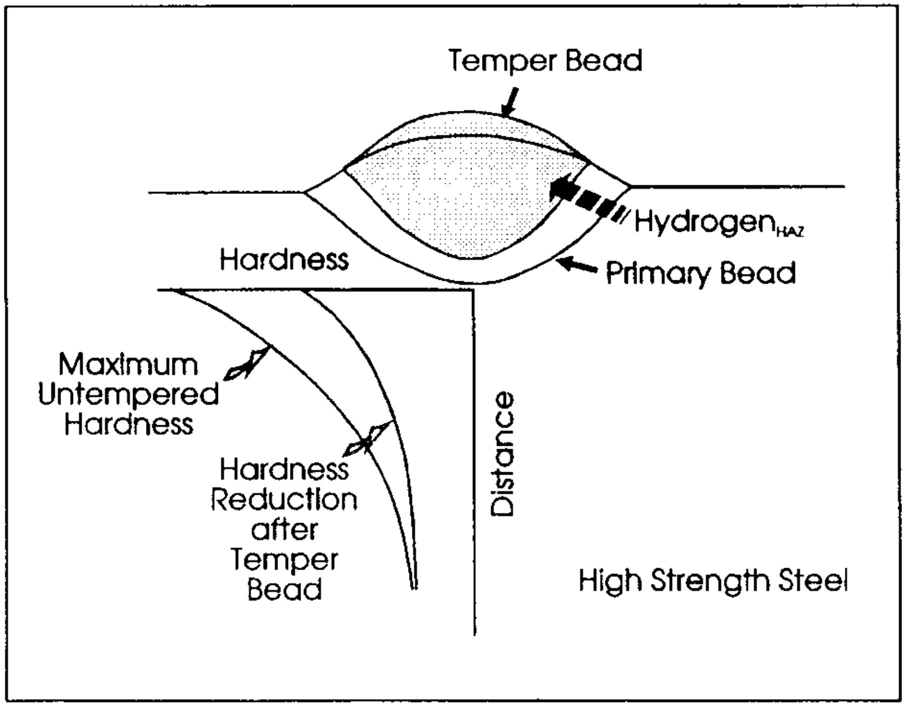
Underwater Wet Welding Electrodes

Special Waterproofing Preparations

- Coatings Reported
  - Organic Coatings
    - Varnish
    - Vinyl
  - Mineral Coatings
    - Rutile Powder
    - Alumina-Silica
    - Aluminum-Silica
  - Metal Powder Coatings
    - Aluminum Powder

UWT - Recent Advances

- Hydrogen & Cracking Control
  - Temper Bead Technique



Advances in Underwater Wet Welding

Chemistry and Materials Related Enhancements

- Improvement in Welding Electrode Design
  - Coating with Specific Functions
    - Thermal Experience Control
      - Exothermic Properties
    - Oxygen Potential Control
      - H-O and C-O Shift
    - Oxide Formation
    - Alloying Element Control
      - Acicular Ferrite Optimization
    - Shielding Gas Control
      - CO/CO_2 Ratio and Volume
    - Arc Stability

Welding Consumables and Weldability

R&D Needs in Wet Welding Consumables Development

- Process
  - SMAW, FCAW
- Type
  - E6013, E7024
  - Oxidizing
  - Nickel-Based
  - Overcoating
- Minimum Porosity
    - H_2, CO/CO_2
  - Controlled Alloy Composition
  - Selected Microstructure
    - Acicular Ferrite
  - Designed Mechanical Properties
    - Toughness, Elongation and Strength
  - Deep/Shallow Water Application

Welding Consumables and Weldability

R&D Needs in Structural Steel Underwater Weldability

- HAZ Hydrogen Cracking
  - Base Metal Hardenability (CE)
  - Electrode Coating/Flux Conditioning
  - Stress Intensity
- Weld Metal Hydrogen Fissuring
  - "Hardened" Microstructure
  - Electrode Coating/Flux Conditioning
  - Stress Intensity
- Weld Metal Porosity
  - Water Depth
  - Electrode Coating/Flux Conditioning
  - Arc Stability
- Chemical Composition Variation
  - Water Depth
  - Controlling Mechanism
- Solidification Cracking
  - Weld Pool Geometry
  - Solidification Rate

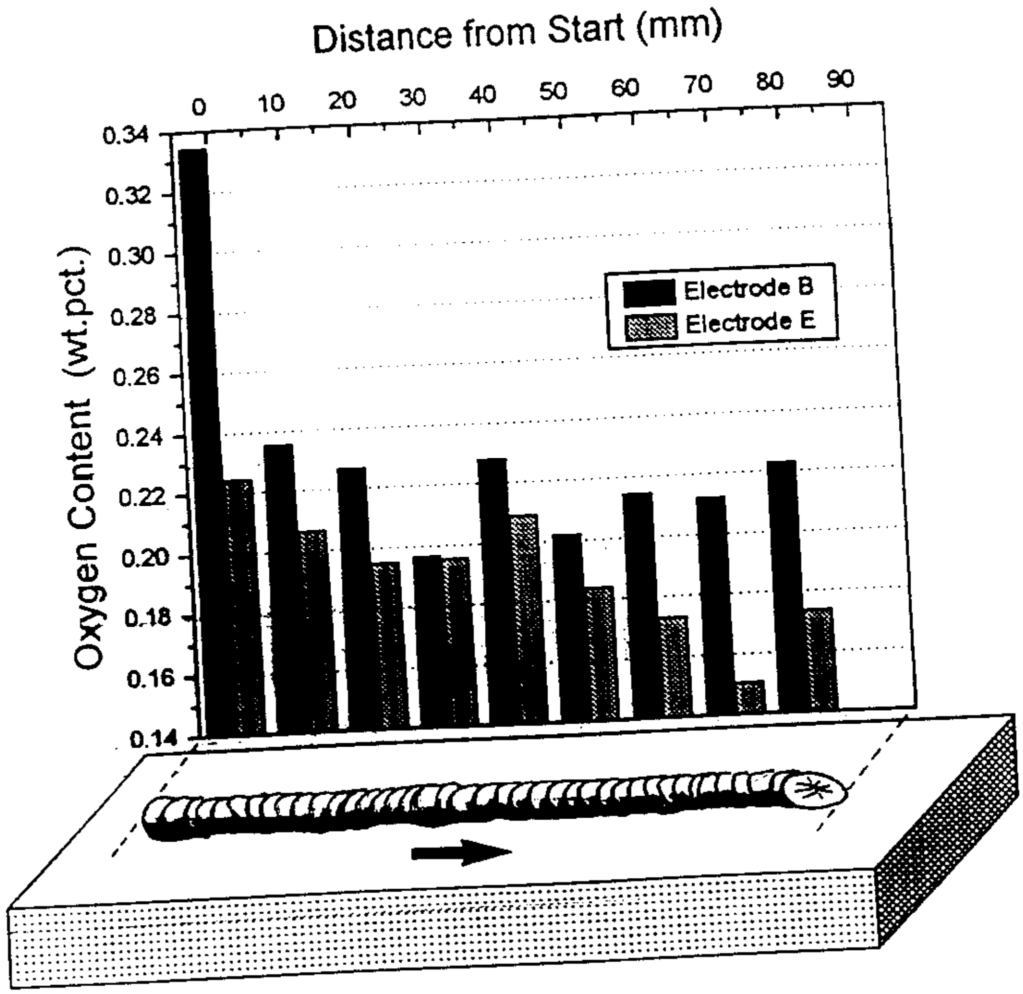


Figure 4.11 Variation of the oxygen content along the length of weld beads deposited by electrodes B and E.

Fundamental Developments in Underwater Wet Welding

Professor Stephen Liu
Center for Welding, Joining and Coatings Research
Colorado School of Mines
Golden, Colorado 80401
U.S.A.

Underwater Welding Seminar at PEMEX/IMP
Ciudad del Carmen, Mexico
February 26, 1999

Underwater Wet Welding Research at CSM

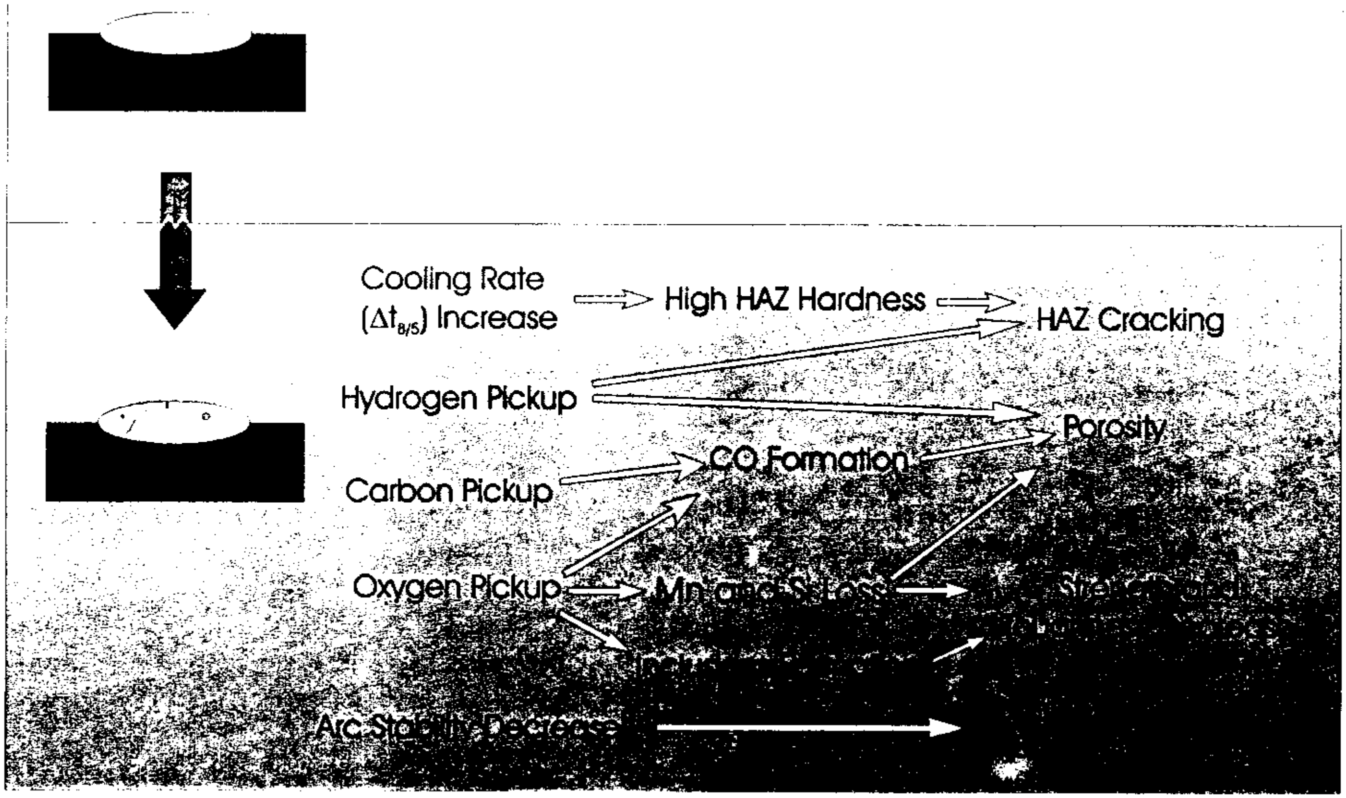
- *Recent Research Collaborators*
  - Dr. Alberto Sanchez - Ecoexel, Mexico
  - Dr. Alexandre Pope - Petrobras, Brazil
  - Dr. Raimundo Medeiros - FBTS, Brazil
  - Mr. Mark Rowe - CSM-CWJCR, USA
  - Mr. Charles Lenfest - Armco, USA
  - Dr. Wesley Wang - Lincoln, USA
  - Dr. David L. Olson - CSM-CWJCR, USA
  - Dr. Santiago Ibarra - BP/Amoco, USA
  - Mr. Tom Reynolds - Global Divers, USA
  - Mr. Whitey Grubbs - Global Divers, USA
- Research Collaborators
  - Prof. Nils Christensen - SINTEF, Norway
  - Prof. Øystein Grong - SINTEF, Norway
  - Dr. Glen R. Edwards - CSM-CWJCR, USA
  - Dr. David K. Matlock - CSM-ASPPRC, USA

Fundamental Developments in Underwater Wet Welding

- Underwater Wet Welding
- Weld Composition Variation
- Weld Porosity Formation
- Fe-O versus H-O Control
- Hydrogen Mitigation
- Solidification Mechanism
- Weld Metal Toughness Improvement
- Summary

Underwater Wet Welding: Background Process and Metallurgical Problems

Problems in Underwater Wet Welding



Underwater Wet Welds - Quality Criteria

- AWS D3.6 Specification
  - Type A Welds - Dry Habitat
    - Structural Applications
    - Customer Requirements
  - Type B Welds - Wet Welds
    - Limited Structural Applications
    - Customer Requirements
  - Type C Welds
    - Non-Structural Applications
    - Crack-Free Welds
  - Type O Welds - Dry Habitat
    - Compliance with Code/Specification
    - Customer Requirements

AWS D3.6 Specification - Minimum Requirement for Class A (Dry) Welds

- Base Metal Strength - 51 to 89 ksi
  - All Weld Metal Elongation - 14%
- Base Metal Strength - 70 ksi
  - CVN Impact Energy - 15 ft-lb @ 32°F
- Ductility
  - Bend Test Radii - 2T

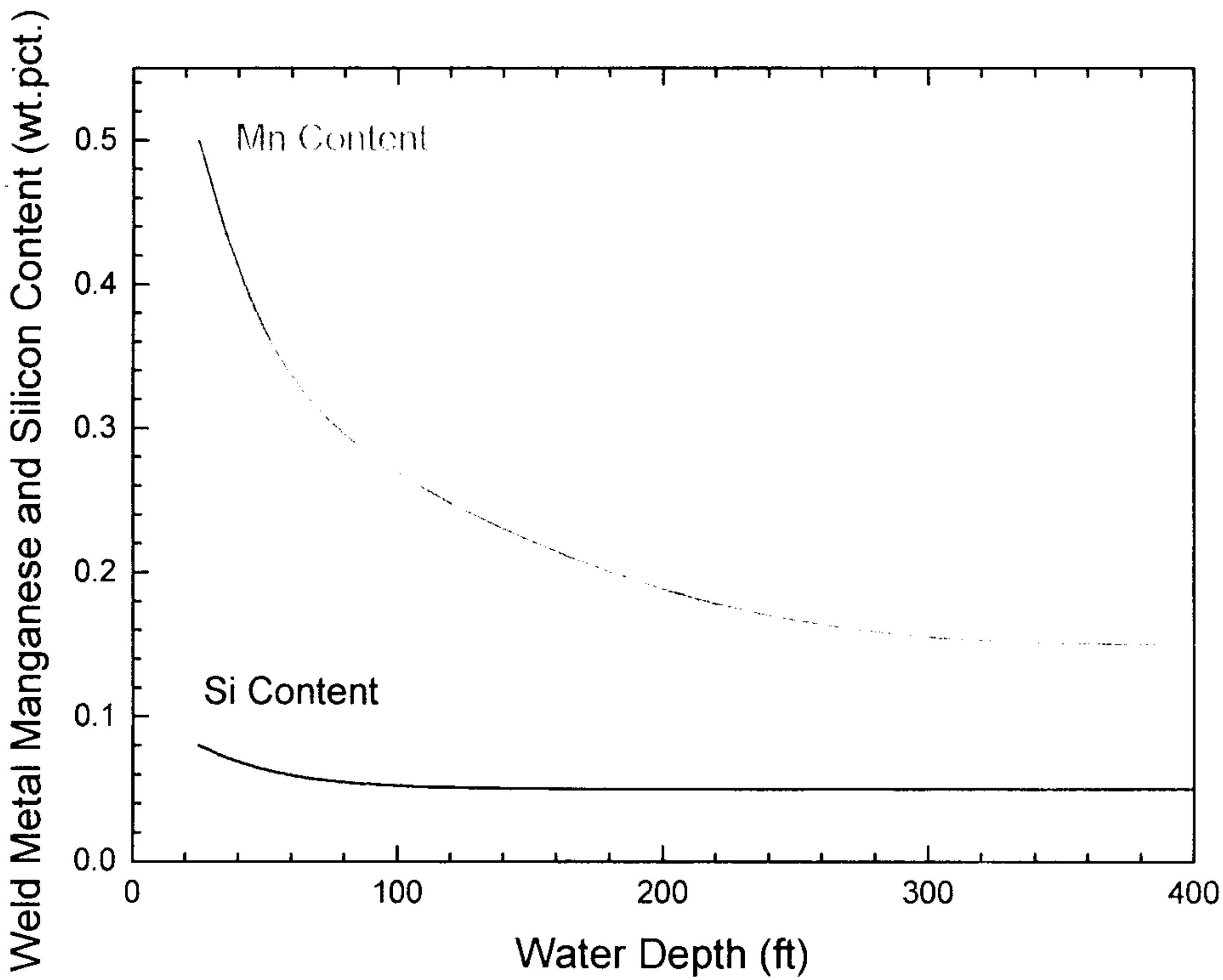
AWS D3.6 Specification - Minimum Requirement for Class B (Wet) Welds

- Porosity Based on Number and Diameter
  - 1.6 mm (1/16 in.) < d < 5 mm (3/16 in.)
    - 7 per inch (Weld) per inch (Plate Thickness) Maximum
  - d > 5 mm (3/16 in.)
    - Not Allowed
  - d < 1.6 mm (1/16 in.)
    - Unrestricted

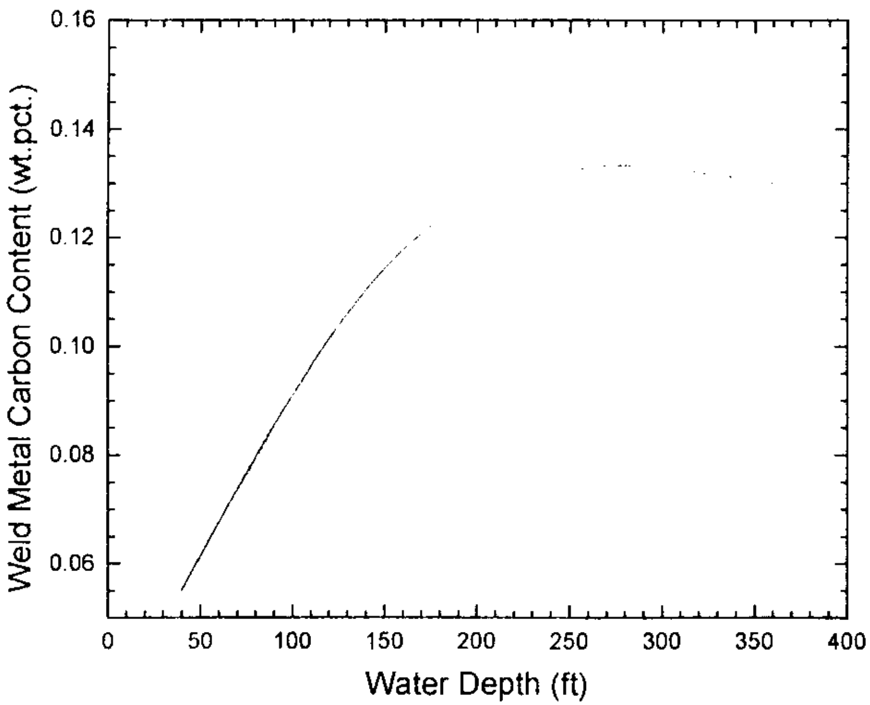
Common Underwater Wet Weld Problems

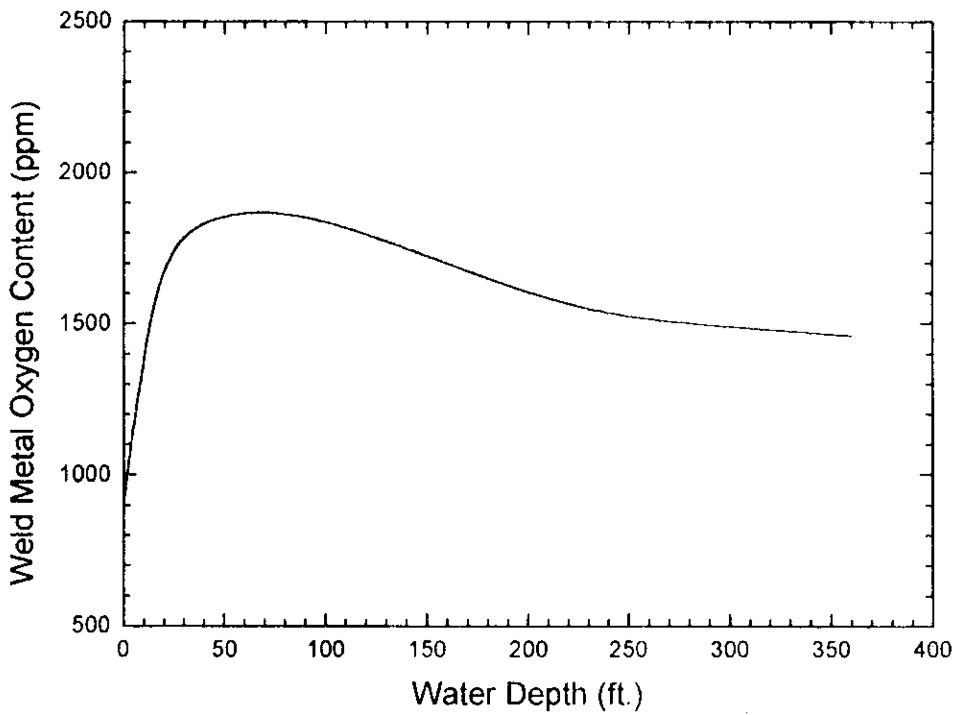
- Alloying Element Loss
- Weld Metal Porosity
- Carbon and Oxygen Pickup
- Hardened Microstructure
- HAZ Cracking
- Slag Entrapment

Weld Pool Phenomena
Hardenability Element Loss



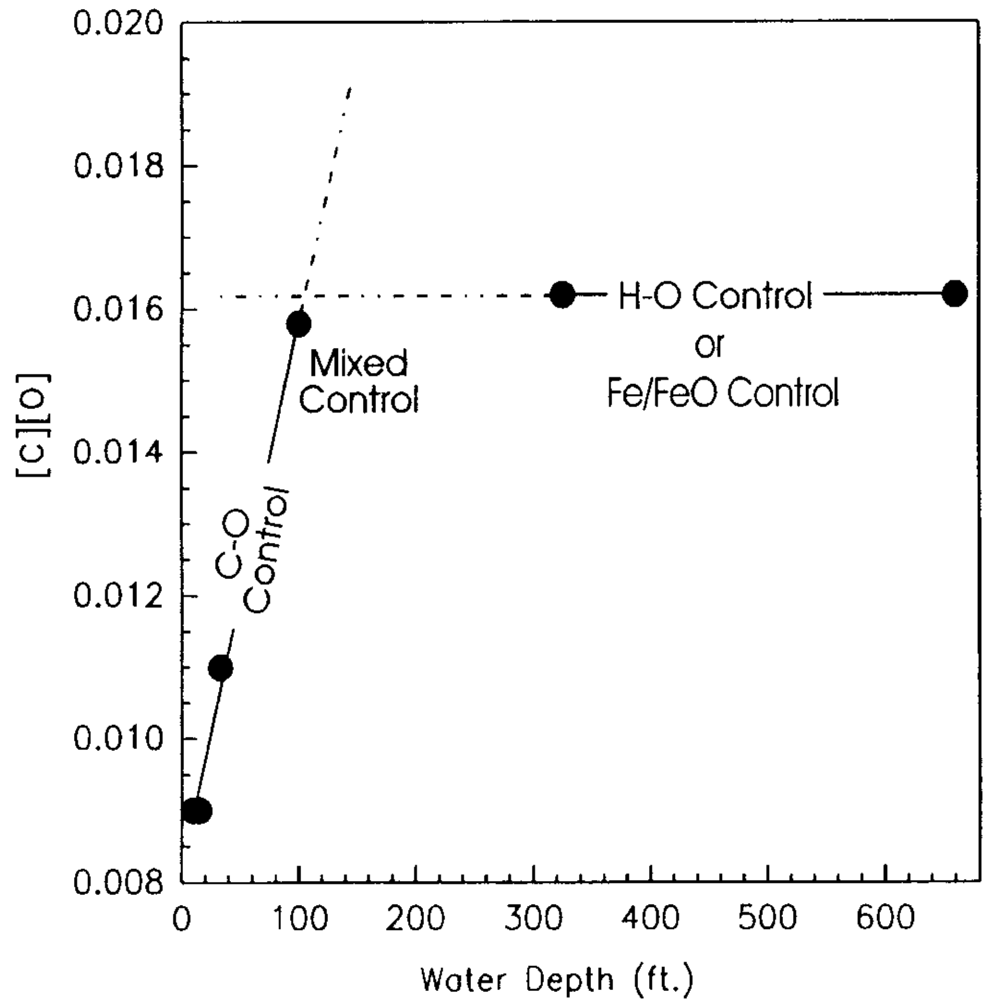
Weld Pool Phenomena
Carbon and Oxygen Pickup





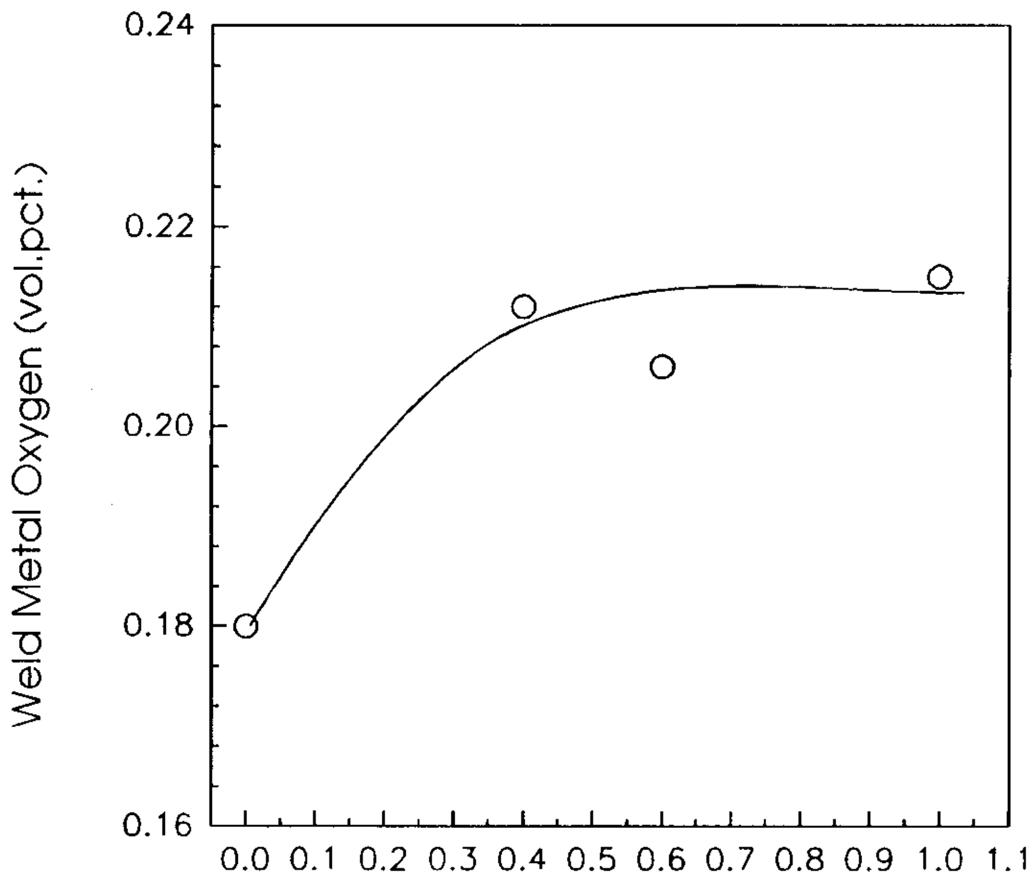
Weld Pool Phenomena

C-O vs H-O Control



Weld Pool Phenomena

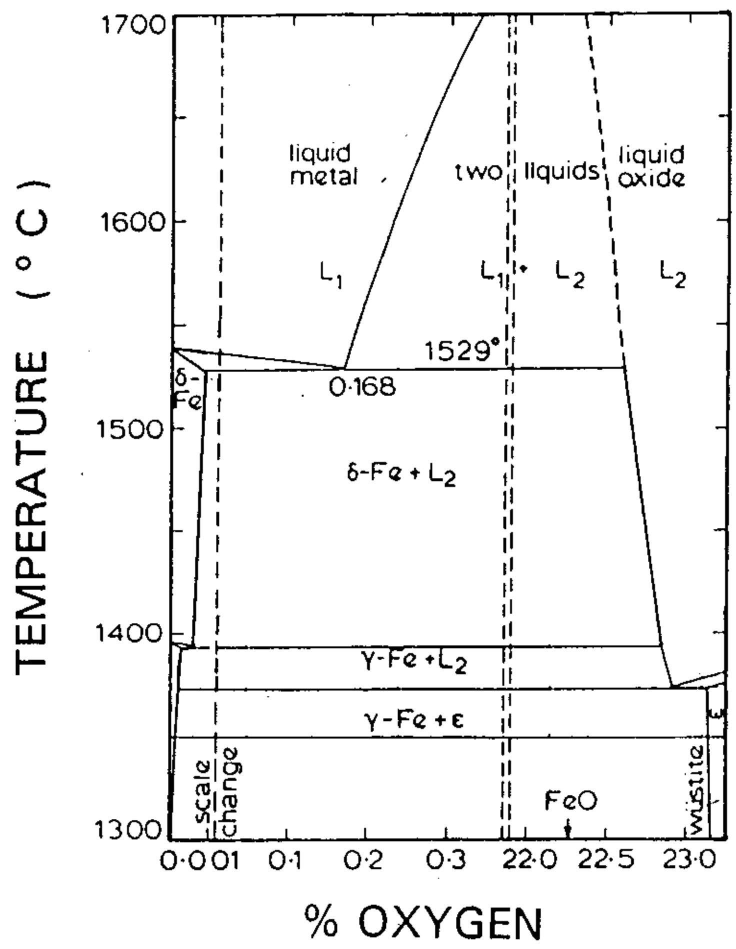
Oxygen Pickup - Fe-FeO Control



$$\alpha = \frac{Fe_2O_3}{Fe_2O_3 + TiO_2}$$

Background: Oxygen in Liquid Iron

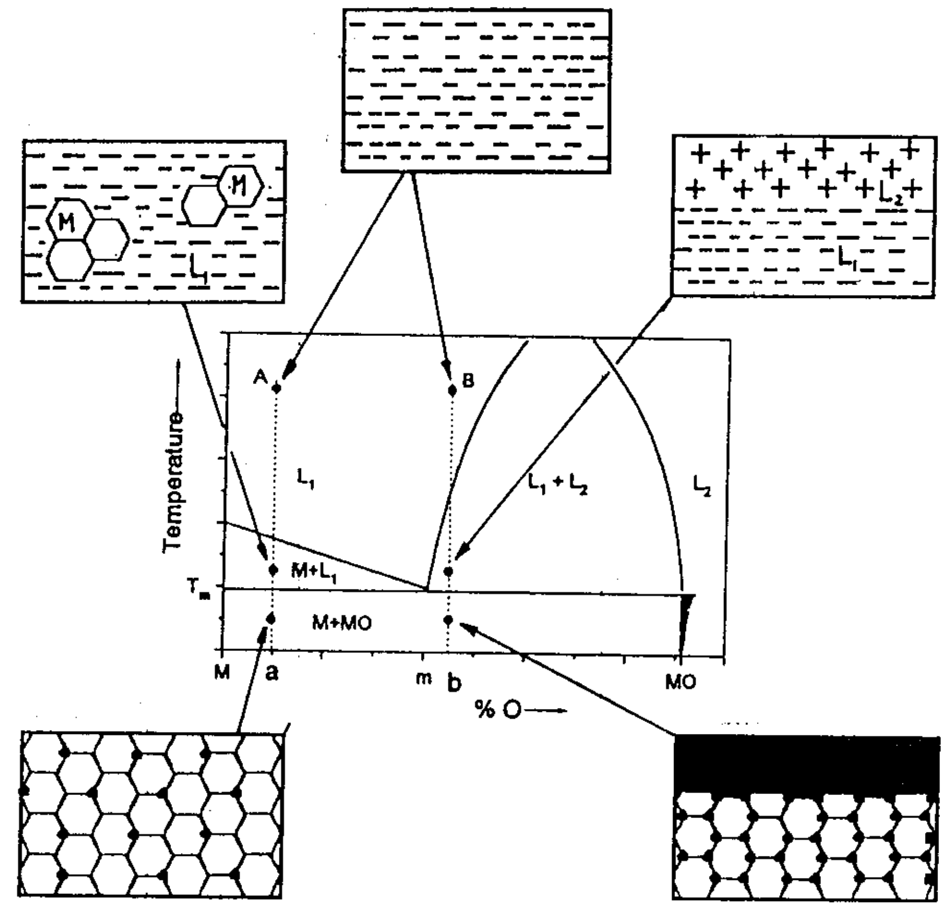
Iron-Oxygen Equilibrium



(van Vlack, 1977)

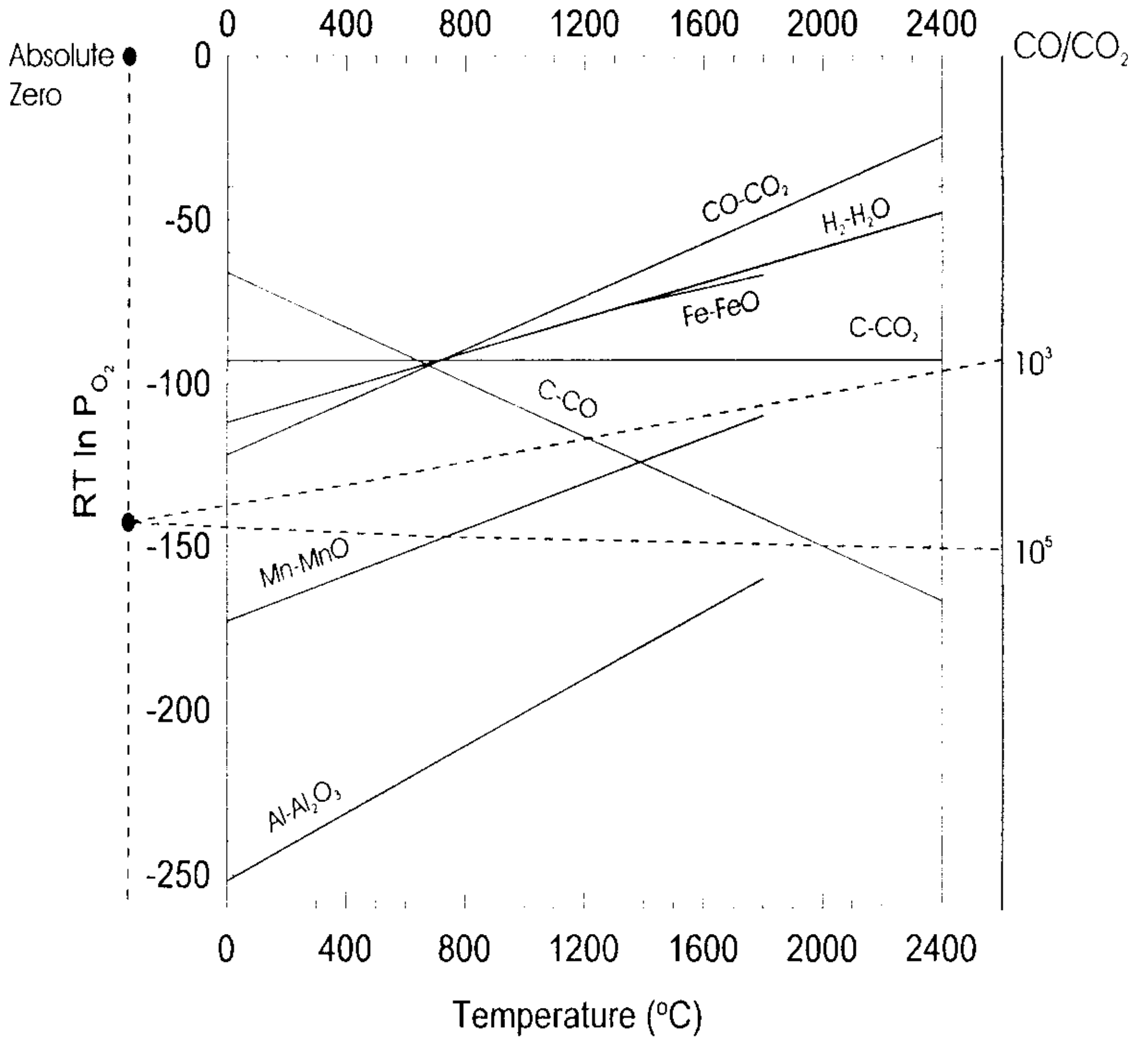
Results and Discussion

Solidification in a Hypothetical M-O System



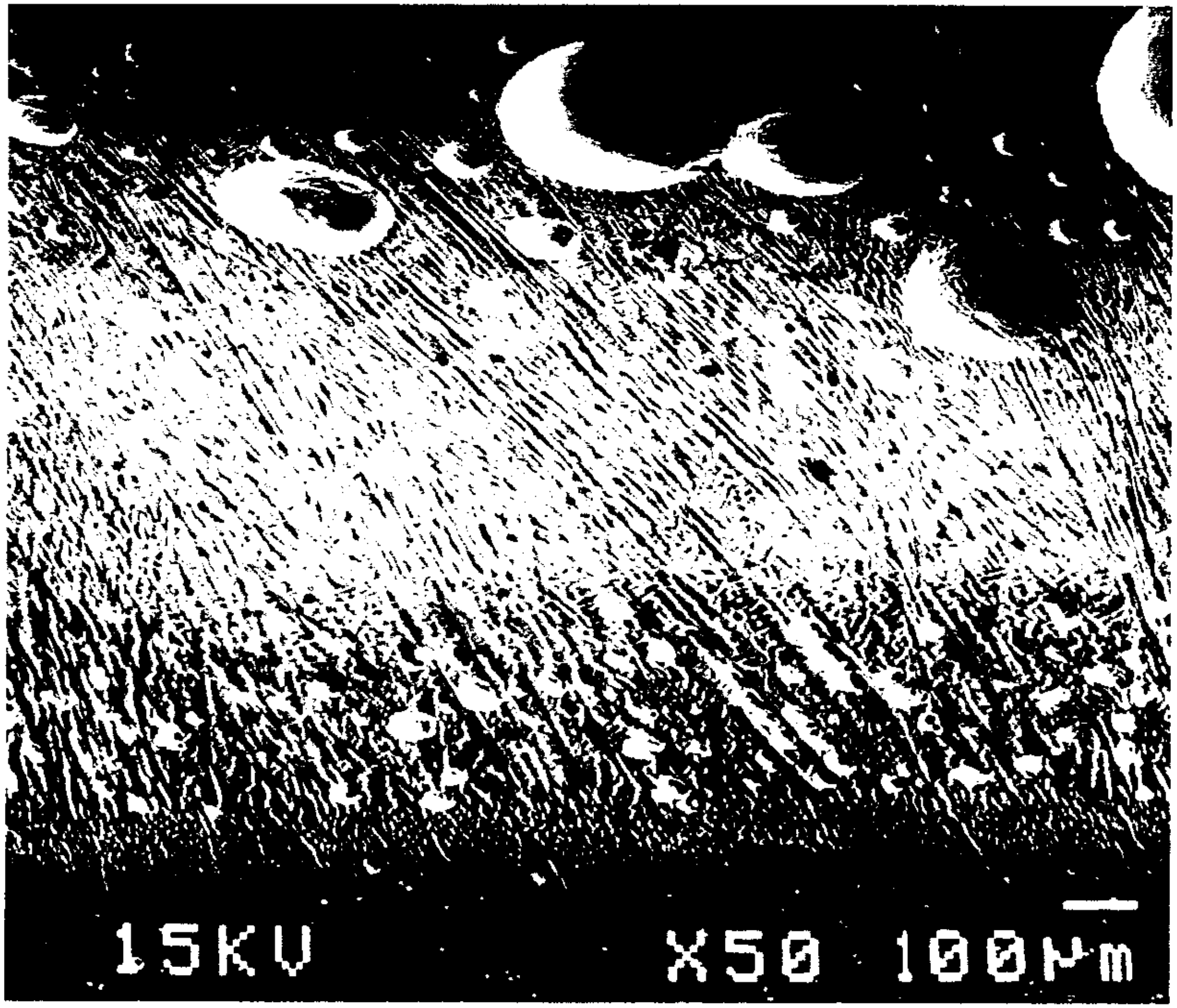
Weld Pool Phenomena

Relative Oxide Stability



Underwater Wet Weld Defects

Weld Metal Porosity



Underwater Wet Weld Defects

Weld Metal Porosity Composition (vol.pct.)

	H_2	CO	CO_2	Others
Suga & Hasui	96	0.4	0.06	--
Silva	62/82	11/24	4/6	--
Gooch	45	8	4	4

Weld Pool Porosity Formation

Gas Producing Chemical Reactions

Hydrogen - Oxygen System

$$H_2O \Leftrightarrow 2\underline{H} + \underline{O} \qquad [\underline{H}]^2[\underline{O}] = K_1 \cdot P_{H_2O}$$

$$H_2O_{(V)} + Fe \Leftrightarrow FeO + H_{2(g)}$$

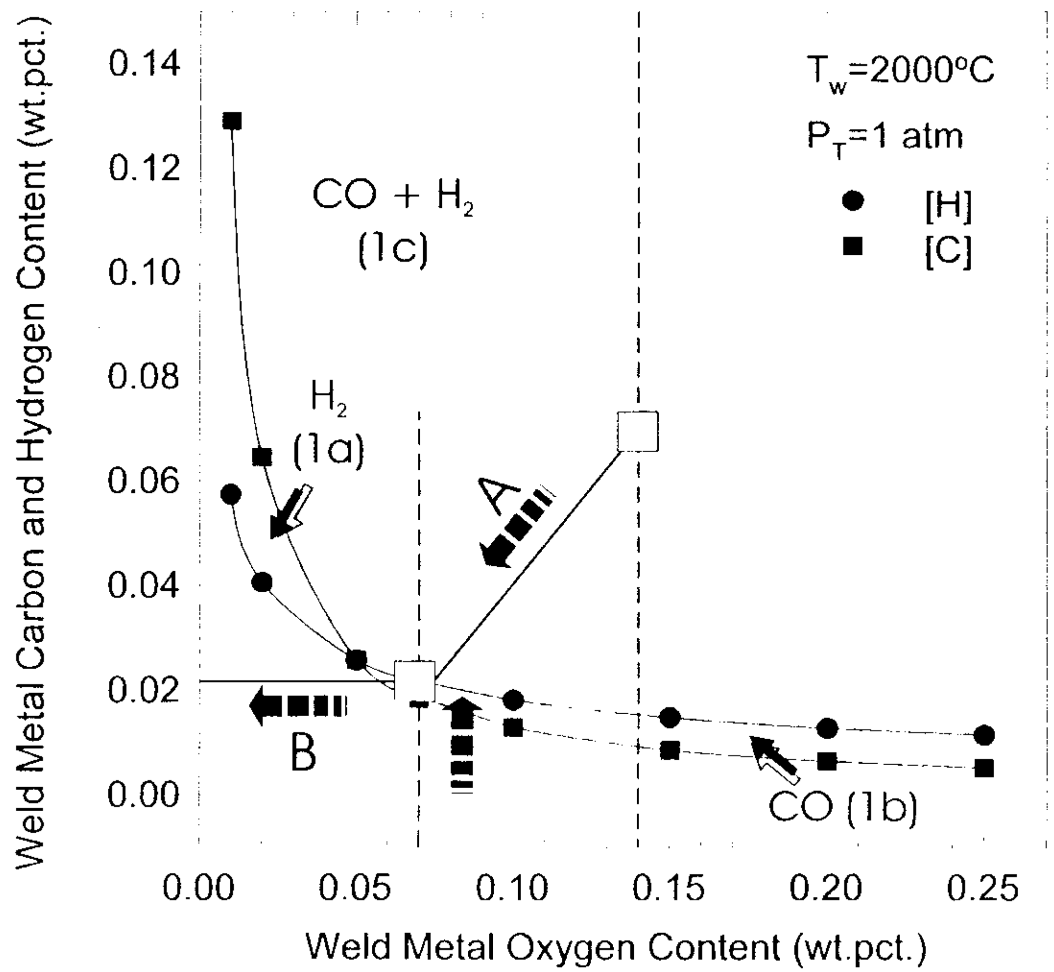
Carbon - Oxygen System

$$2CO_{2(g)} \Leftrightarrow 2CO + O_2$$

$$CO \Leftrightarrow \underline{C} + \underline{O} \qquad [\underline{C}][\underline{O}] = K_2 P_{CO}$$

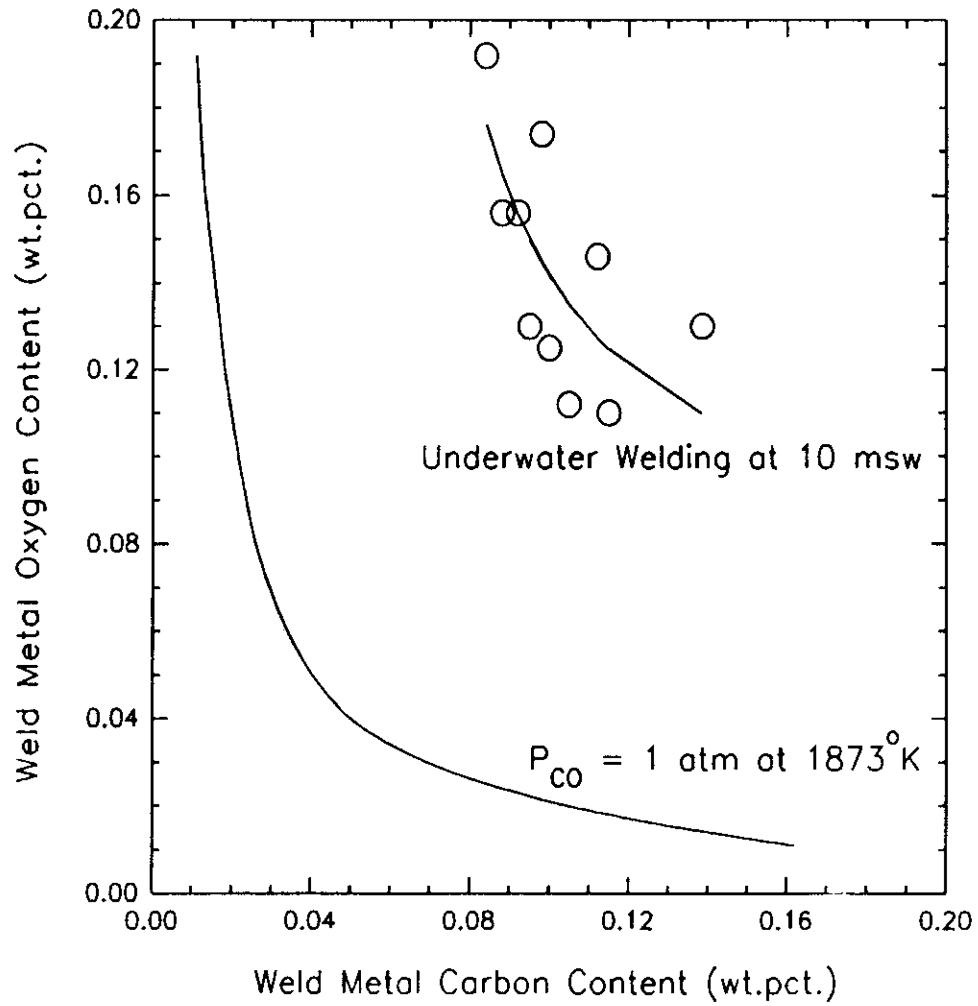
Weld Pool Porosity Formation

Origin of Porosity - Liu et al.



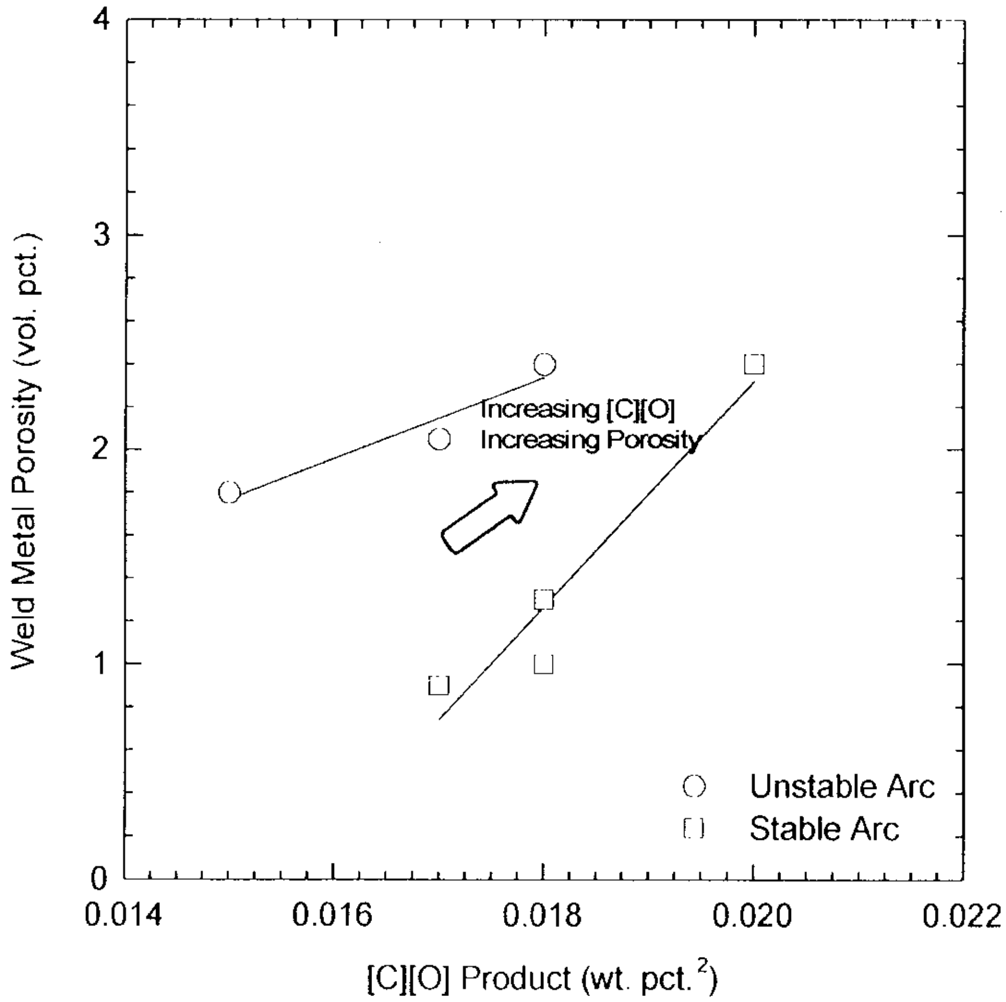
Weld Pool Phenomena

Carbon-Oxygen "Equilibrium"



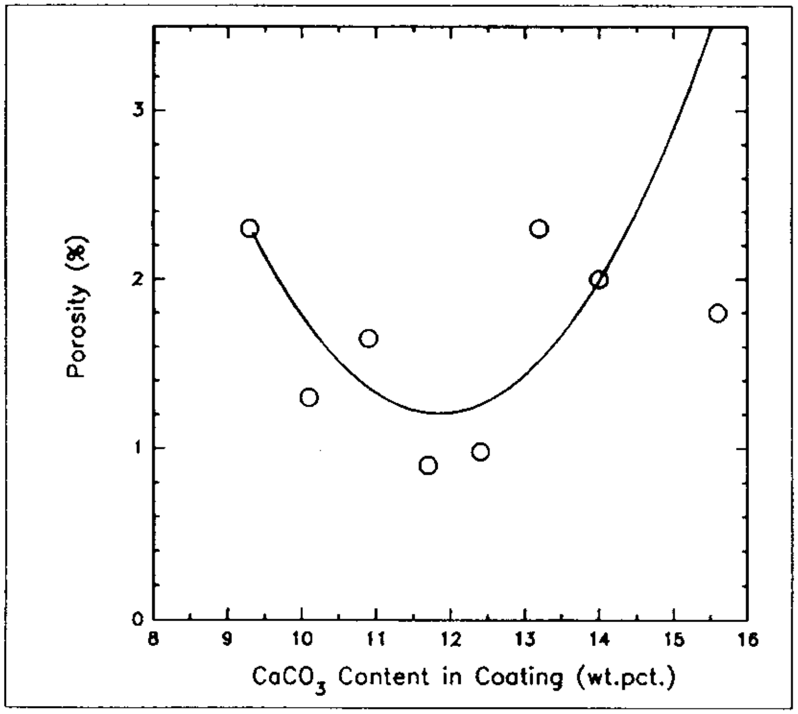
Weld Pool Porosity Formation

Origin of Porosity - Sanchez et al.



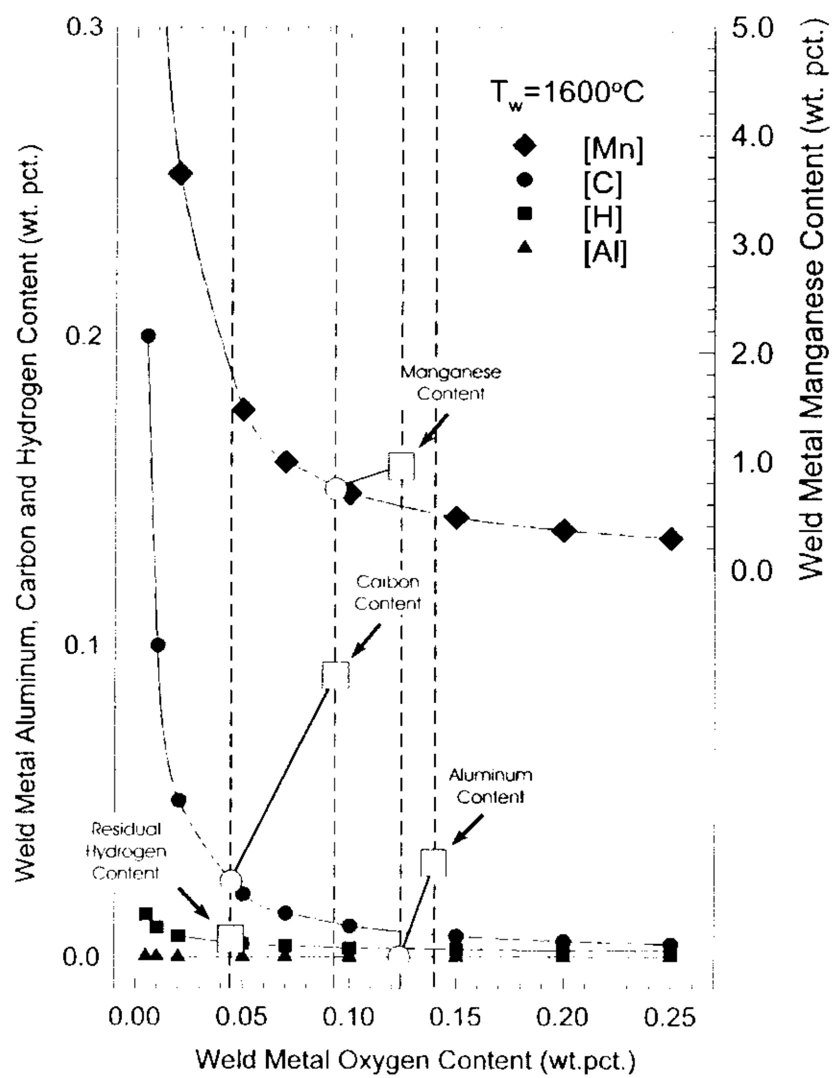
Trends in Underwater Wet Welding Consumables Research

- Effect of CaCO3
  - Weld Metal Porosity



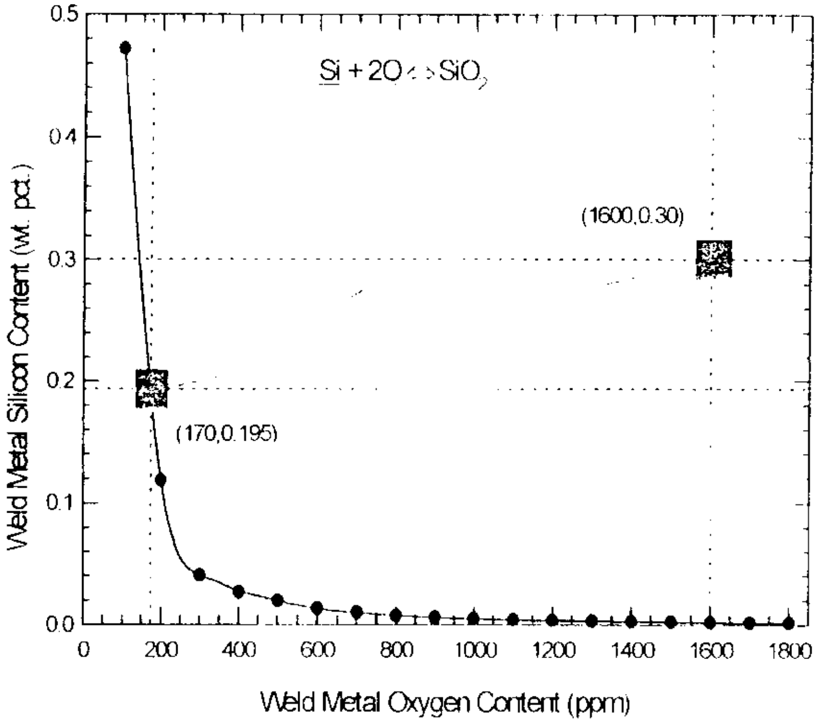
Weld Pool Phenomena

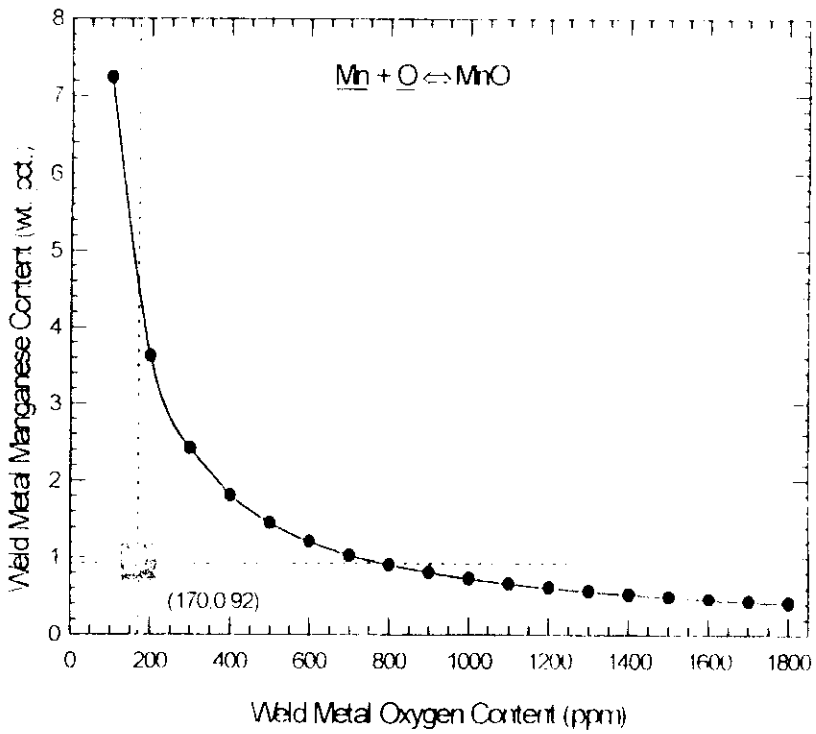
Porosity Prediction



[Si]-[O] and [Mn]-[O] Diagrams - III

SMAW - Anderson Data



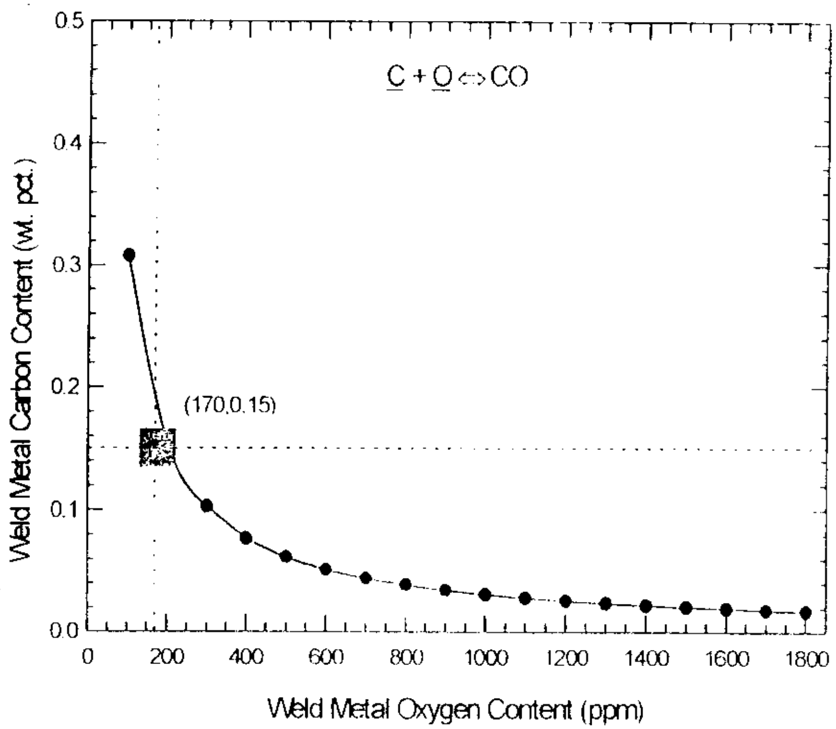


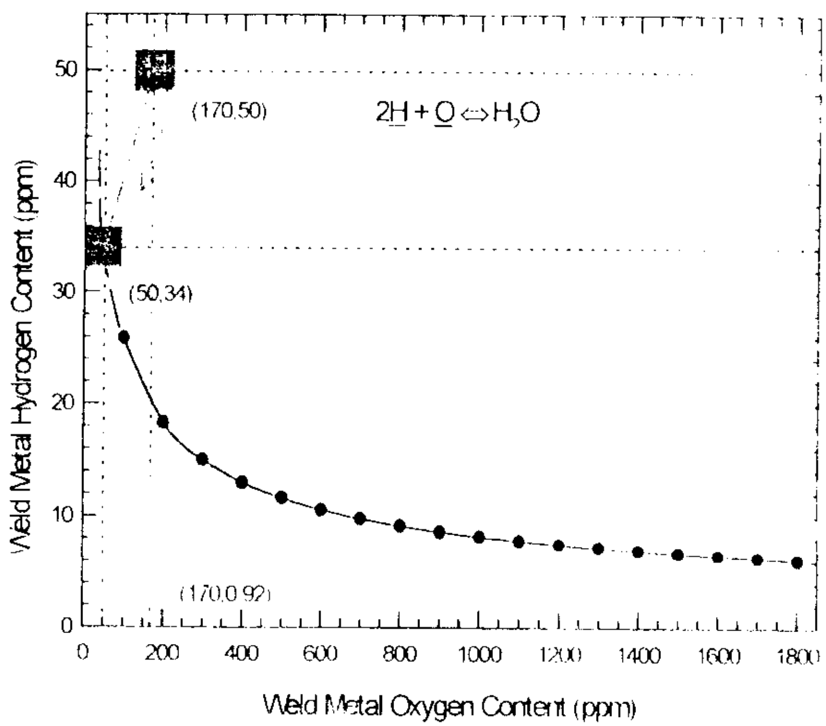
Initial Composition: C - 0.15 wt. pct., Mn - 0.92 wt. pct., Si - 0.30 wt. pct., O - 1600 ppm, H - 50 ppm

CSM-CWJCR

[C]-[O] and [H]-[O] Diagrams - III

SMAW - Anderson Data

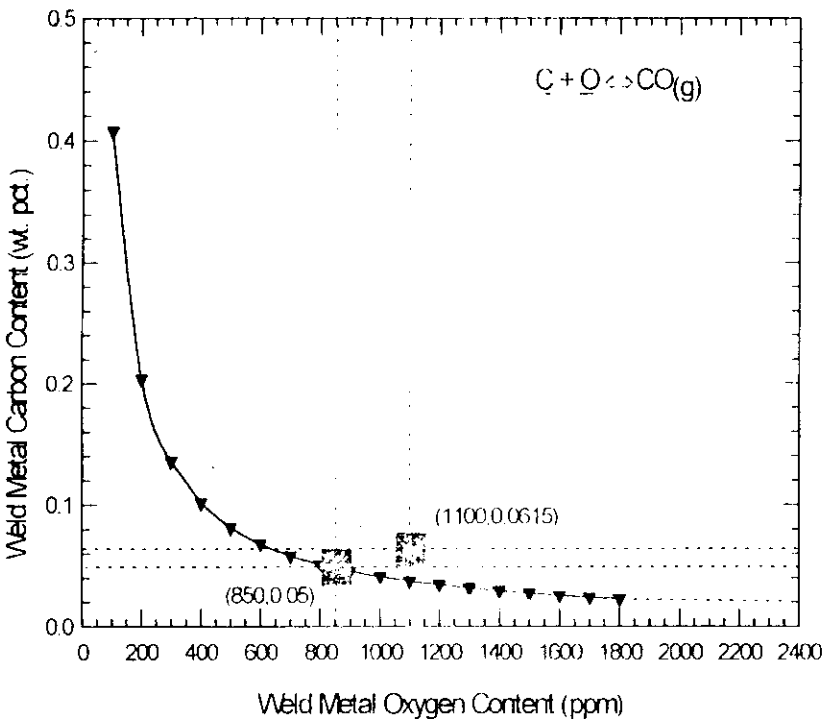


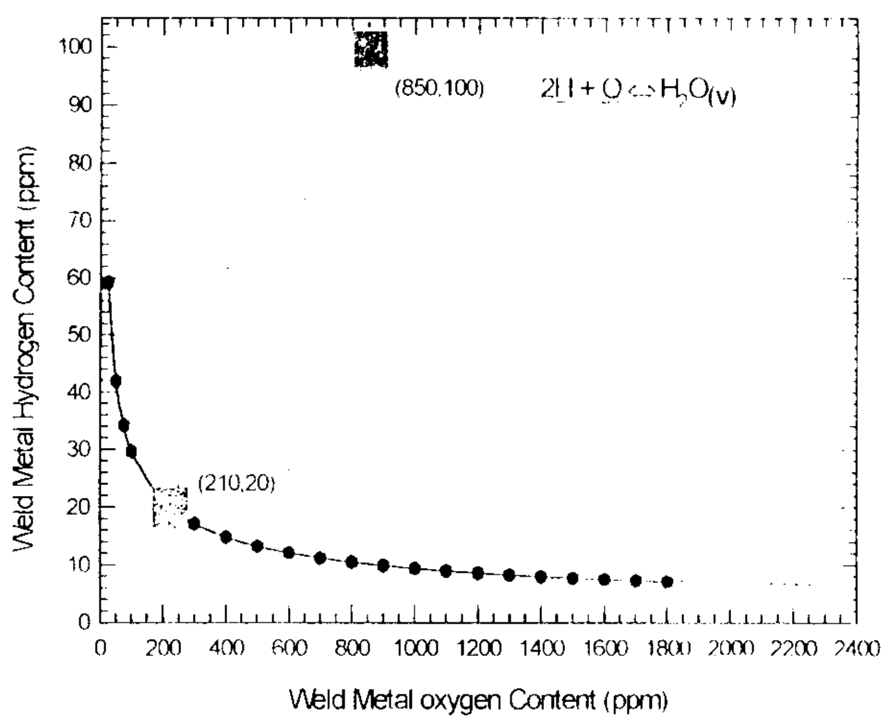


Initial Composition: C = 0.15 wt. pct., Mn = 0.92 wt. pct., Si = 0.30 wt. pct., O = 1600 ppm, H = 50 ppm

[C]-[O] and [H]-[O] Diagrams - II

SMAW - UWW - Pope Data

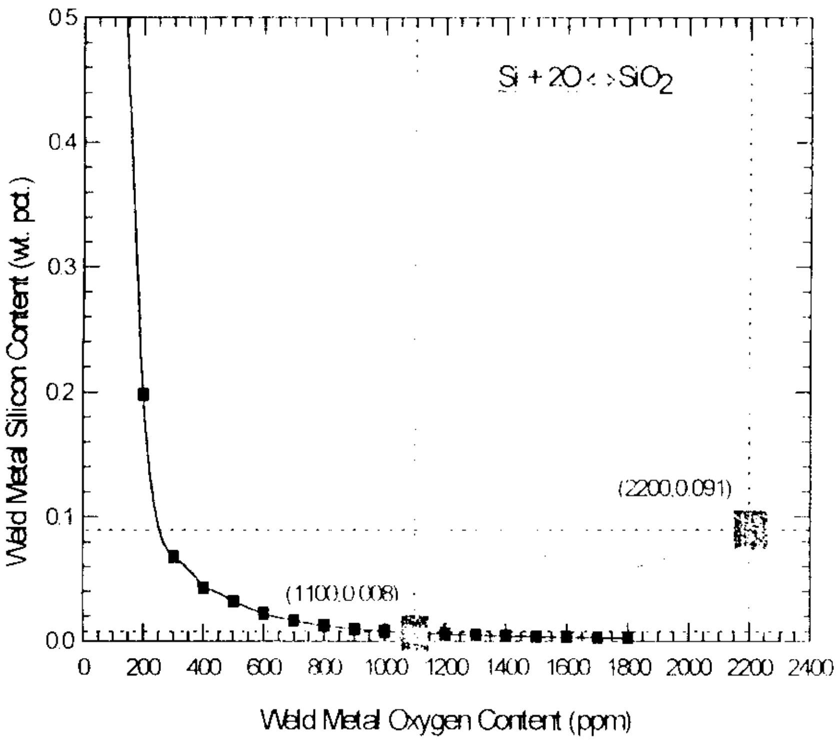


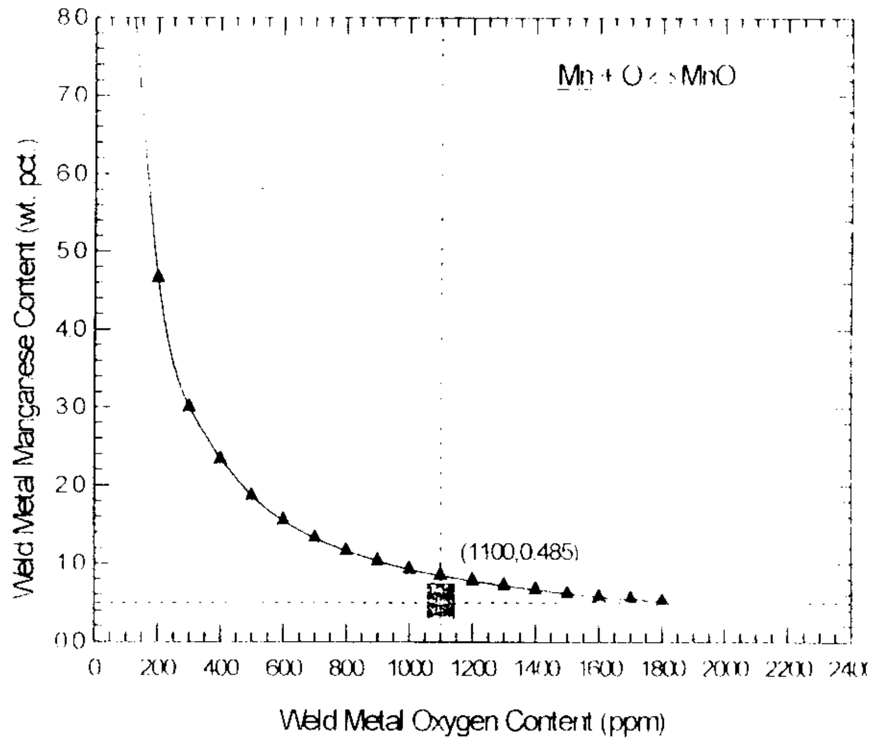


Initial Composition: C - 0.062 wt. pct., Mn - 0.485 wt. pct., Si - 0.091 wt. pct., O - 2200 ppm, H - 100 ppm

[Si]-[O] and [Mn]-[O] Diagrams - II

SMAW - UWW - Pope Data



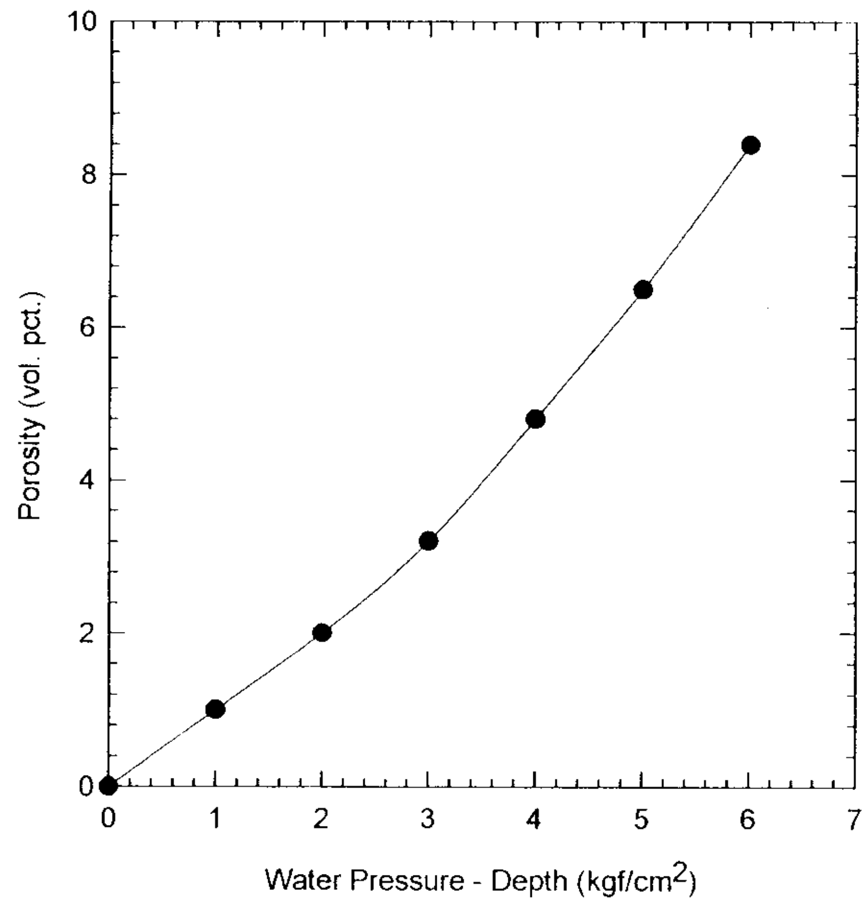


Initial Composition: C = 0.062 wt. pct., Mn = 0.485 wt. pct., Si = 0.091 wt. pct., O = 2200 ppm, H = 100 ppm

CSM-CWJCR

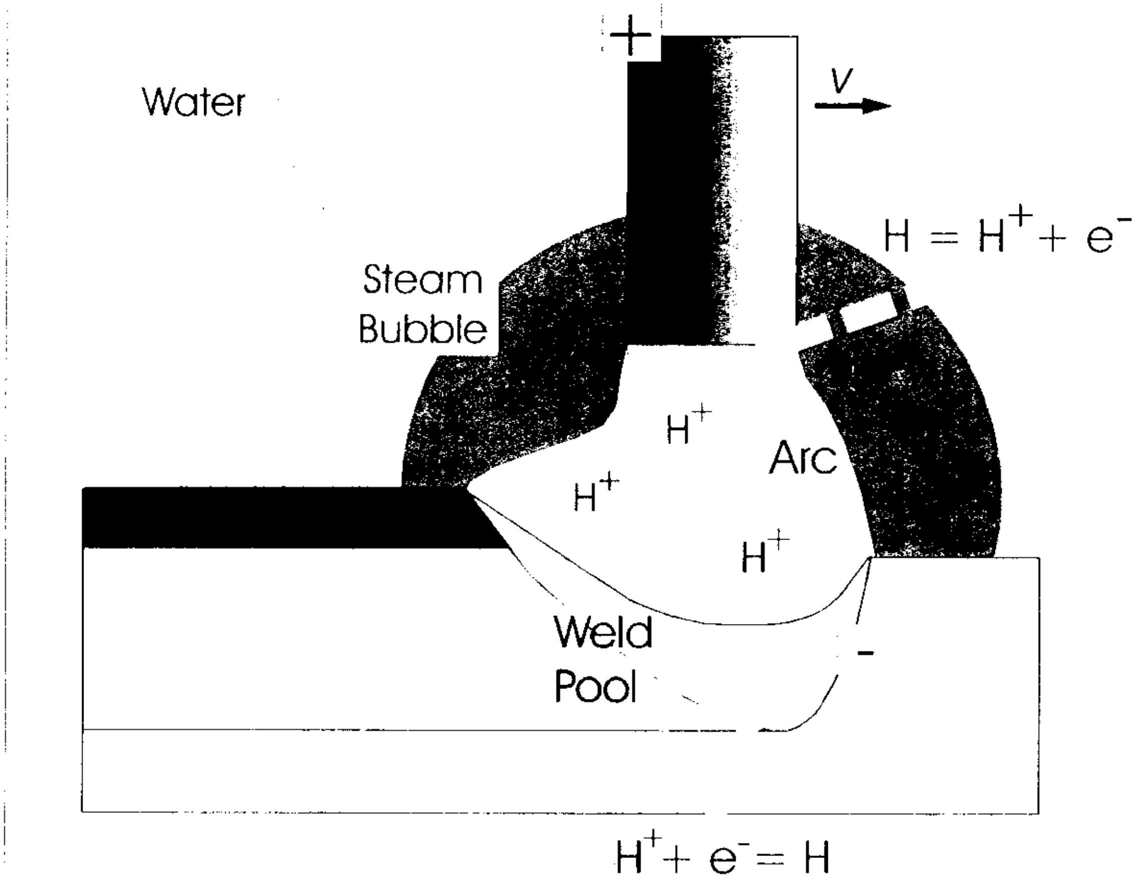
The Effect of Altitude on Welding

Weld Porosity-Water Pressure Relationship



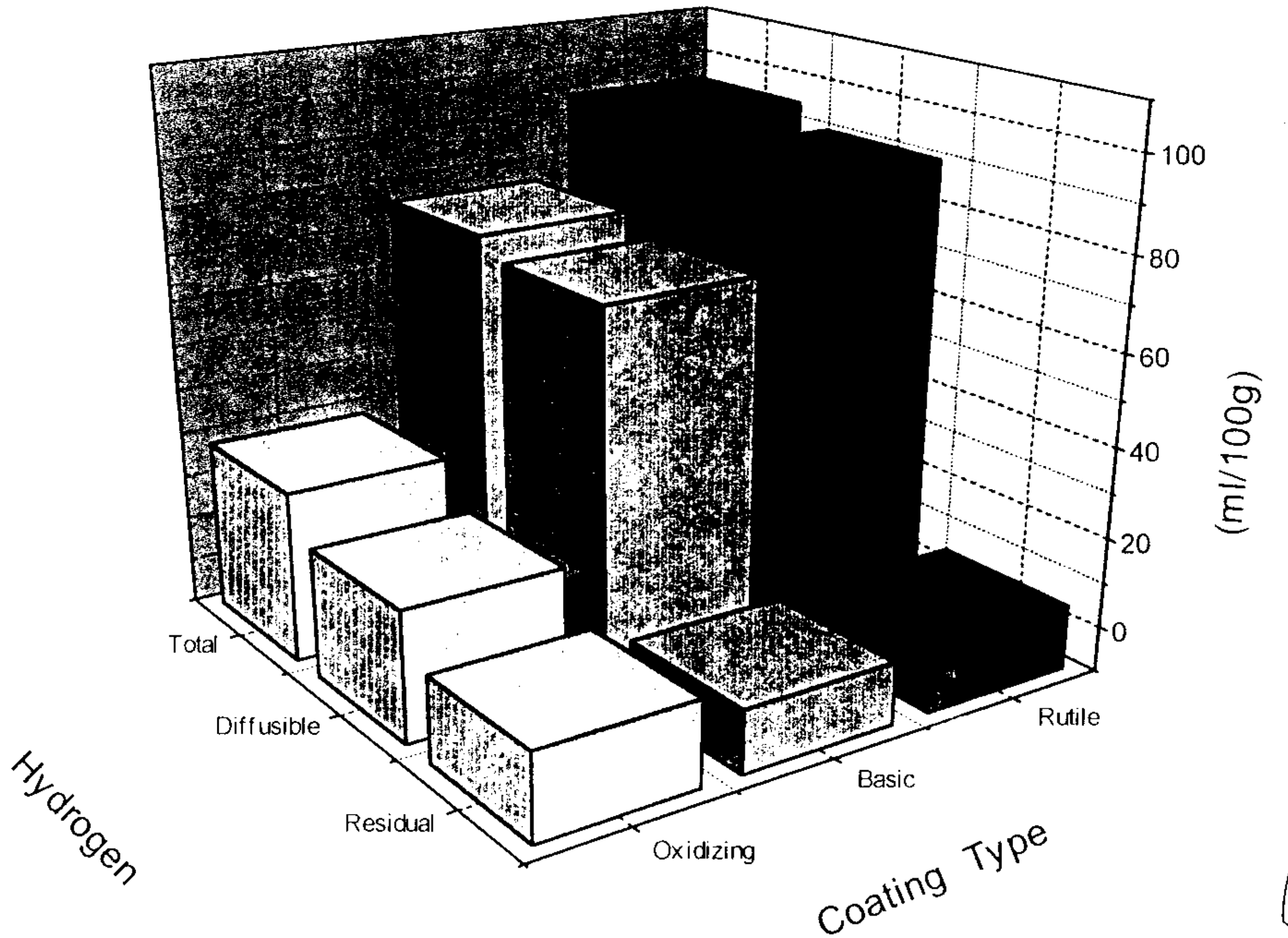
Underwater Wet Welding

Arc Environment

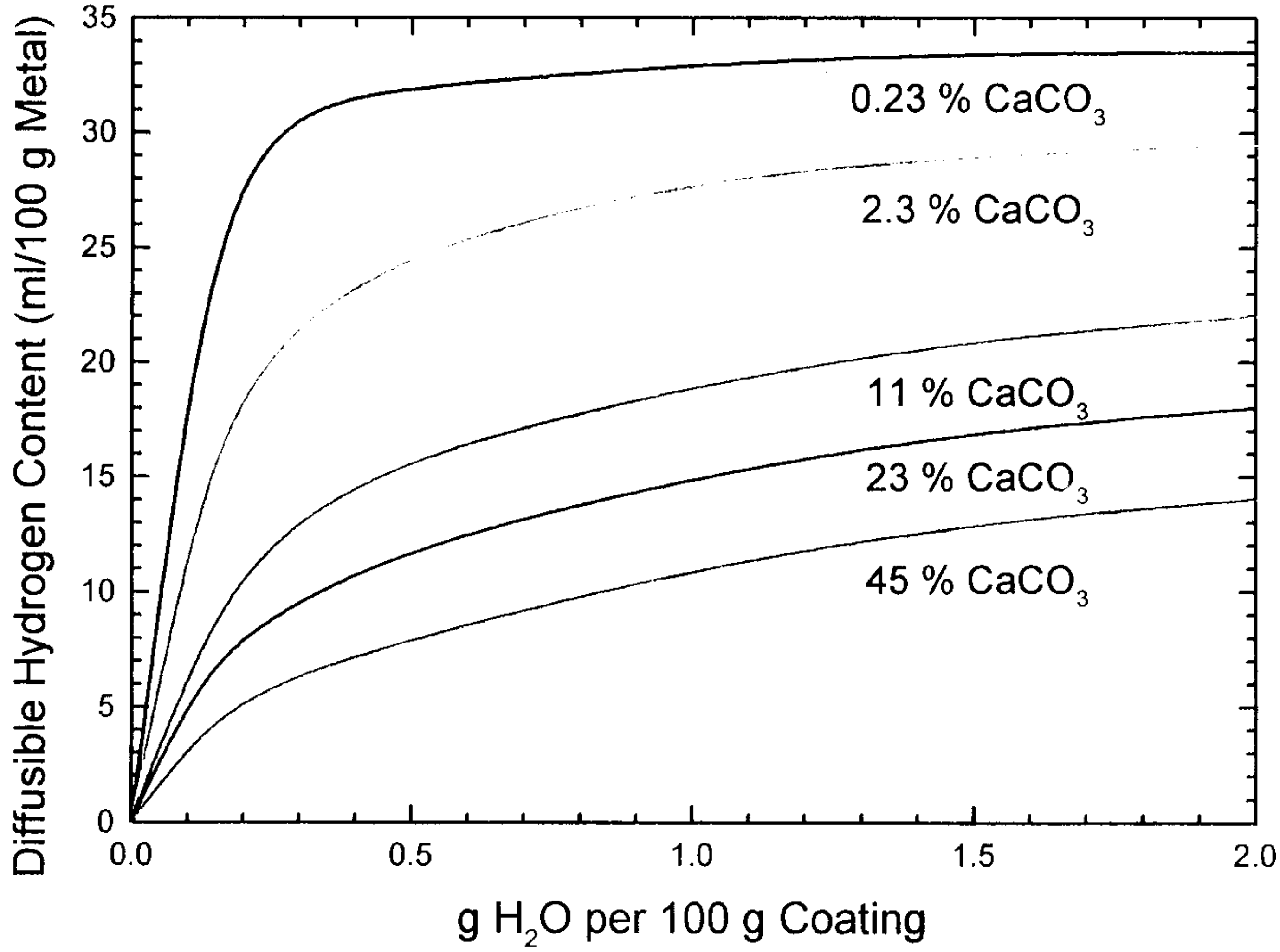


Oxidizing Electrodes and Polarity: Hydrogen Mitigation in Underwater Wet Welding

Underwater Weld Metal Hydrogen Content (Gooch, 83)

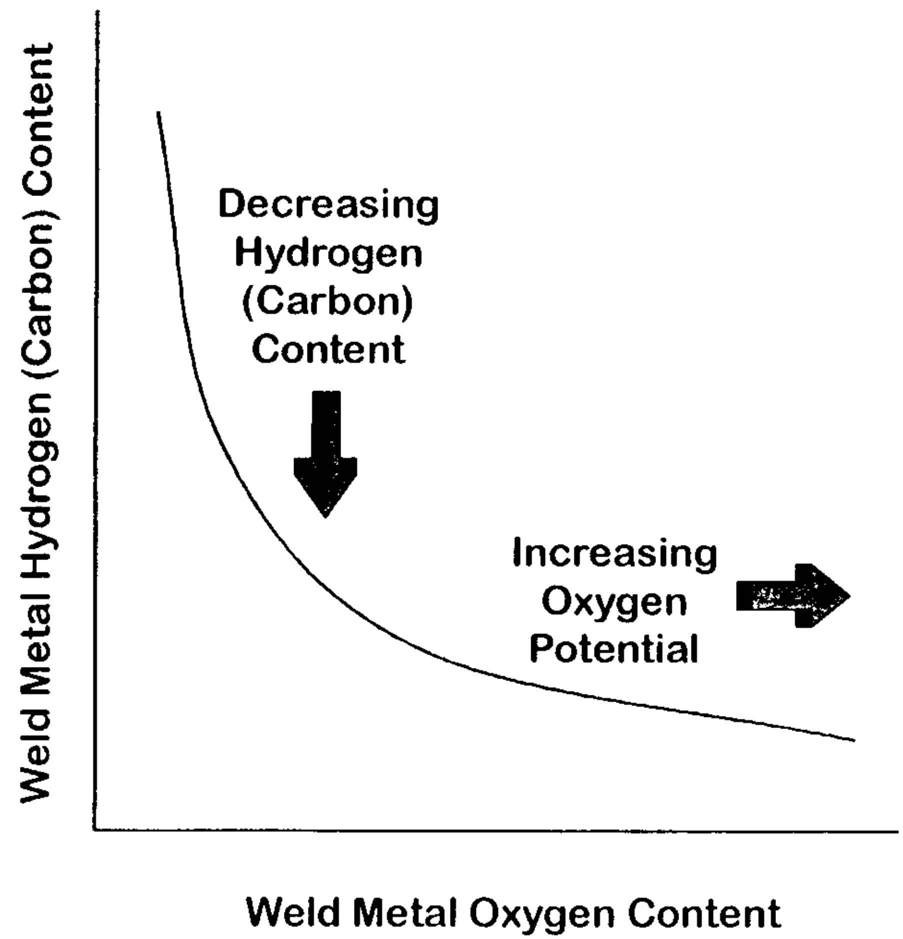


Weld Metal Hydrogen Control by Means of Basic Flux Ingredients

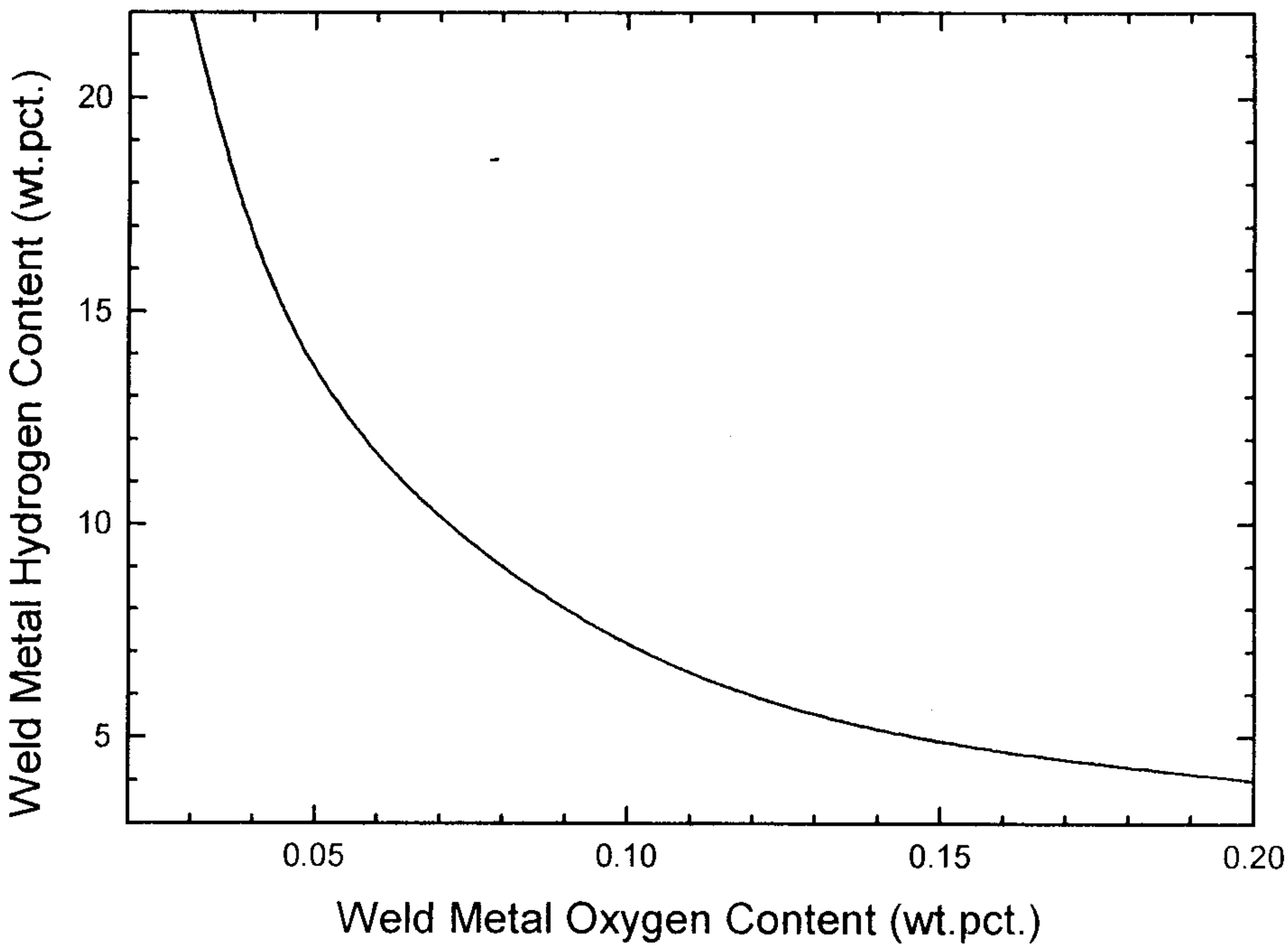


Underwater Wet Welding: Oxidizing Electrodes

Hydrogen-Oxygen Relationship

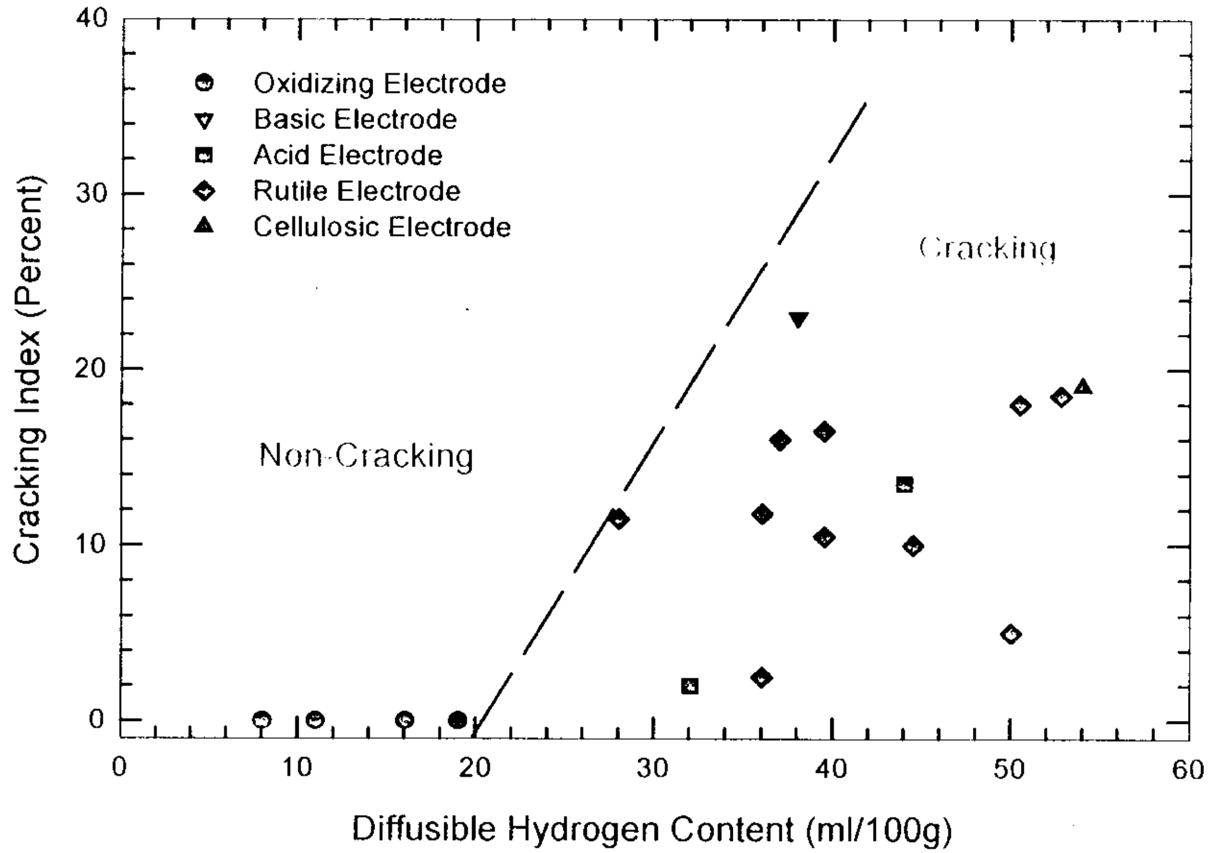


Hydrogen-Oxygen Relationship as a Strategy of Hydrogen Control



Underwater Wet Weld Quality: Controlling Factors

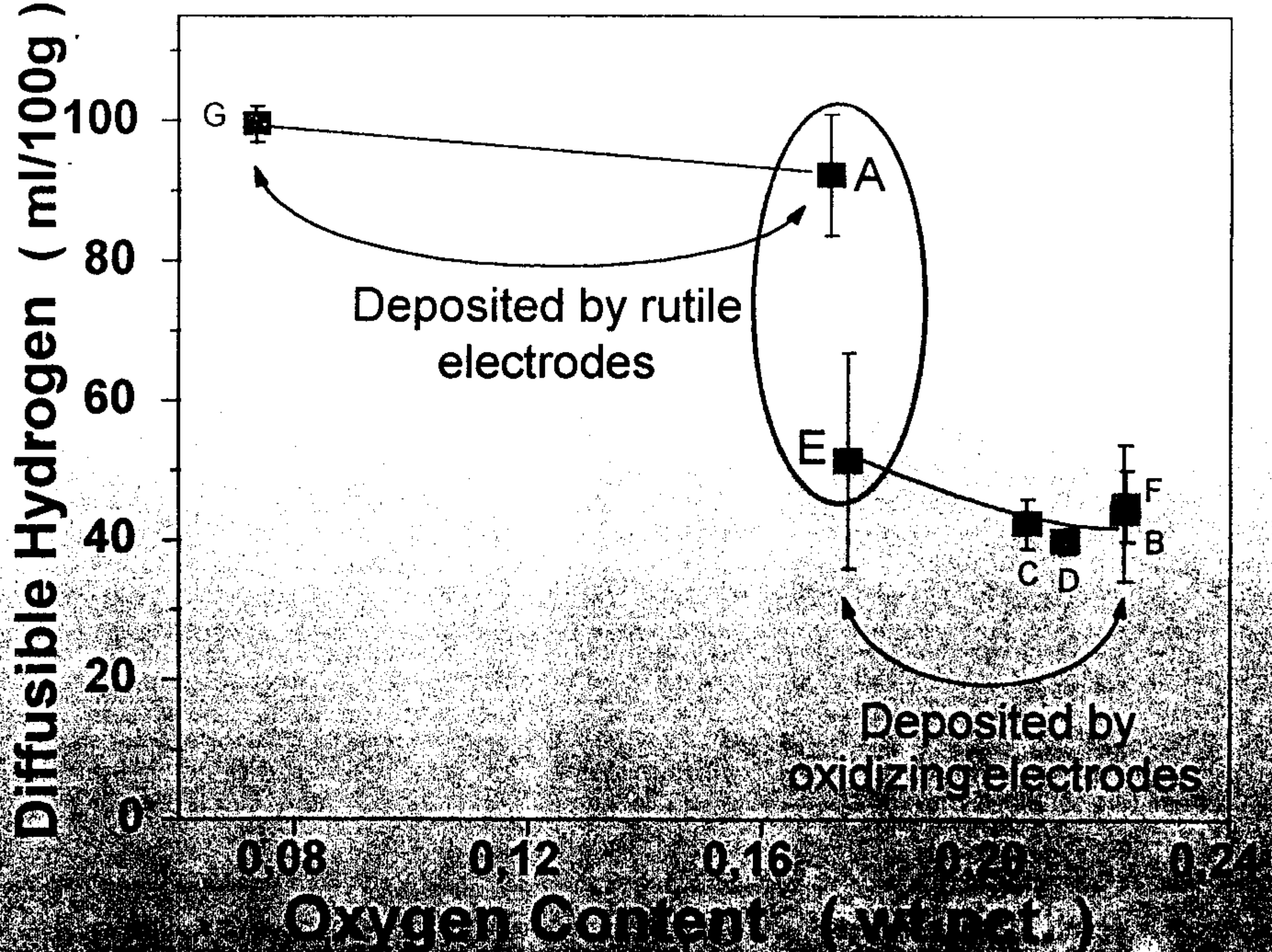
Weld Cracking Susceptibility



Nóbrega (1983)

Results and Discussion:

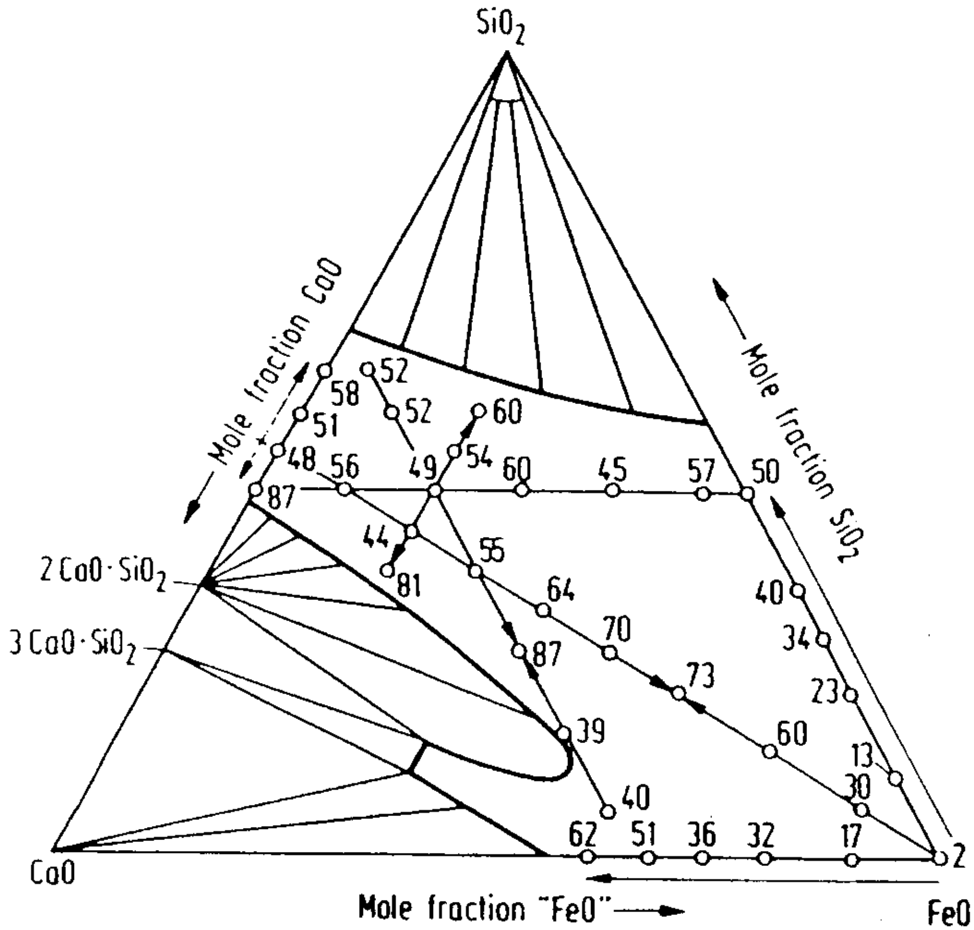
Diffusible Hydrogen Content



- Welds deposited by electrodes A and E have quite different diffusible hydrogen

Oxidizing Electrodes and Polarity:
Hydrogen Mitigation in Underwater Wet Welding

Solubility of Hydrogen in Slags (Schlackenatlas, 81)



Results and Discussion:

Micrography of the slag at the electrode tip

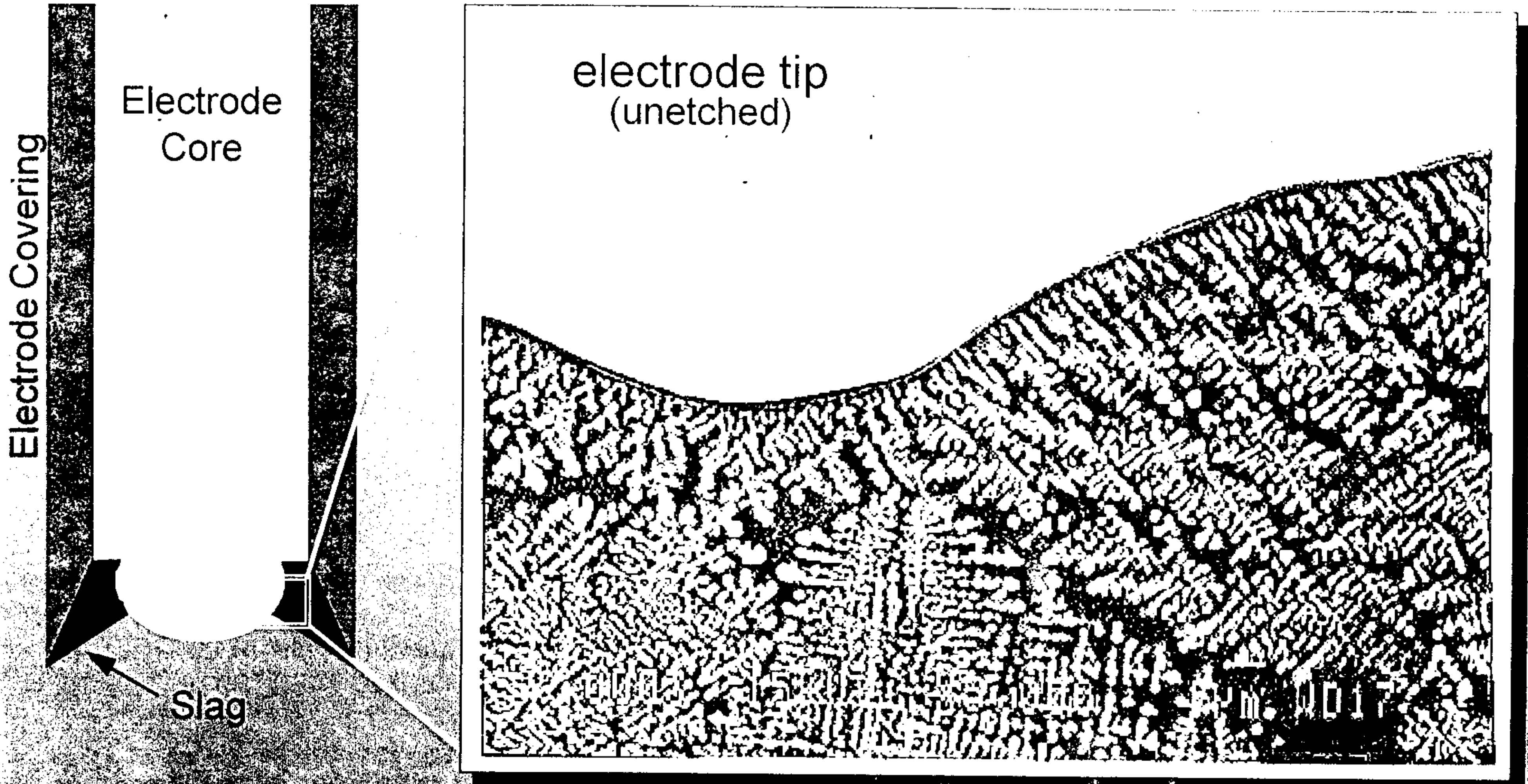
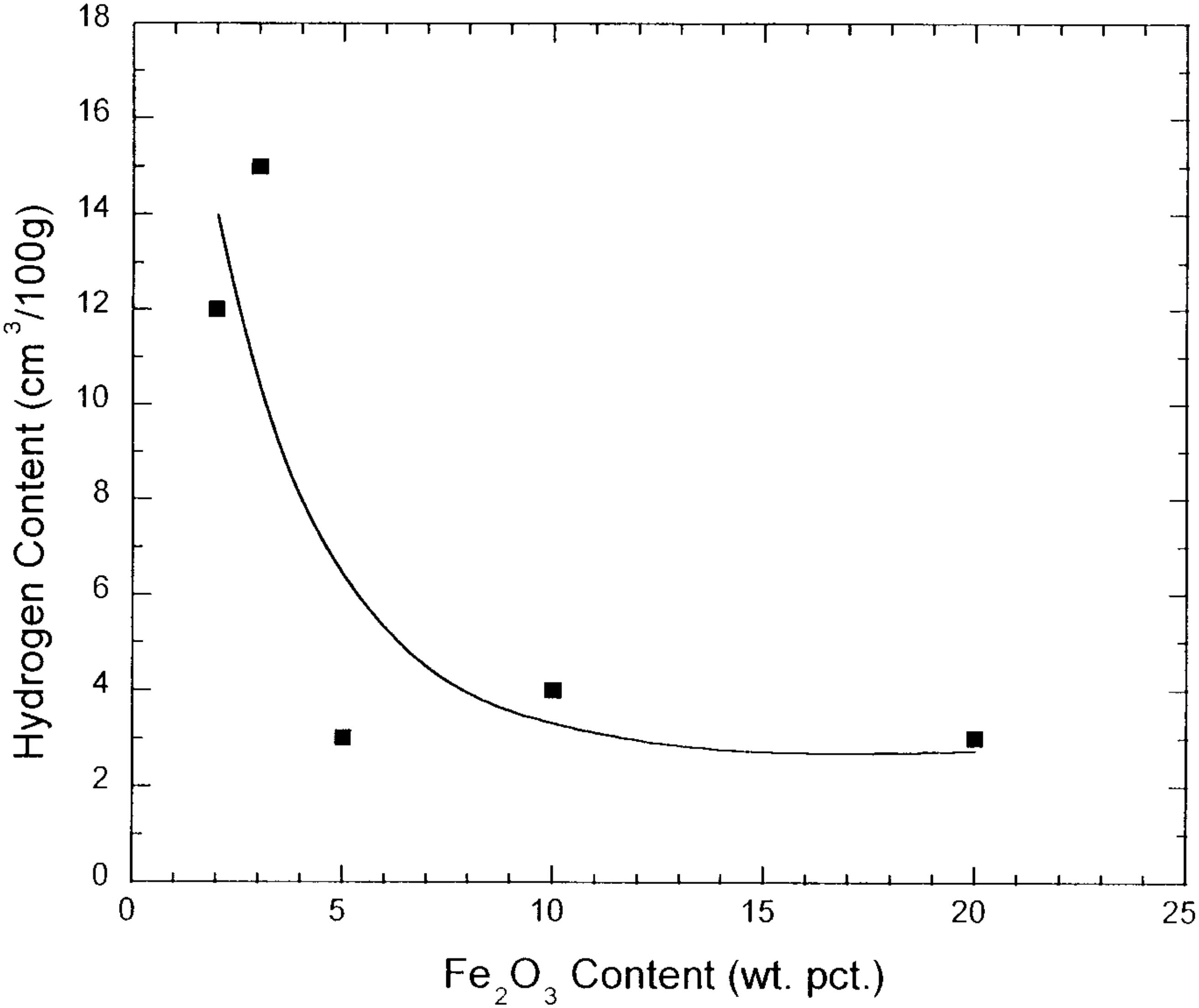
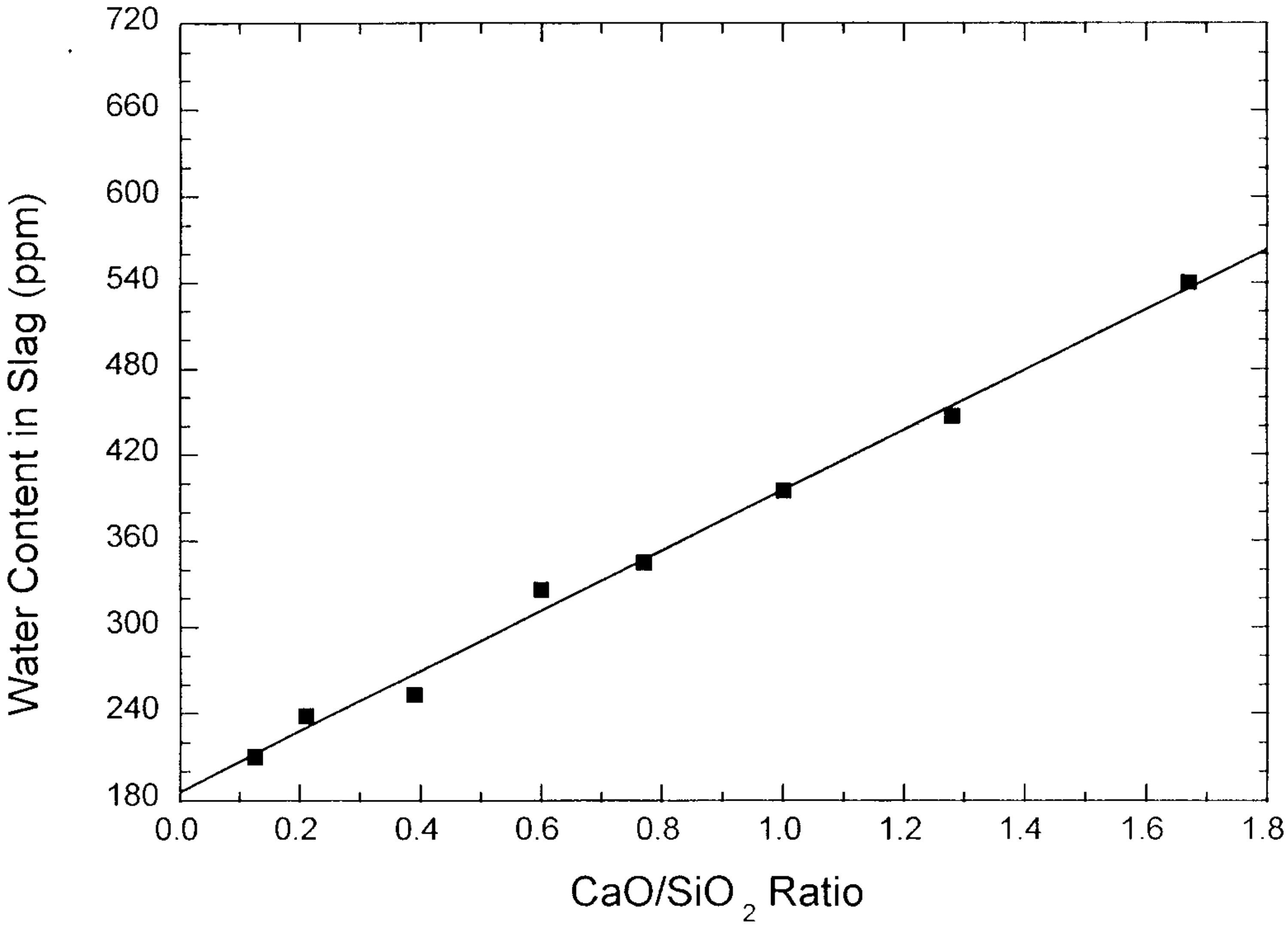


Figure 4.10 Scanning electron micrograph of a longitudinal section at the crater of a weld deposited by electrode E. Most of the wüstite rich slag (W) separated before the solidification leaving silicate rich slag (S) caught interdendritically. Etched in nital 2. Magnification: 1000 x

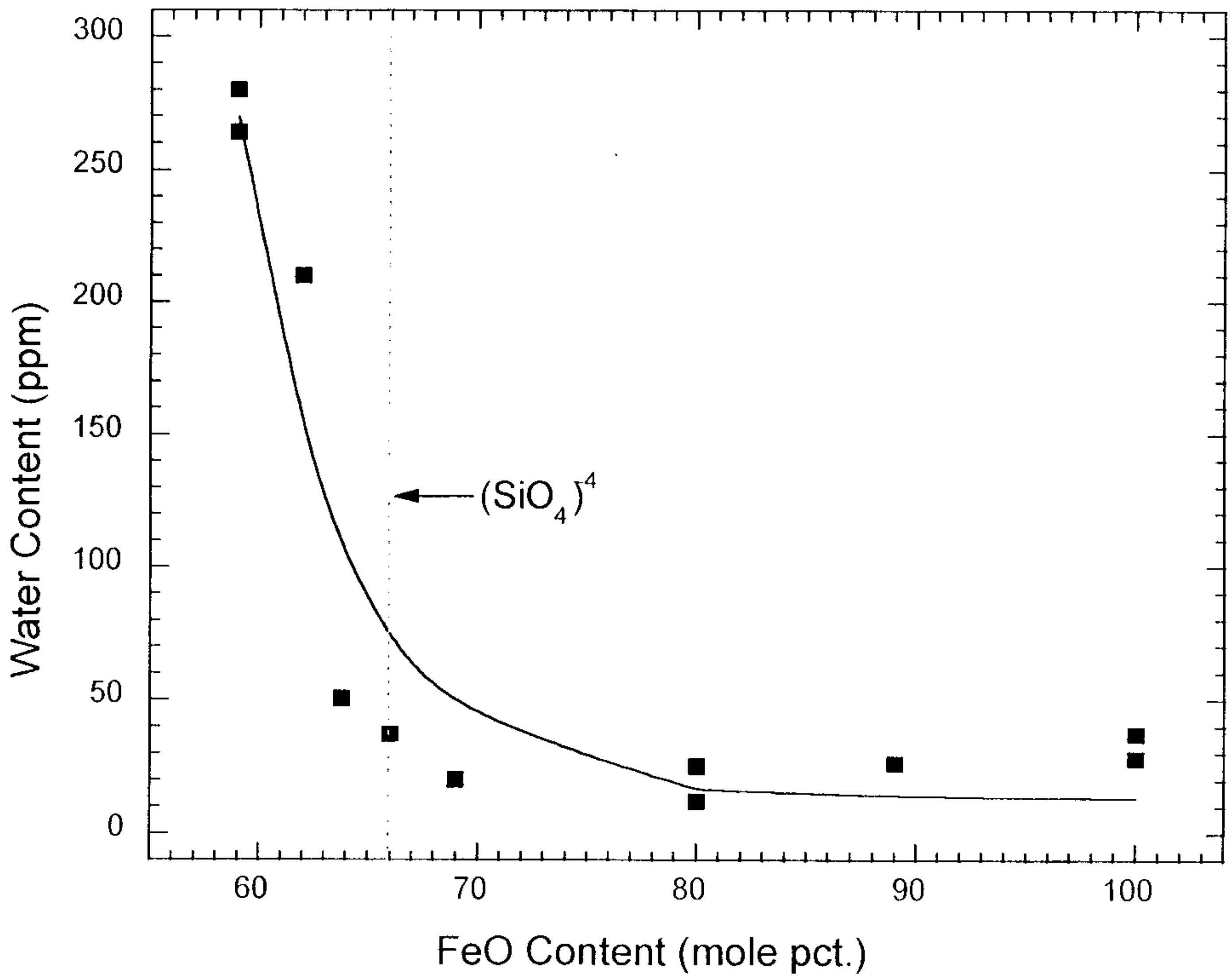
Weld Metal Hydrogen Content as a Function of Slag Composition - Forno, Peover and Powell - 1971



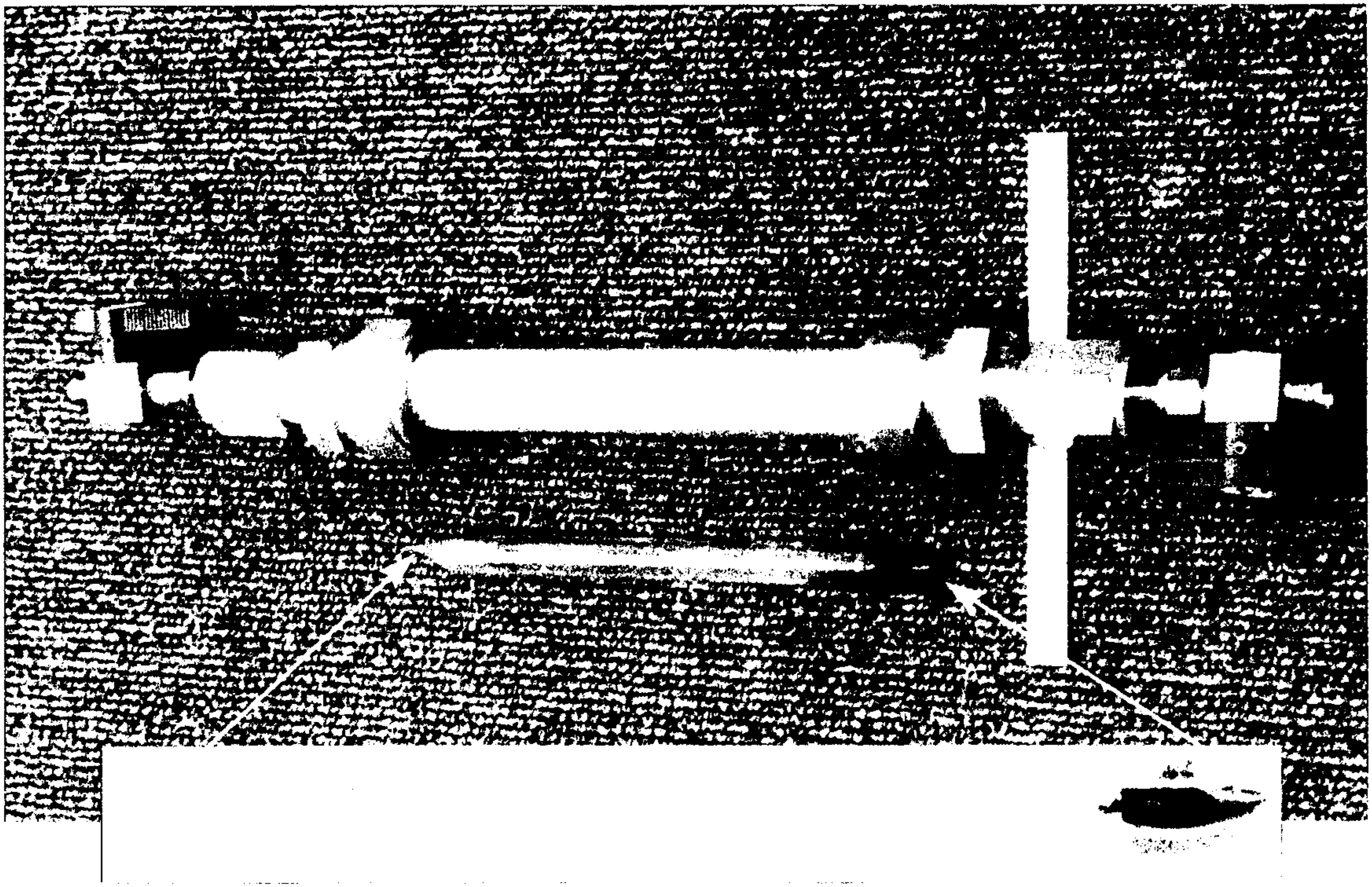
Moisture Content as a Function of Slag Composition - Sachdev, Majdic and Shenck - 1972



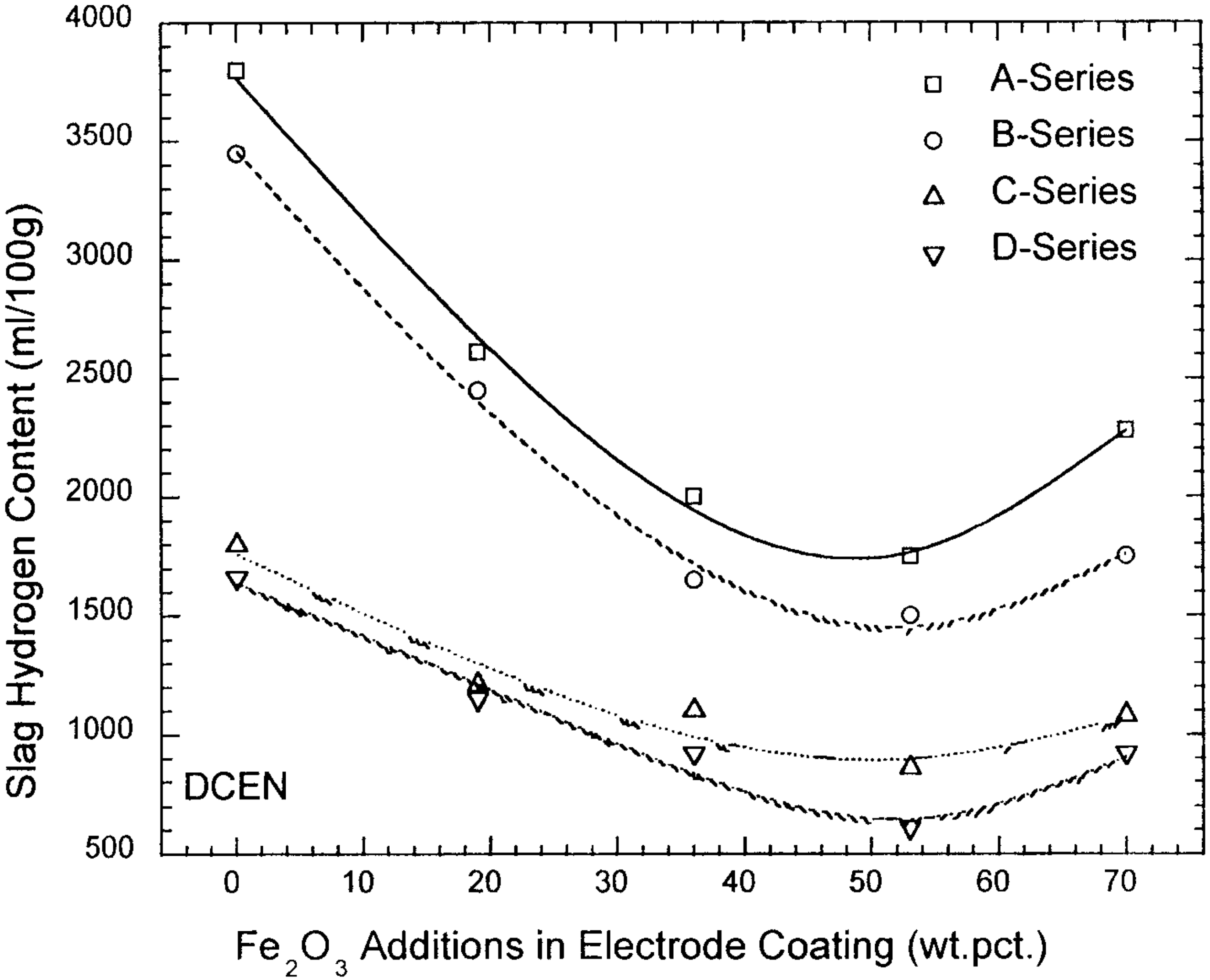
Moisture Content as a Function of Slag Composition - Uys and King - 1963



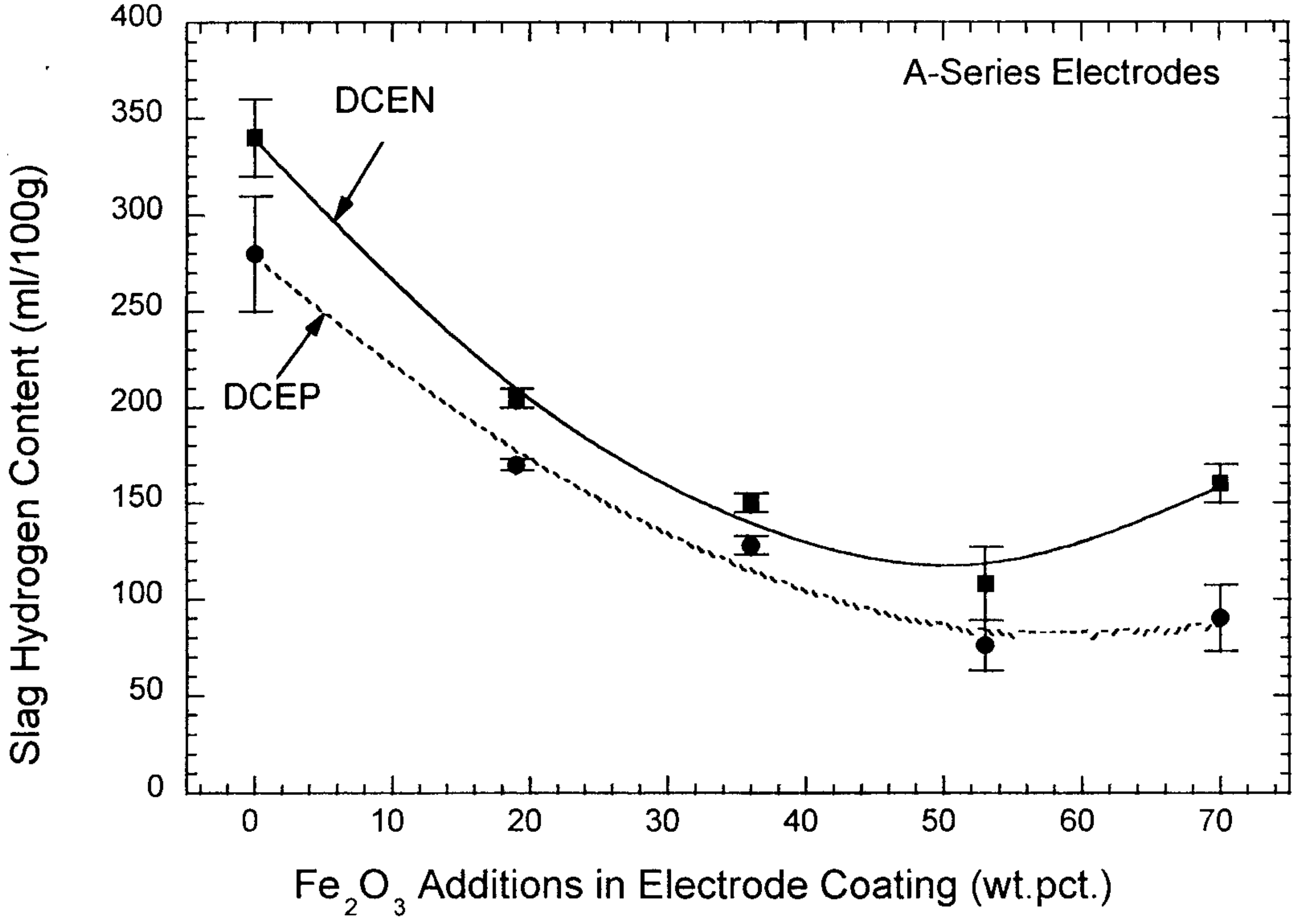
Procedure of Slag Moisture and Hydrogen Analysis - Slag Encapsulation



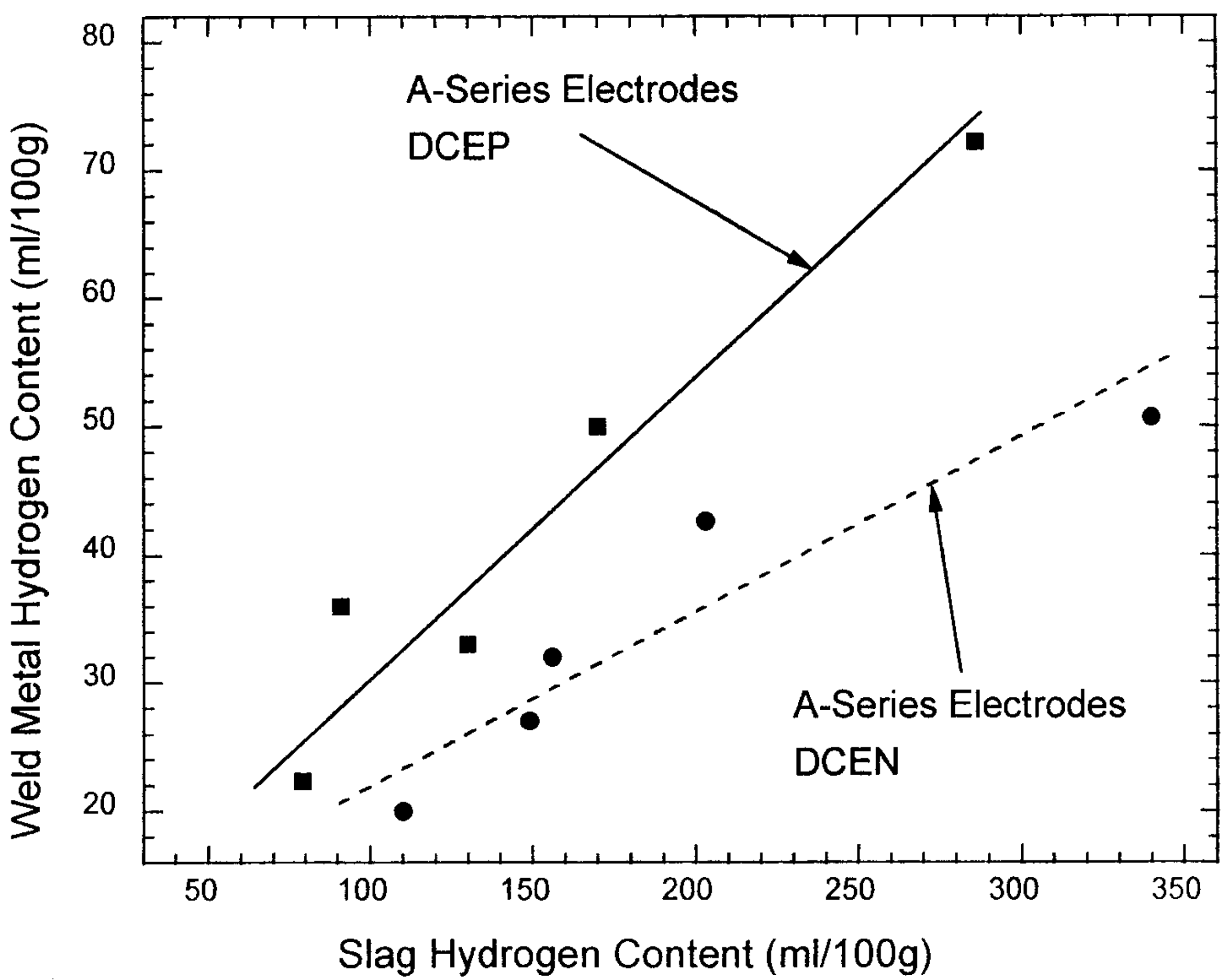
Slag Hydrogen Content as a Function of Slag Composition



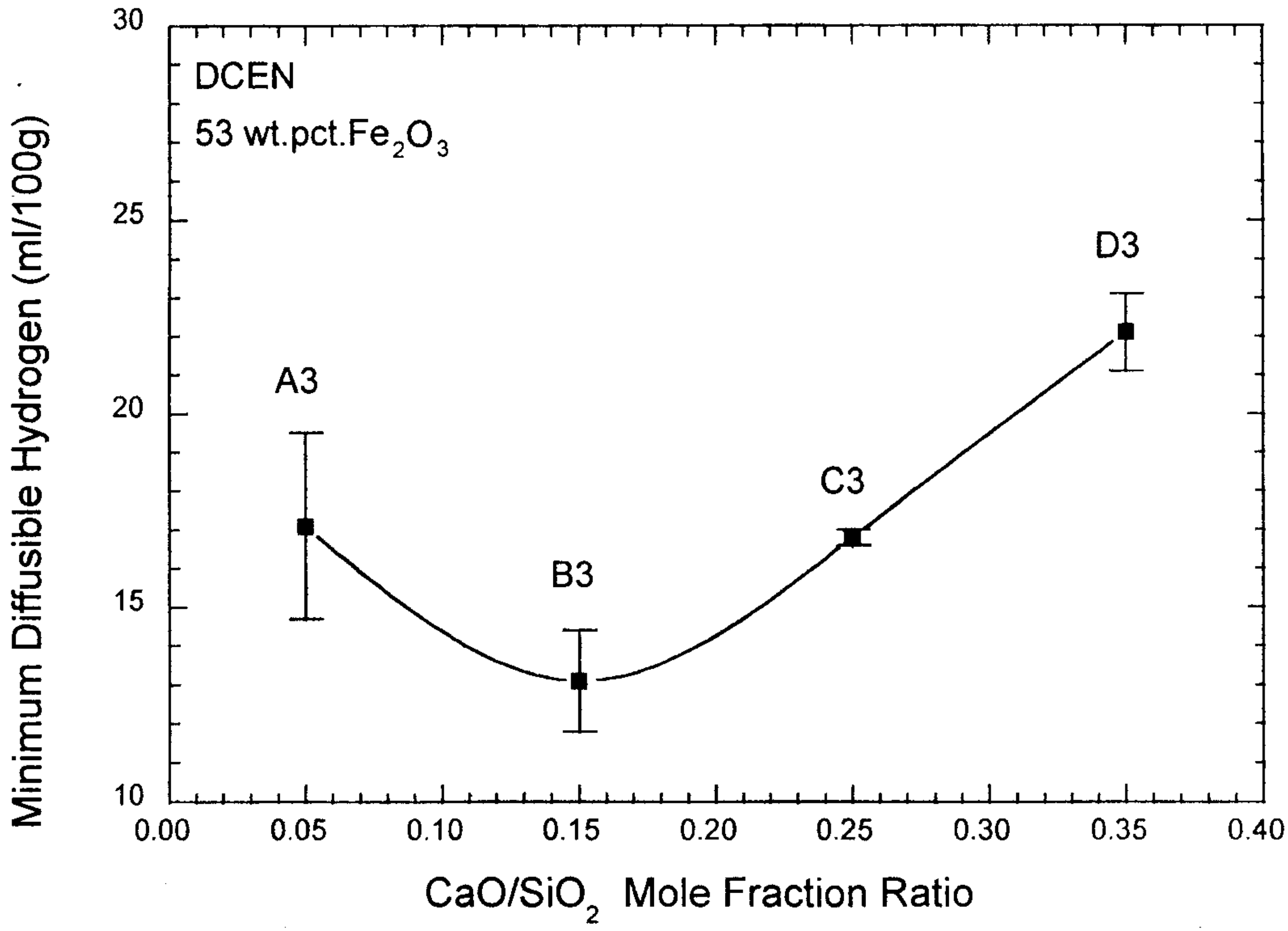
Slag Hydrogen Content as a Function of Slag Composition



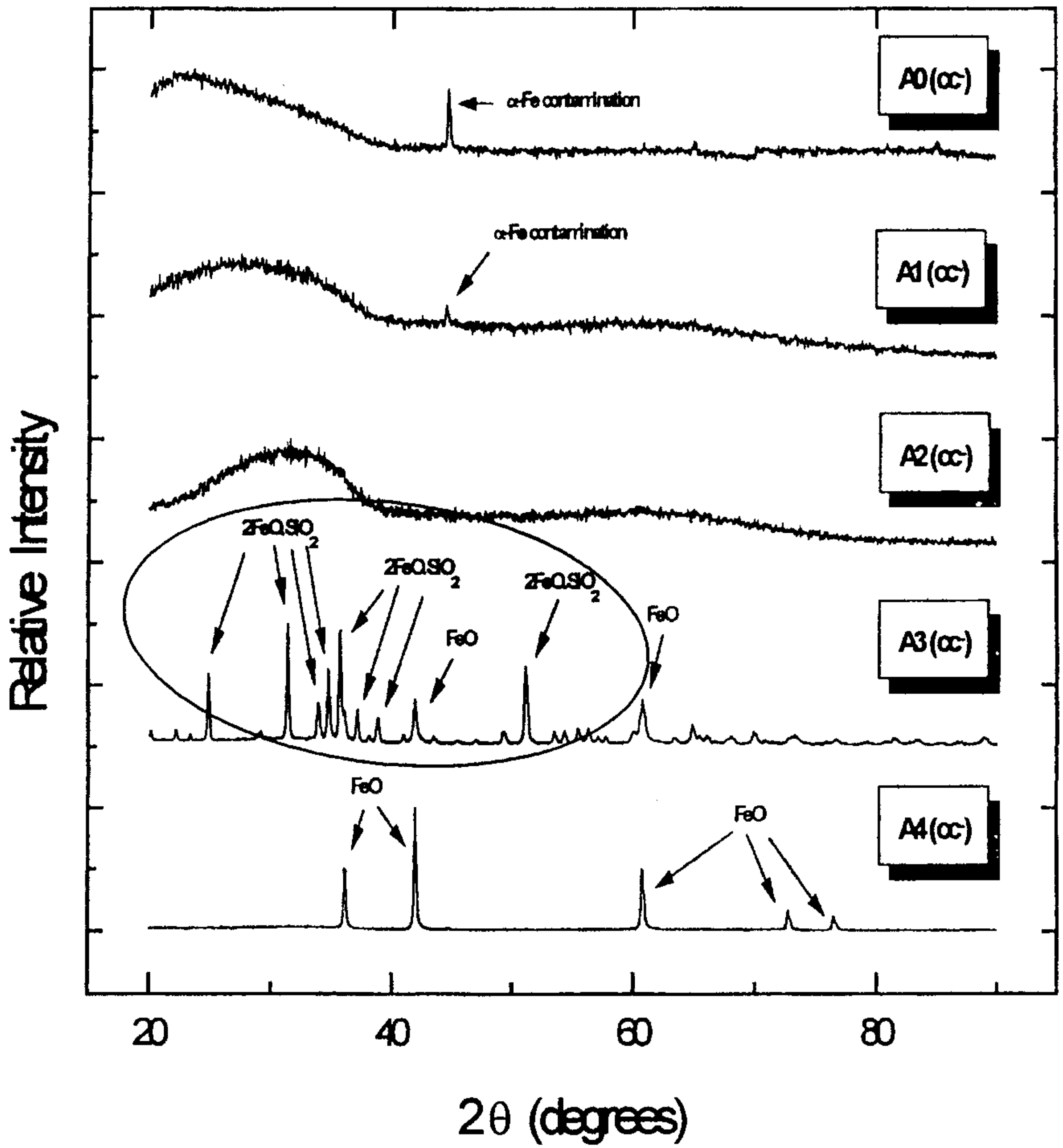
Weld Metal Hydrogen versus Slag Hydrogen Content



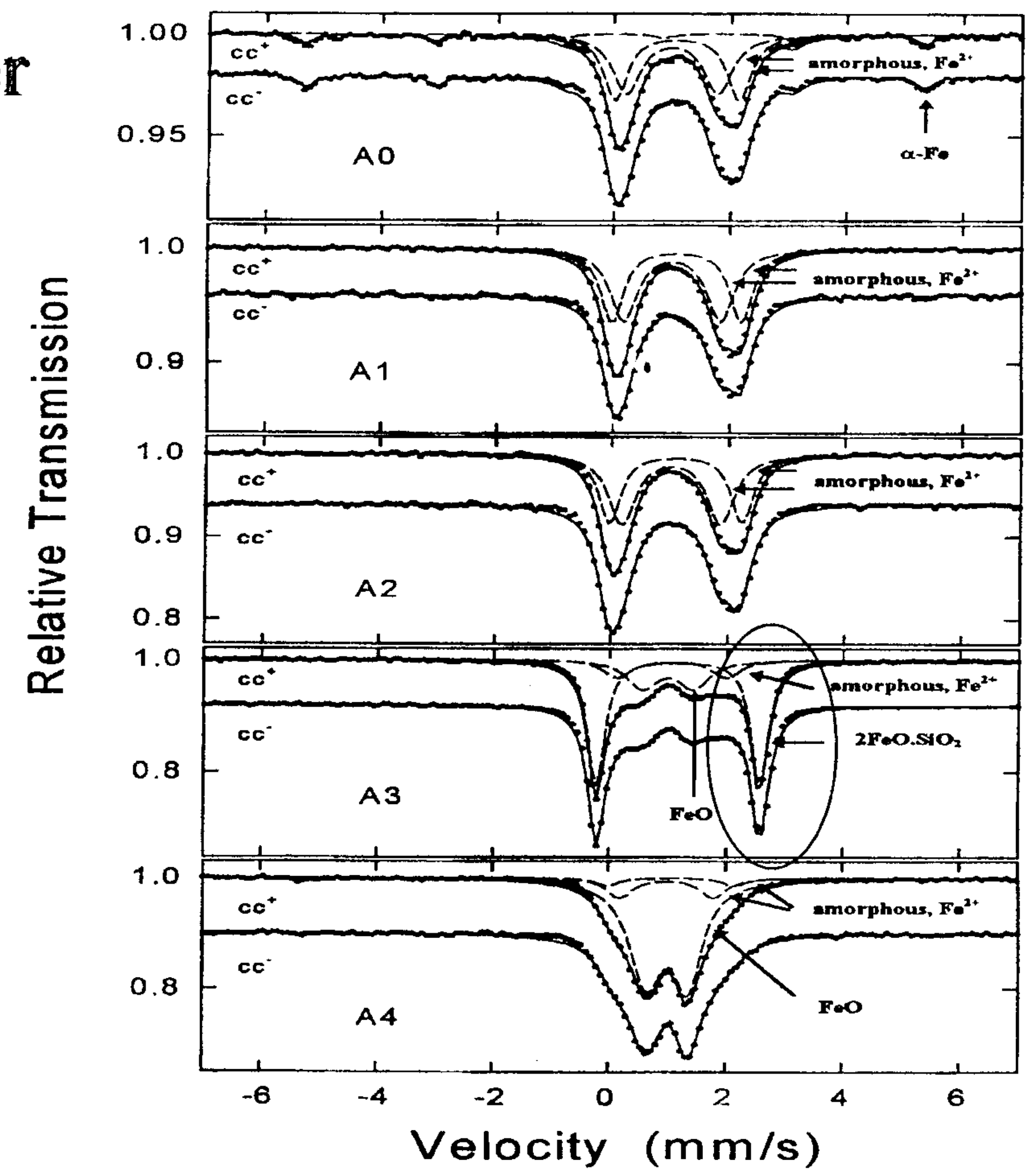
Weld Metal Diffusible Hydrogen as a Function of Slag Composition



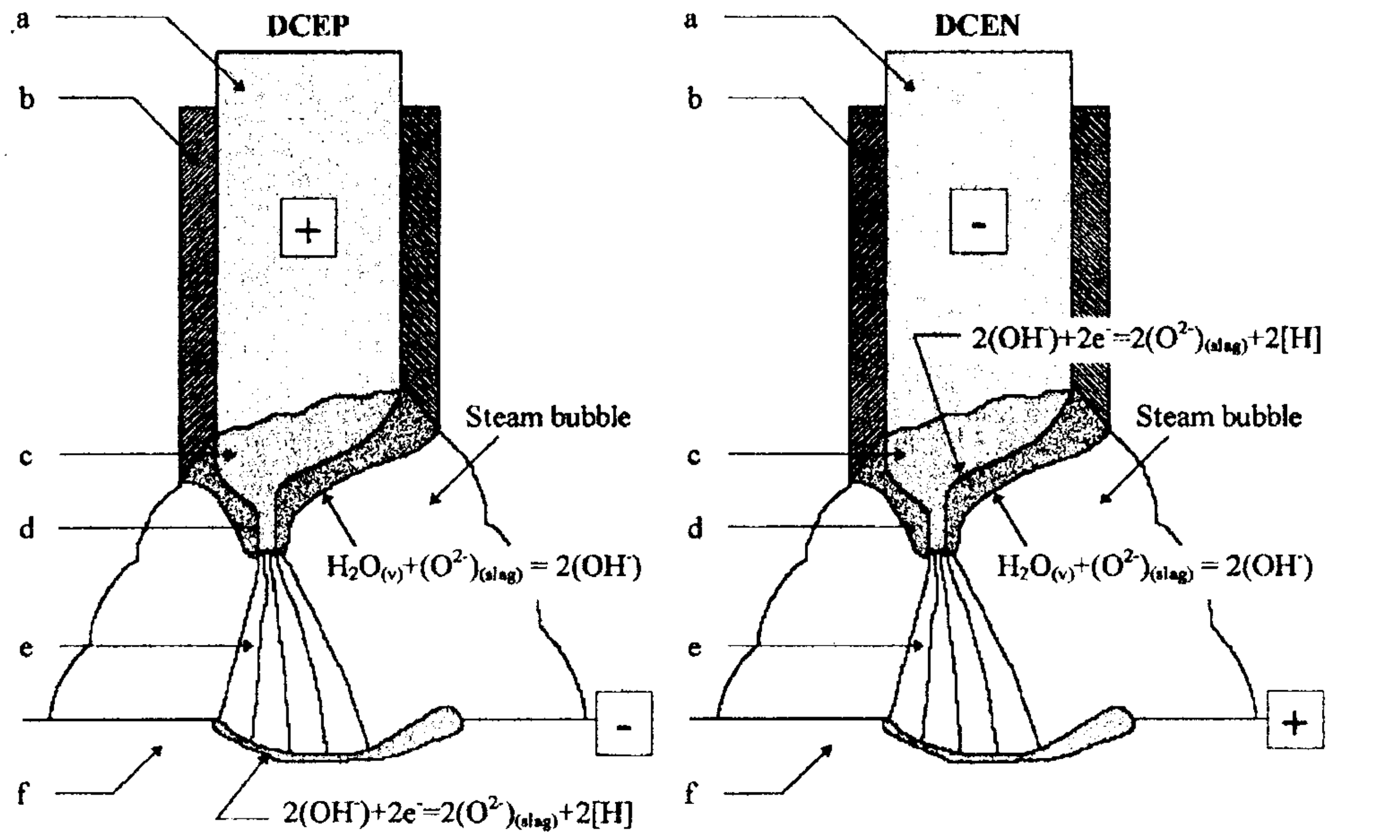
X-Ray Diffraction Analysis of Slag



Mössbauer Analysis of Slag



Electrochemical Reactions involved in Weld Metal Hydrogen Pickup for DECP and DCEN



a - core wire; b - electrode coating; c - liquid electrode tip; d - molten slag; e - arc plasma; f - base metal

Electrochemical Reactions involved in Weld Metal Hydrogen Pickup for DECP and DCEN

- A Possible Reaction at the Slag/Environment Interface

$$H_2O_{(gas)} + O^{-2}{}_{(slag)} \Leftrightarrow 2(OH^-)_{(slag)} \quad (1)$$

- Possible Cathodic Reactions at the Slag/Metal Interface

$$2(OH^{-1})_{(slag)} + 2e^- \Leftrightarrow 2(O^{-2})_{(slag)} \quad (2)$$

$$[\underline{H}] + [\underline{O}] + e^- \Leftrightarrow (OH^-)_{(slag)} \quad (3)$$

- Possible Anodic Reaction

$$Fe \Leftrightarrow (Fe^{+2}) + 2e^- \quad (4)$$

- Overall Slag/Metal Reaction

$$2(OH^-) + Fe \Leftrightarrow (Fe^{+2}) + 2(O^{-2})_{(slag)} + 2[\underline{H}] \quad (5)$$

Electrochemical Method correlating Total Weld Metal Hydrogen Content with P_{H_2O} and a_{FeO}

- Calculation of Reaction Constants

$$K_1 = \frac{(a_{OH^-})^2}{a_{O^{2-}}} \cdot \frac{1}{p_{H_2O}}$$

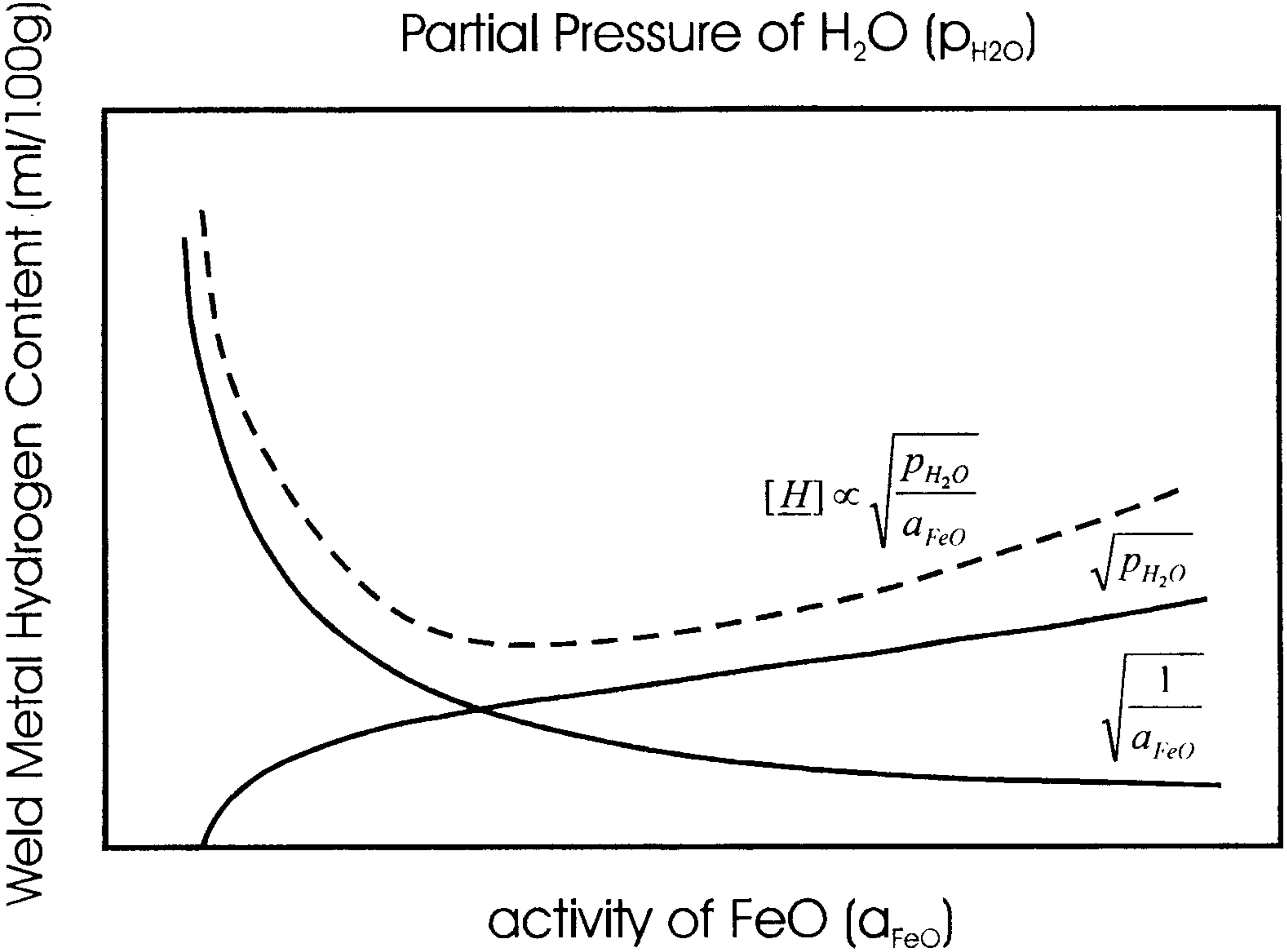
$$K_5 = \frac{a_{Fe^{+2}} \cdot (a_{O^{-2}})^2 \cdot [\underline{H}]^2}{(a_{OH^-})^2 \cdot a_{Fe}}$$

$$K_{FeO} = \frac{a_{Fe^{+2}} \cdot a_{O^{-2}}}{a_{FeO}}$$

- Substituting K_5 and K_{FeO} into K_1

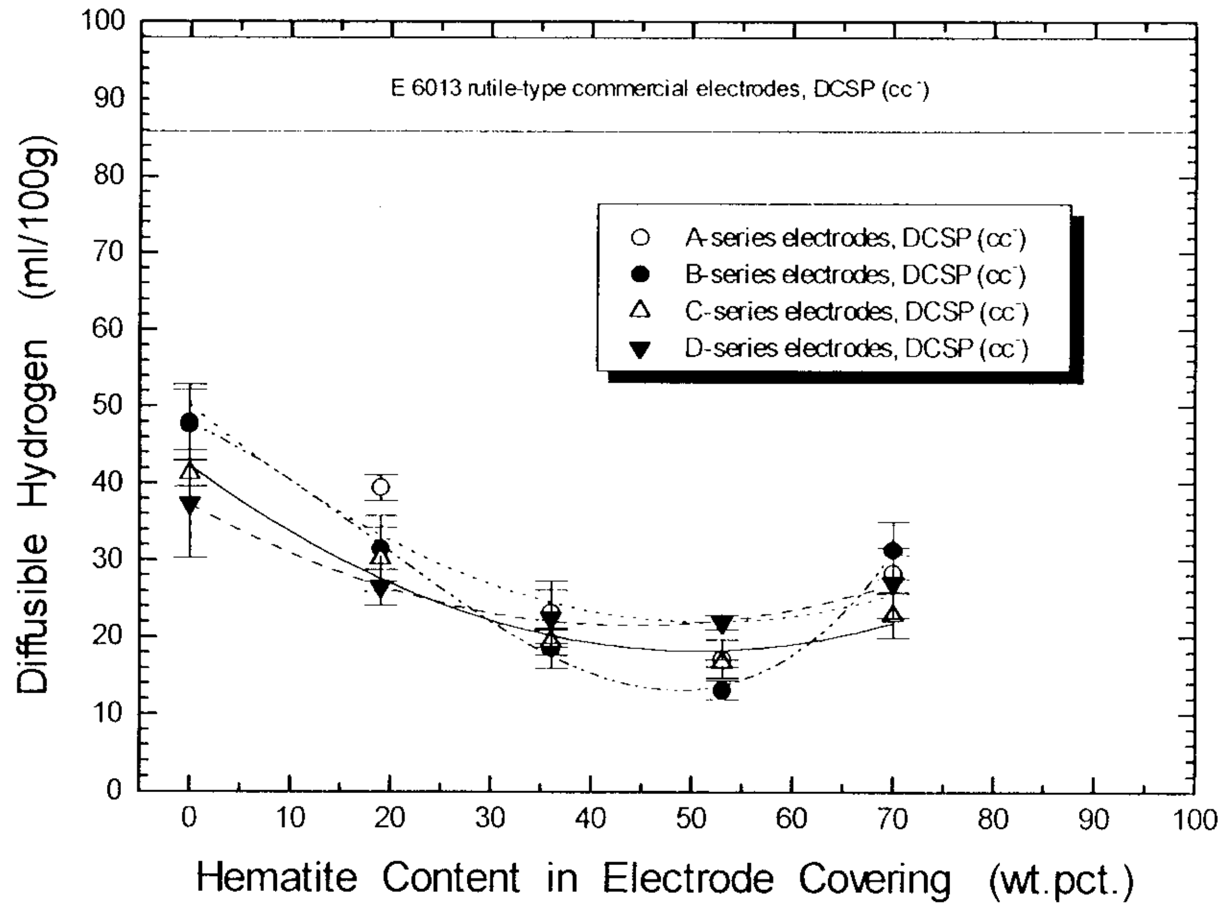
$$[\underline{H}] = \sqrt{\frac{K_1 \cdot K_2}{K_3} \cdot \frac{p_{H_2O}}{a_{FeO}}}$$

Combined Effect of a_{FeO} and p_{H2O}



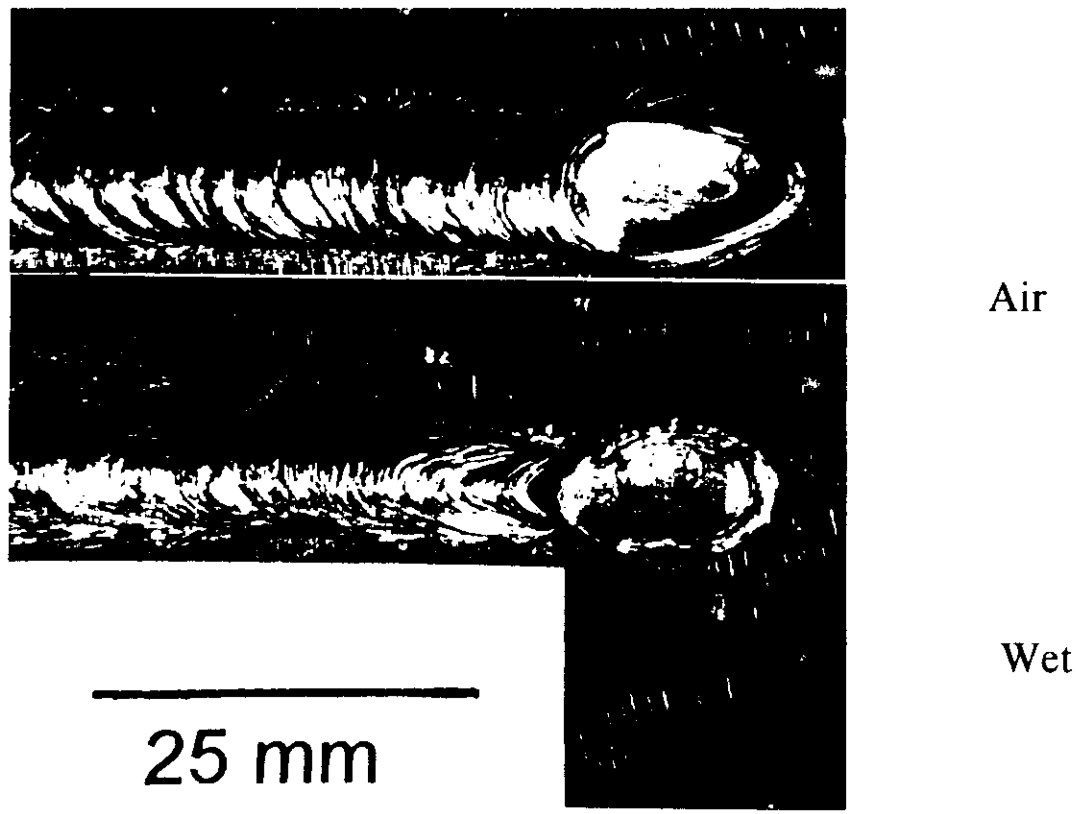
Oxidizing Electrodes and Polarity: Hydrogen Mitigation in Underwater Wet Welding
Results and Discussion

- Diffusible H Content vs Flux Coating Hematite Content - DCSP



Results and Discussion

Comparison of Weld Crater Shapes

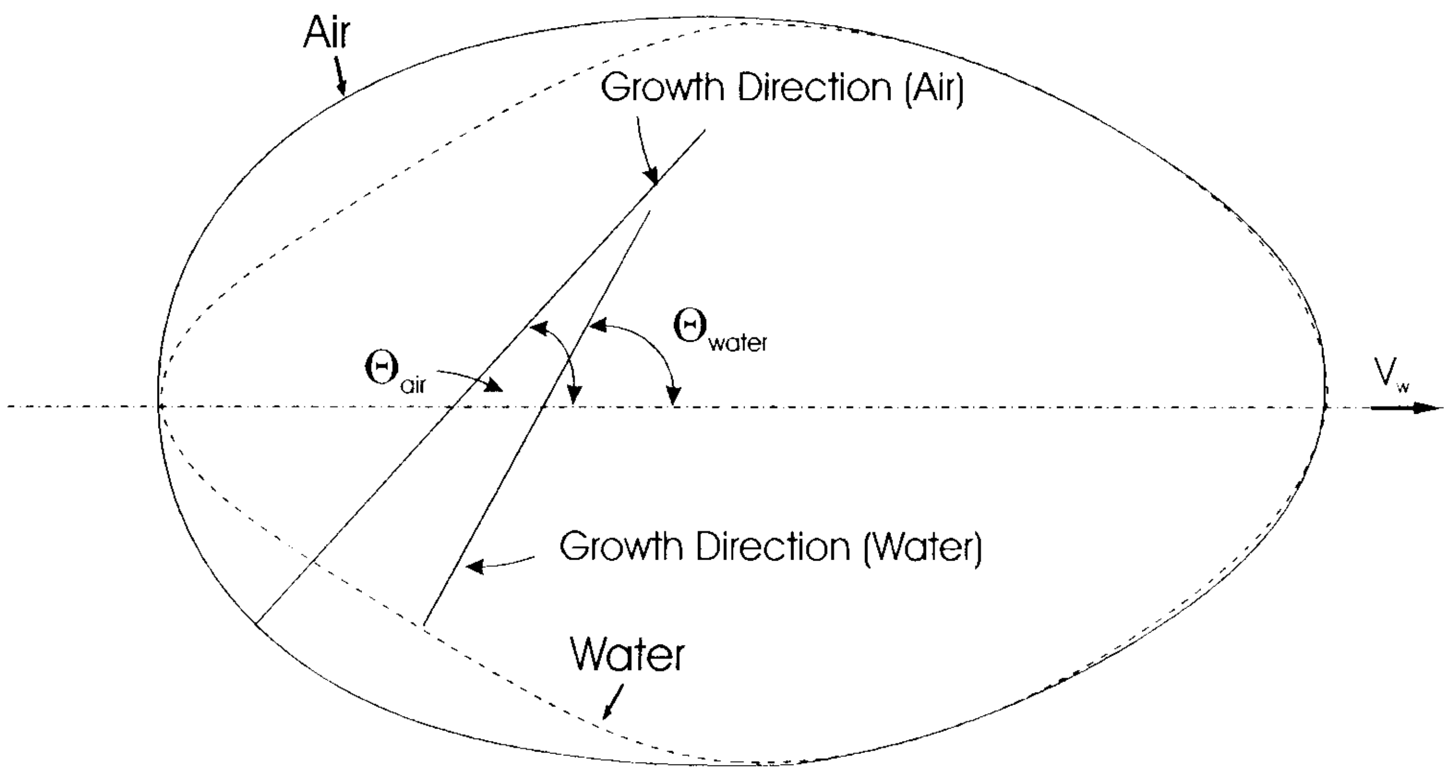


- ✓ Air- deposited welds showed an elliptical crater
- ✓ Wet weld showed a tear-drop geometry
- ✓ Both crater have the same length

Weld Pool Phenomena

Solidification Rate Change

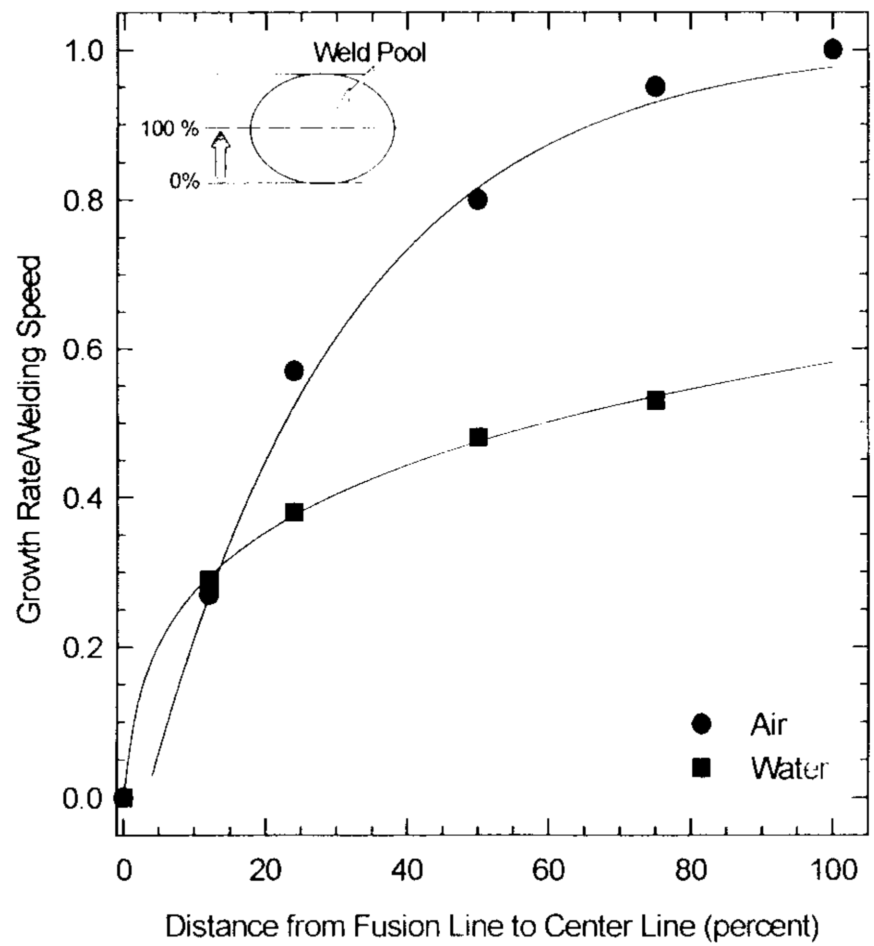
- Weld Pool Shape Change



Weld Pool Phenomena

Solidification Rate Change

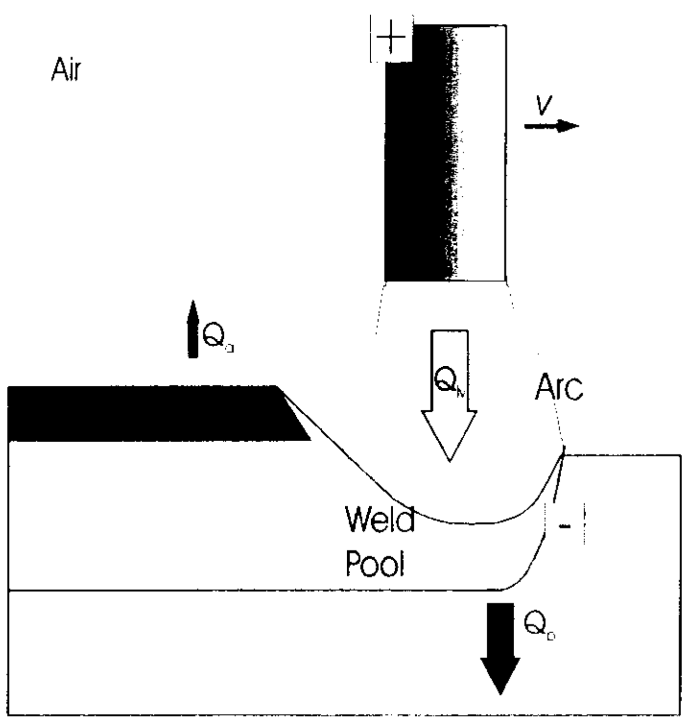
- Normalized Growth Rate

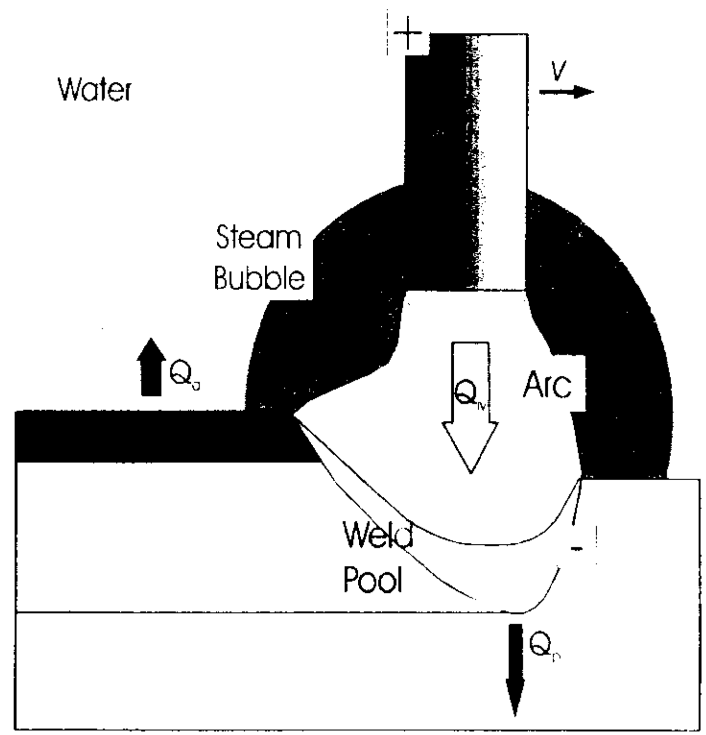


Weld Pool Phenomena

Solidification Rate Change

- Heat Transfer Conditions





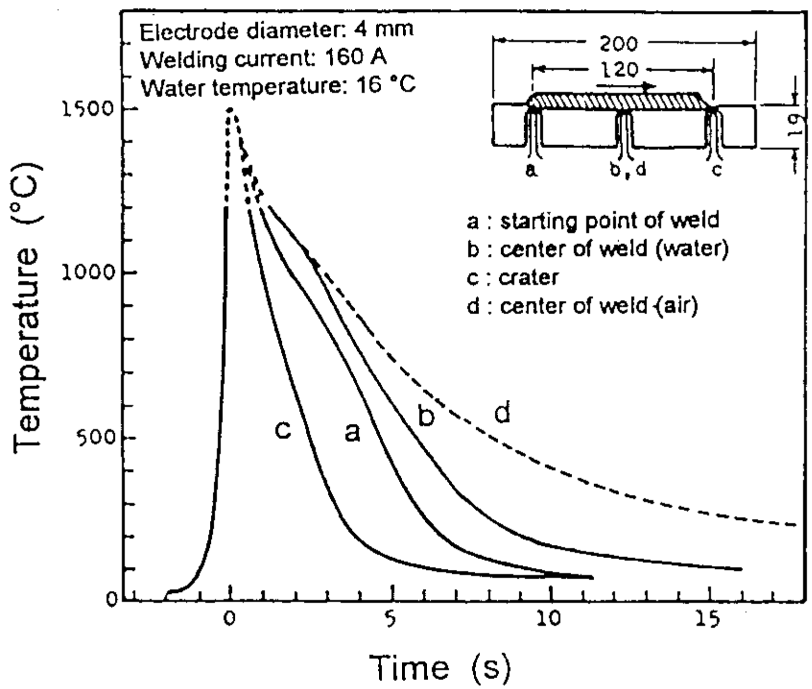
Weld Pool Phenomena

Solidification Rate Change

- Stage 1: Solidification
  - ▸ Lower Weld Pool Heat Loss
  - ▸ Lower Solidification Rate
    - Larger Columnar Grains
- Stage 2: Solid-State Transformations
  - ▸ High Quench Rate
  - ▸ Faster γ-to-α Transformation Rate
    - Finer Microstructures
      FS(B), Microconstituents

Introduction

Thermal Cycles of Points in the Heat Affected Zone

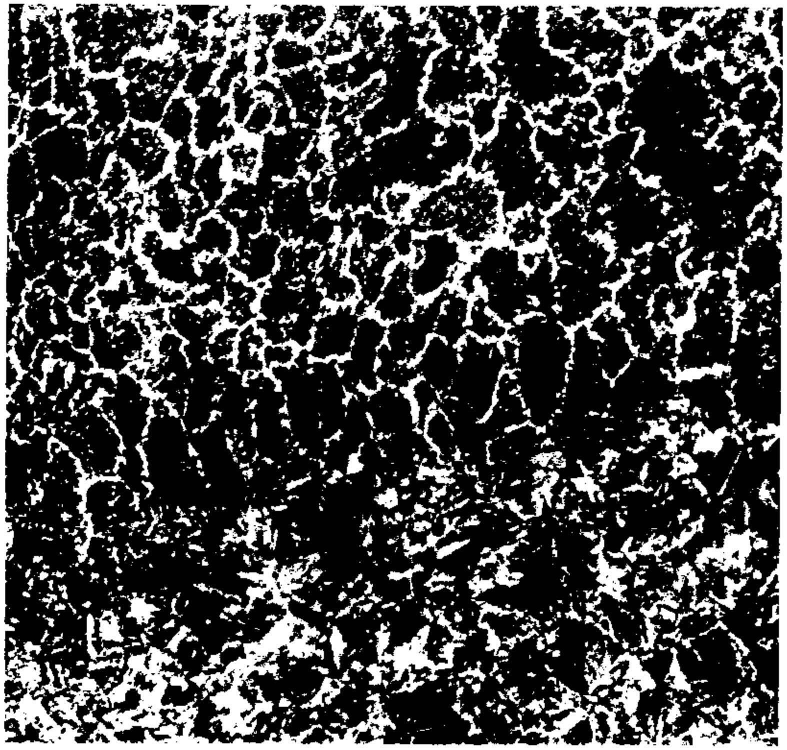


(Hasui and Suga, 1980)

- For $T < 1000°C$ ($t > 3$ sec) cooling rates of underwater wet welds are higher than air-deposited welds (curves b and d)
- At high temperatures ($T > 1000°C$) cooling rates seem to be similar

UWW Welding Electrodes Formulation

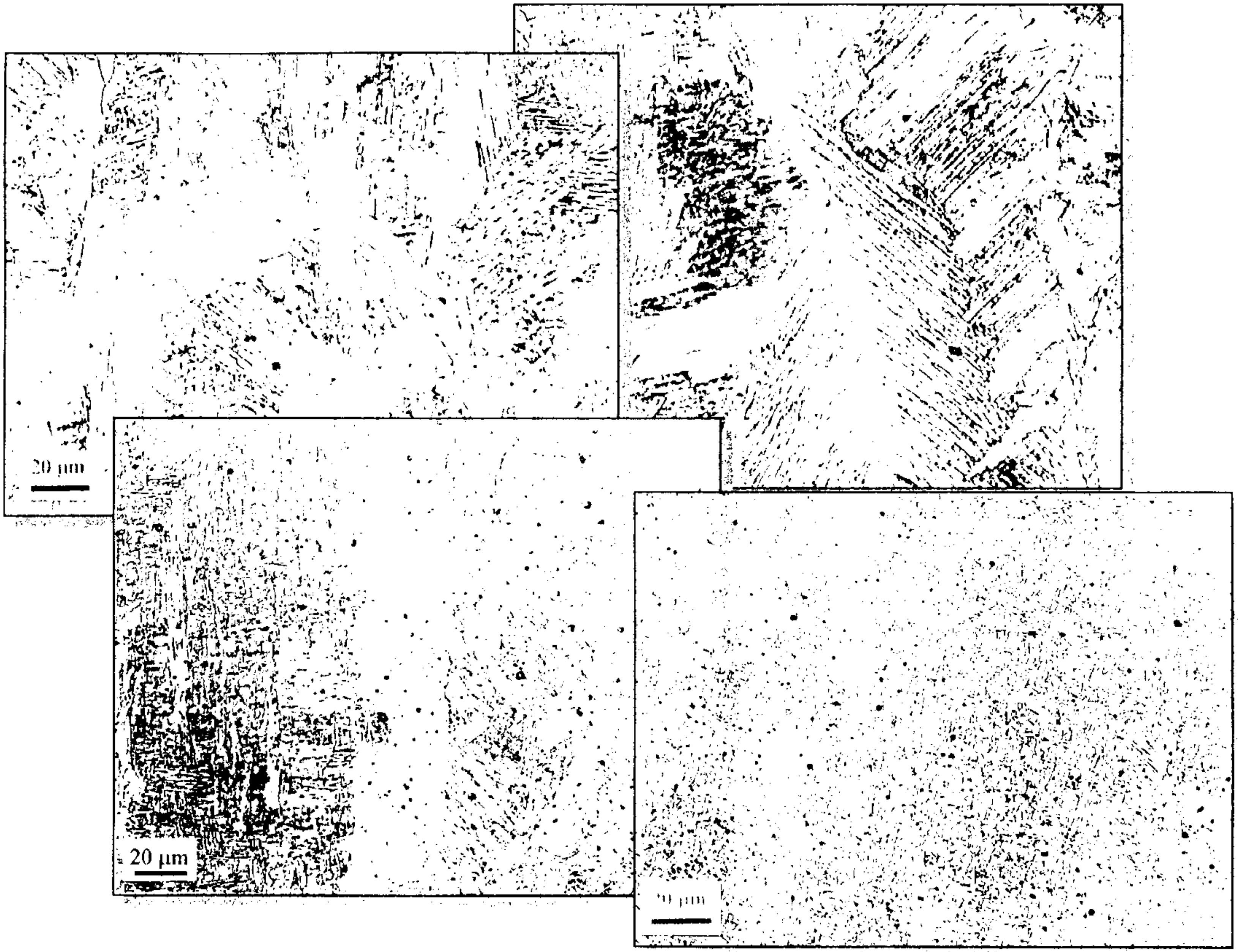
Concept III - Columnar Grain Size Control



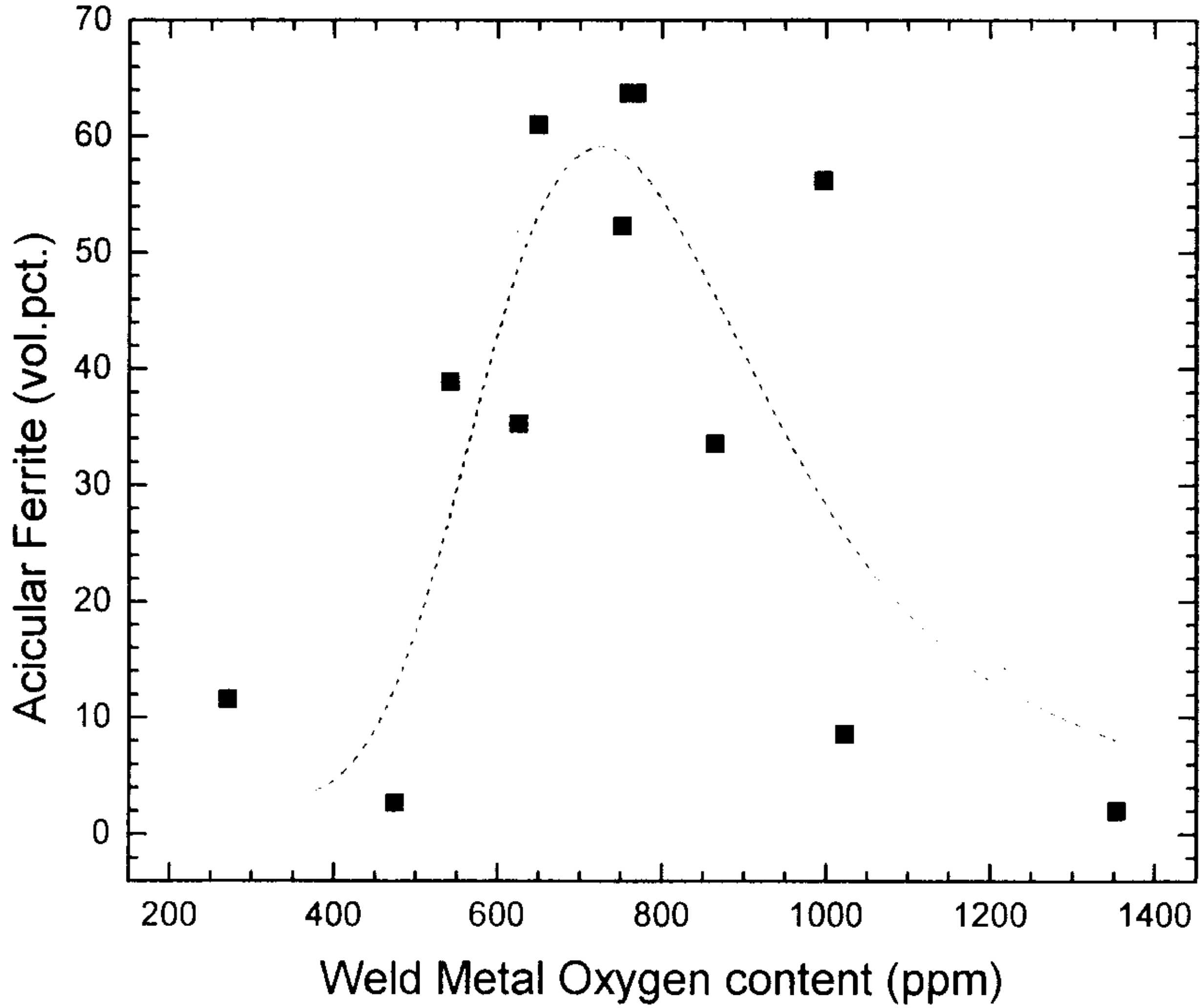
Surface Weld

UWW Weld

Underwater Wet Weld Microstructure

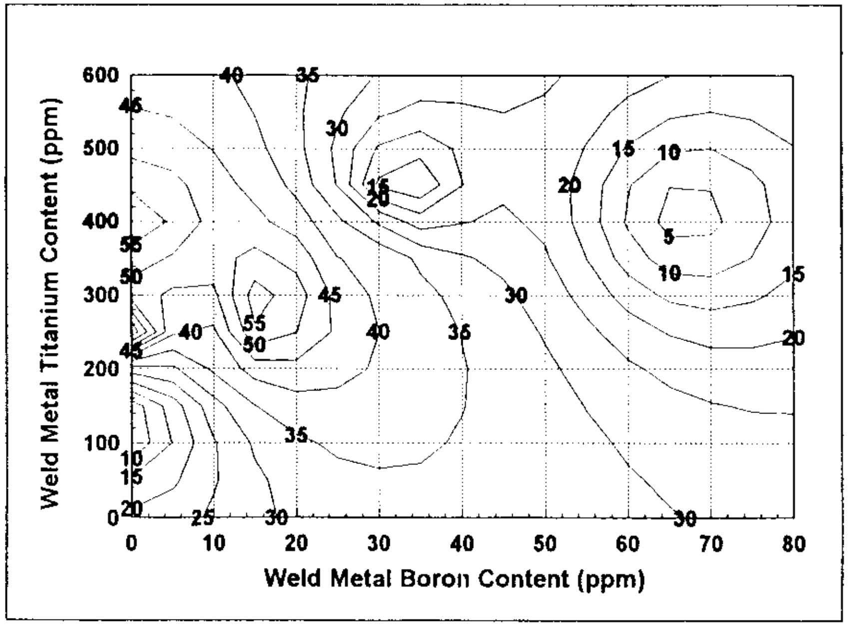


Microstructure as a Function of Weld Metal Oxygen Content



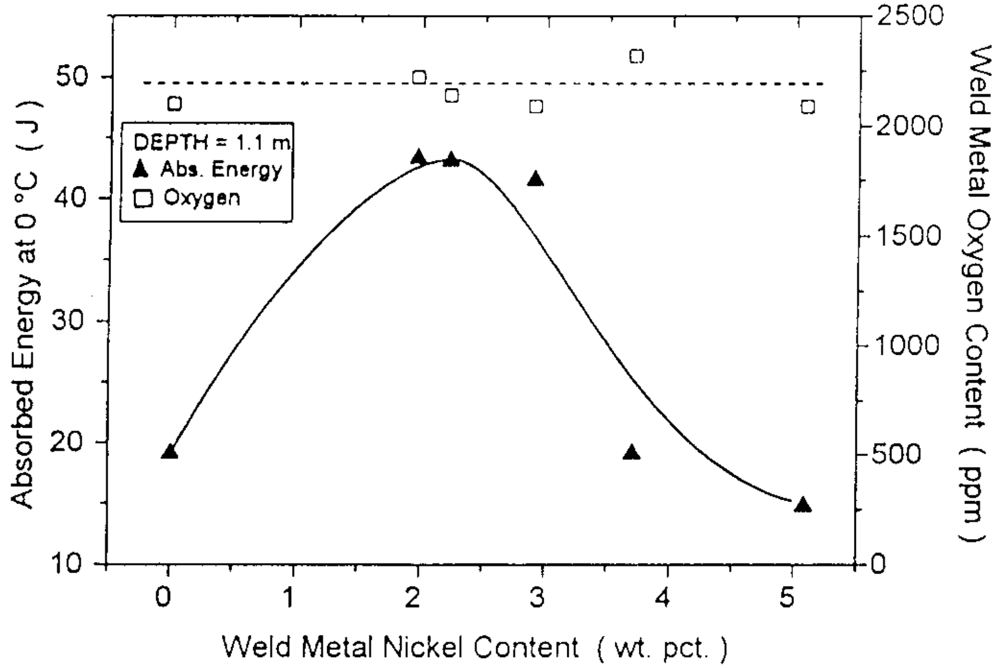
Trends in Underwater Wet Welding Consumables Research

- Effect of Titanium and Boron
  - Weld Metal Microstructure Map - Acicular Ferrite



Results and Discussion

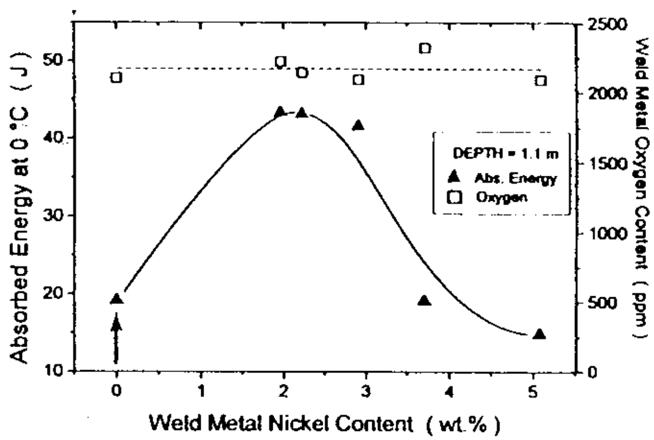
Weld Metal Impact Resistance

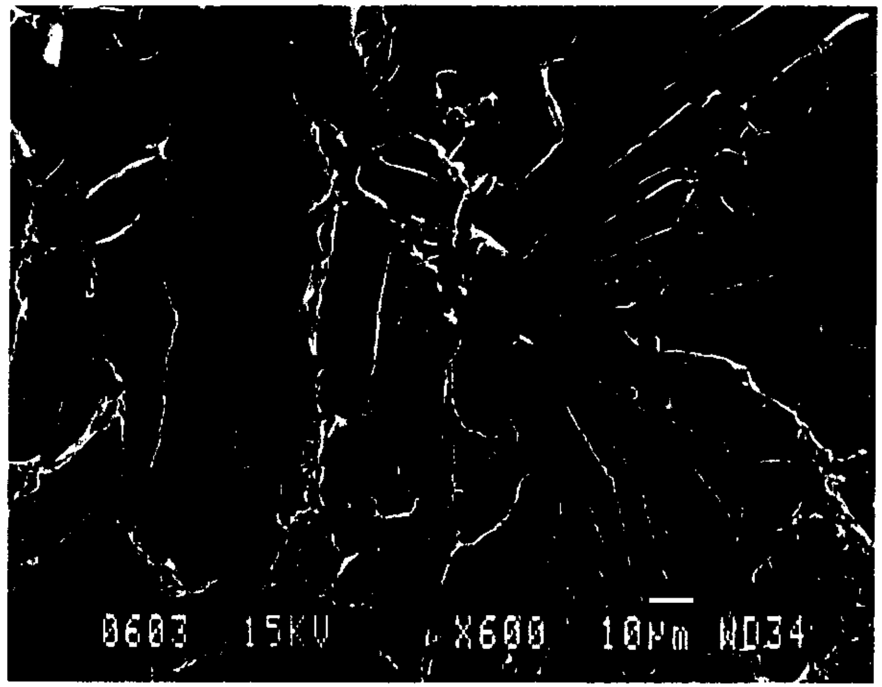


- ✓ Oxygen content remains constant at approximately 2200 ppm for any nickel content
- ✓ A maximum in the absorbed energy occurs for nickel contents between 2 and 3 wt.pct.

Results and Discussion

Fractographic Analysis of Charpy Specimens

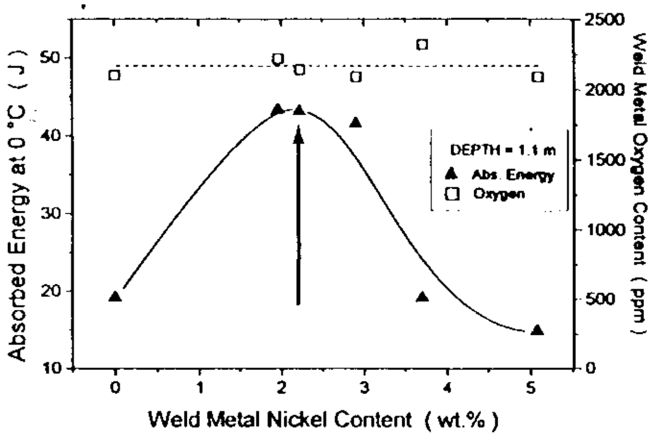


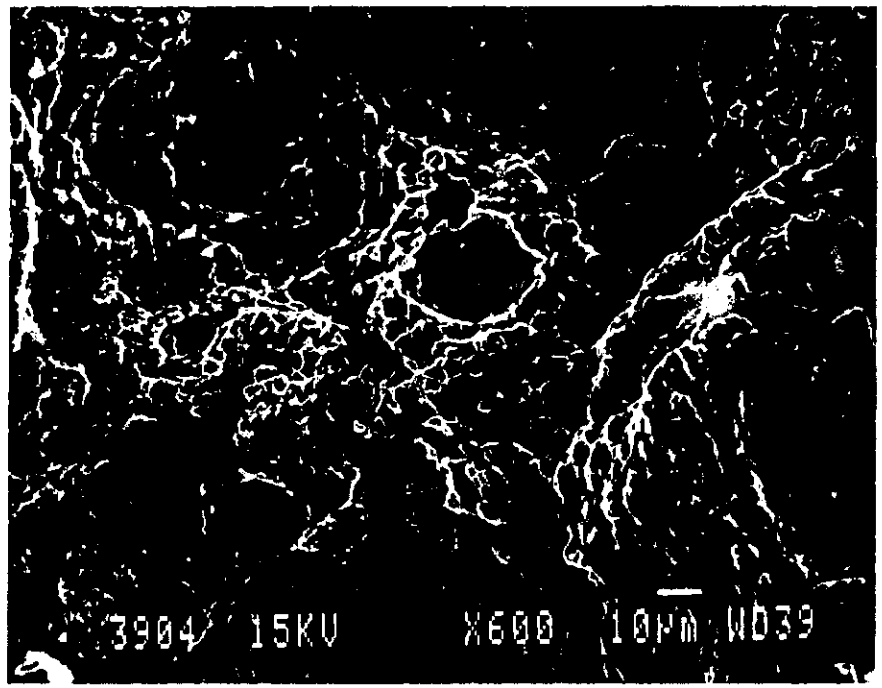


✓ Welds without nickel fractured by cleavage

Results and Discussion

Fractographic Analysis of Charpy Specimens

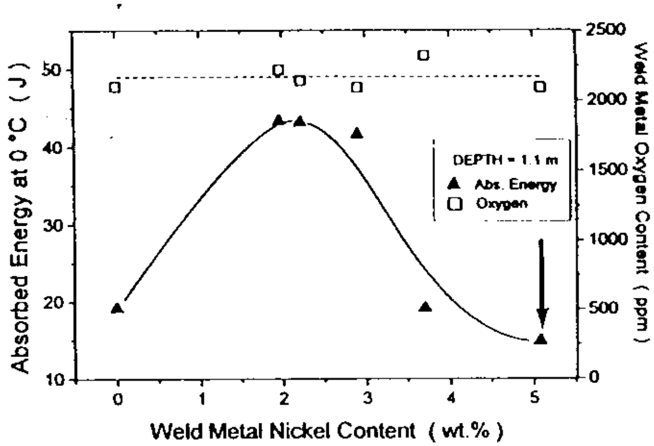


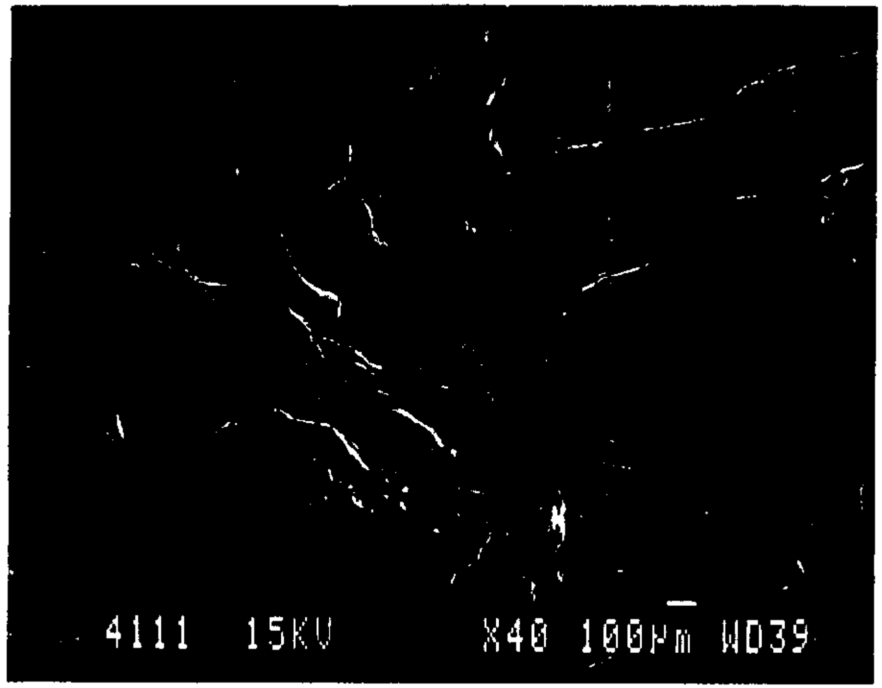


✓ Welds with 2.2 wt.pct. of nickel fractured by rupture (microvoid coalescence)

Results and Discussion

Fractographic Analysis of Charpy Specimens





✓ Welds with 5 wt.pct. of nickel presented extensive areas with solidification cracks

Results and Discussion

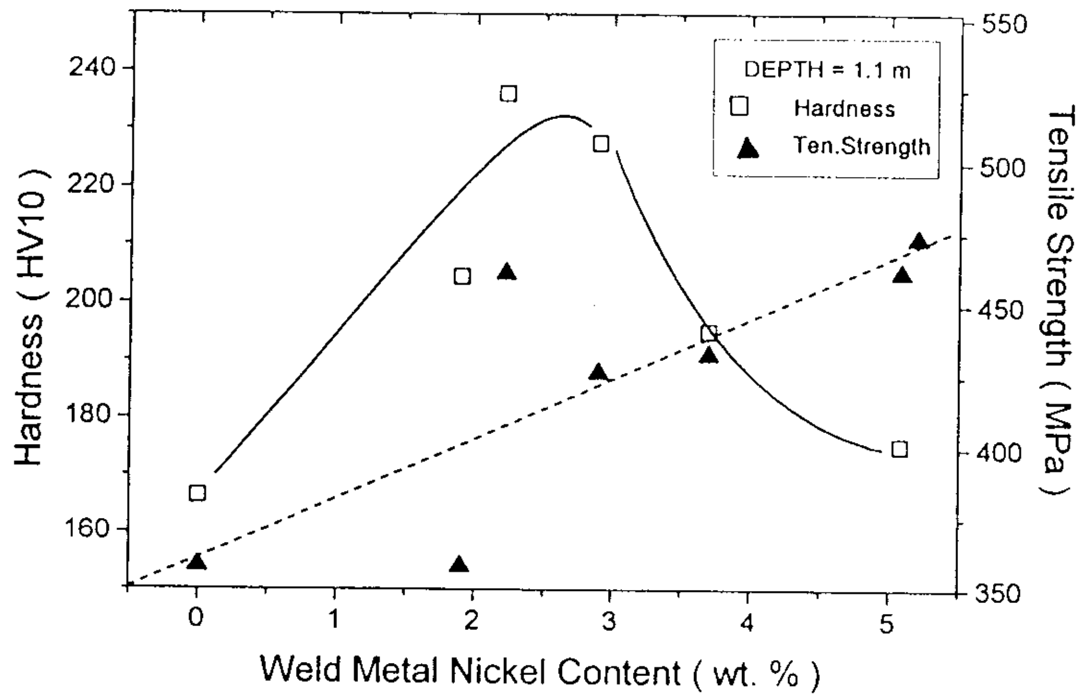
Influence of Nickel on Impact Resistance

- The increase in impact resistance that occurred from 0 to 2.2 wt. pct. nickel can be attributed to:
    1. Grain size refinement, and
    2. Increase in the stacking fault energy which facilitates cross slip of dislocations.

- The drop in impact resistance is explained by the presence of solidification cracks which act as stress raisers and reduce the effective cross-sectional area of the specimen.

Results and Discussion

Weld Metal Tensile Strength



- ✓ Tensile strength presents a maximum value for nickel contents between 2 and 3 wt.pct.
- ✓ Weld metal hardness increases constantly with nickel contents up to 5 wt.pct.

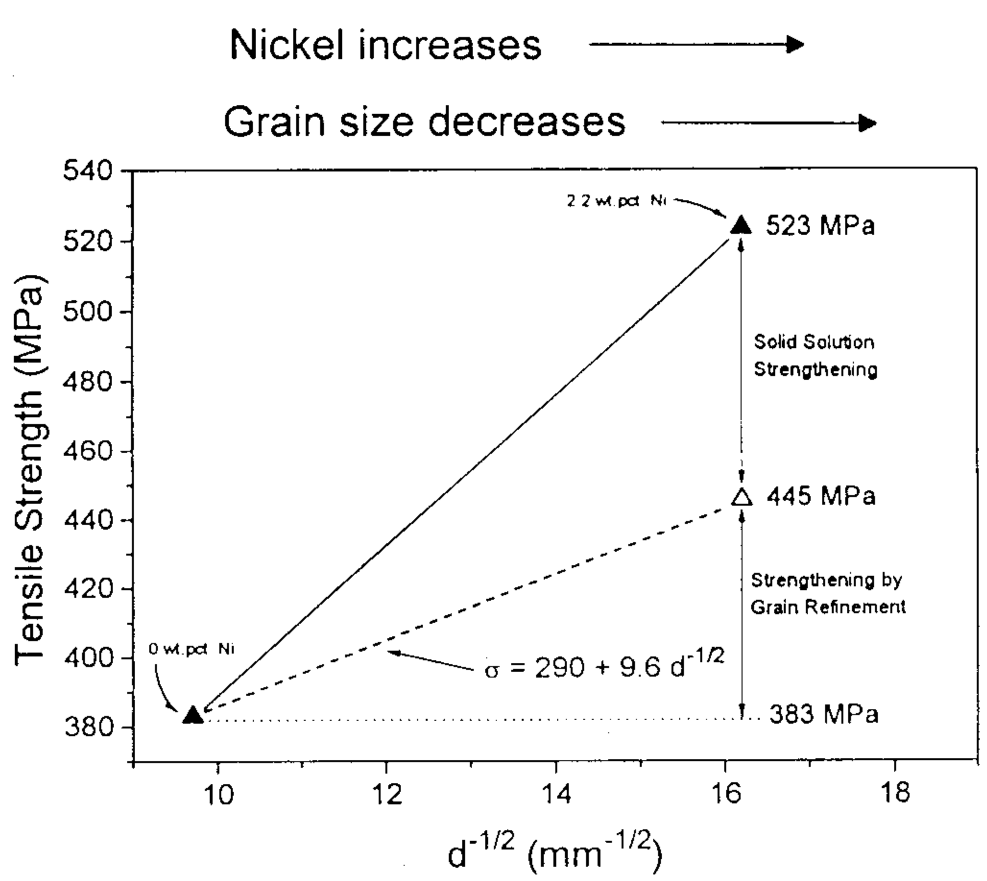
Results and Discussion

Influence of Nickel on Tensile Strength

- The increase in tensile strength that occurred from 0 to 2.2 wt. pct. nickel can be attributed to:
  1. Grain size refinement, and
  2. Solid solution strengthening.
- The drop in tensile strength is explained by the presence of solidification cracks which act as stress raisers and reduce the effective cross-sectional area of the specimen.

Results and Discussion

Influence of Nickel on Tensile Strength



Underwater Wet Welding: Hydrogen Mitigation

Other Techniques

- In-Situ Postweld Treatment
  - Heating Underwater Wet Weld with an Oxy-Fuel/Plasma Arc Torch Immediately after Its Completion.
  - Temperature Increase decreases HAZ Hardness and Diffusible Hydrogen Content.
- Temper Bead
  - Depositing a Bead in a Controlled Fashion (Location from Toe Line) over a Previous Weld.
  - Local Temperature Increase decreases HAZ Hardness and Diffusible Hydrogen Content.

Underwater Wet Welding Seminar
PEMEX/IMP, Ciudad del Carmen
Mexico
February 26th, 1999

Practical Case Studies of Underwater Wet Welding

Thomas J. Reynolds, P.E.
Global Divers & Contractors

Jointly Sponsored by
PEMEX/IMP - MMS

Presentation Overview

- Applications of Underwater Wet Welding/Case Studies
- Designing for Wet Welded Repairs
- Joint Industry Underwater Development Program
- Underwater Welding and Pipeline Modifications and Repairs

Applications of Underwater Wet Welding

- Corrosion
- Storm Loads
- Vessel Impacts
- Installation Mishaps
- Fatigue
- Structural Modifications

Applications of Wet Welding: Corrosion

Corrosion Protection Systems – Cathodic Protection

- Passive Systems – Sacrificial Anodes
  - High Up Front Costs/Low Maintenance Cost
- Active Systems – Impressed Current
  - Low Up Front Costs/Moderate Operating Cost
- Both Systems Required Several Weeks to become fully polarized

Applications of Wet Welding: Corrosion

Corrosion Protection System Failure

- **Passive Systems**
  - Debris Loads on Structure
  - Pipelines Continuity with the Jacket
  - Anodes with greater than 50% depletion
  - Potential difference less than –800 to –850 mv
- **Active Systems**
  - Intermittent Activation of System, Jacket never becomes fully polarized

Applications of Wet Welding: Storm Loads

- Hurricane Season *July - November*
- Winter Storms *December - March*

9 Months of the year

Applications of Wet Welding: Vessel Impacts

Material Barge Collides with Jacket Leg at Waterline

- 8 Pile Jacket used to drill and keep open pressure relief wells for the Caminada Sulfur Mine, Grand Isle Field
- Significant damage to corner jacket leg and pile
- An underwater vertical K brace failed due to collision loads
- Structure constantly discharged water with dissolved sulfur, high H_2S risk

Applications of Wet Welding: Vessel Impacts

Material Barge Collides with Jacket Leg at Waterline

- Structure supports a permanently mounted workover rig used to reopen relief wells as they became scaled up
- Due to the collision damage, structure could not support loads imposed by workover rig
- Every 4 to 6 weeks, all of the relief wells required some kind of workover
- If the pressure built of too high in the underground sulfur mine, the formation could become damaged

Applications of Wet Welding: Vessel Impacts

Material Barge Collides with Jacket Leg at Waterline

- Wet welding provided the fastest, least costly repair options
- Hyperbaric welding (habitat) was not considered do to the high risk of H_2S gas contaminating the habitat
- Required fabrication of repair member could be accomplished at site
- Wet Welding for repairing the damaged leg was avoided in the splash by installing a grouted leg clamp that was dry welded at the +10' and wet welded at the –15' elevation

Designing for Wet Welded Repairs

Suggested Weld Allowable (in Shear)

P = Unit Stress in pounds per linear inch

F = Fillet Leg Size (inches)

G = Root Gap (inches)

E = Tensile Strength of Weld Metal, 70 ksi

.226E = Allowable Unit Stress

Designing for Wet Welded Repairs

Suggested Weld Allowable (in Shear)

P=(0.707(F-G))0.226E

Example: 3/8 in. Fillet Weld, with a 1/16 in Root Gap

P=(0.707(.375 in. - .0625 in.)) (.266)(70,000 lb., in2)

P=((0.707)(.3125 in))(18,620 lb../in2)

P=4,114 pounds force per linear inch of fillet weld

Joint Industry Underwater Development Program

- Strategic Alliance Developed between The Colorado School of Mines (The Center for Joining and Welding Research at CSM) and Global Divers & Contractors in 1992

- Phase 1 of the Joint Industry Underwater Welding Development Program initiated in 1993

Joint Industry Underwater Development Program

- **Phase 1 Accomplishments**
  - Developed Wet Welding Procedures Suitable for Welding Highly Crack Susceptible Material (CE_{IIW}=0.462, with C=0.20 wt. Pct.) utilizing the Multiple Temper Bead Technique with no HAZ cracks <u>and</u> an improved electrode formulation that reduced porosity and improved toughness

Joint Industry Underwater Development Program

- **Phase 1 Accomplishments**

  Through the use of MTB and the reduction of porosity, wet welds met and/or exceeded the AWS D3.6 "Class A" Requirements in:

  - Visual Examination
  - Radiography
  - Fillet Weld Shear Strength
  - All Weld Metal Tensile and Yield Strength
  - Vickers 10 kg Hardness, max 325 HV10
  - Charpy V-Notch Impact Energy

Joint Industry Underwater Development Program

Phase 2 Test Matrix, Experimental Depth to 400 FSW (122MSW)

Task 1 Ferro-manganese additions were made to the Phase 1 formulation to evaluate the changes in the chemical composition, porosity, and microstructure with depth

Task 2 Titanium and boron additions are made to the Fe-Mn optimized formulations from Task 1 to evaluate the changes in mechanical properties, chemical compositions, porosity, and microstructure

Joint Industry Underwater Development Program

Phase 2 Test Matrix, Experimental Depth to 400 FSW (122MSW)

Task 3 For optimum columnar grain size control, experimental fluxes will be formulated with three levels of rare earth elements

Task 4 Microstructure Evaluations of the Reheated Weld Metal, plus Correlation of chemical composition, tensile and impact properties

Underwater Welding, Pipeline Modifications and Repairs

- Hyperbaric Dry Welding on Pipelines
- Wet Welding on Pipelines

Underwater Welding, Pipeline Modifications and Repairs

- Hyperbaric Dry Welding on Pipelines
  - Hot Tapping into trunklines
  - Installing Emergency Shutdown Valves (ESV)
  - Removing Damaged Pipe Due to Corrosion or Impact
  - Tying in Pipelines to Risers or Existing Lines

Underwater Welding, Pipeline Modifications and Repairs

- Wet Welding on Pipelines

United States Department of Transportation requires that all Pipeline Welding in OCS waters and in the Continental U.S. be in Accordance with API Standard 1104

The state-of-the-art Wet welds meet all the mechanical requirements except for the bend test and porosity requirements

Research Program: Underwater Wet Welding of Pipeline Steels

- **Underwater Wet Welding of Pipeline Steels**

  With the Edison Welding Institute under contract with the Pipeline Research Council

  Program Objectives:

  - To investigate and develop underwater wet welding techniques suitable for pipeline tie-in and repair welds
  - Significantly reduce the cost of pipeline tie-in and repair operations
    - Reduced response time
    - Reduced production shut-in time
    - Minimized pollution risk

Research Program: Underwater Wet Welding of Pipeline Steels

- **Program Tasks**
  - Task 1. Produce and Evaluate Sleeve Fillet Welds
  - Task 2. Pressure Test Sleeve Repair Assembly
  - Task 3. Produce and Evaluate Open-Root Butt Welds

Summary:

Wet Welding has many applications:

Corrosion	Vessel Impacts
Storm Loads	Installation Mishaps
Fatigue	Structural Modifications

Designing applications is Straightforward

Scalloped Sleeves	Shear Pups
Doubler Plates	Minimize Overhead Welding

Continued Research

- Joint Industry Underwater Development Program
- Strategic Alliance between CSM and Global Divers

PEMEX / IMP / MMS

UNDERWATER WET WELDING SEMINAR

February 26, 1999

Ciudad del Carmen, Mexico

Rodger D. Holdsworth
AWS D3b Subcommittee

PURPOSE OF PRESENTATION

- To provide a overview of the American Welding Society (AWS) D3 Committee on Welding and Marine Construction and the D3b Sub Committee on Underwater Welding.

- To provide some insights on the history of underwater welding and Standards evolution.

PURPOSE OF PRESENTATION

- To provide information on the the latest D3.6 Specification for U/W Welding scheduled for distribution May 1999 and ISO Standards related to U/W Welding.

- To provide the status of the 2003 edition of the AWS D3.6 Specification presently under development.

AWS D3 Committee

- During the first World War, a committee was appointed to consider the feasibility of constructing welded ships vs riveted construction methods to increase production and improve ship structures.
- The committee advocated the use of unit prefabrication, and an experimental welded mid section assembly was ready for welding by the end of WWI.

AWS D3 Committee *(continued)*

- Between the two World Wars there was not much welding research in the shipbuilding industry. However, some all-welded ships were being constructed prior to Pearl Harbor.
- During WWII new shipyards designed for all-welded construction of ships.
- The Liberty ship was one of the first mass-produced ships to utilize welded construction.

AWS D3 Committee *(continued)*

- The beginning of intensive ship structure research was prompted by unexpected major failures.
- Factors which cause a normally ductile material to act in a brittle manner were not understood at that time.

AWS D3 Committee *(continued)*

- Welded ships were then designed and built with more consideration given to material behavior under load and to provide for the smooth flow of stresses from one member to another.
- Competent overall supervision for welded construction was emphasized.

AWS D3 Committee *(continued)*

- The AWS D3 Committee for Welding in Marine Construction in cooperation with the American Bureau of Shipping, Regulatory Agencies and other Organizations, has issued guides, specifications, codes on hull construction for over 50 years.

AWS D3b Sub-Committee

- The AWS Sub-Committee for U/W Welding was formed in 1971 by the AWS D3 Committee for Welding in Marine Construction in recognition of the need for guidance in U/W welding to specify and produce welds of a predictable performance level for U/W Welding applications.
- The first edition of the Specification for U/W Welding was published in 1979.

AWS D3b Sub-Committee

(continued)

- Over the years the AWS D3.6 Specification for U/W Welding gained International recognition as the guiding standard for both dry and wet U/W Welding.
- The Specification in these few short years gained broad acceptance, not only in Ship Husbandry, but other industries to include: Offshore Oil, Ports and Harbors, Nuclear Power, Mining and other applications.

AWS D3b Sub-Committee

(continued)

- The AWS D3b Sub-Committee is made up of a balanced group of members representing Operators (Owners, U.S. Navy, Oil / Gas, Nuclear), Contractors (Diving / Equipment / Suppliers), Inspection / Testing (Laboratories, Inspection, 3rd Party), Government (Regulatory Agencies), and Institutions (Universities, Education/ Training).

AWS D3b Sub-Committee

AMERICAN WELDING SOCIETY D3B SUBCOMMITTEE ON UNDERWATER WELDING

INTERNATIONAL STANDARDS ORGANIZATION TC - 44
CHAIRMAN
Mr. J. P. Gourmelon
SECRETARY
Mrs. H. Brun-Maguet

AWS D3B/TC44
WORK GRP.
INT. AFFAIRS
Jim Ibarra

AWS D3B
CHAIRMAN
Rodger Holdsworth

D3 COMMITTEE ON WELDING INMARINE CONSTRUCTION
CHAIRMAN
Rodger Holdsworth

EUROPEAN COMMITTEE FOR STANDARDIZATION CEN/TC 121
D3B REPRESENTATIVE
Mr. Peter Szelagowski

AWS D3B
SECRETARY
Len Connor

GROUP "A"	GROUP "B"	GROUP "C"	GROUP "D"	GROUP "E"	GROUP "F"
FORMAT COMPOSITION AND EDITING	DESTRUCTIVE TESTING, METALLURGICAL ANALYSIS AND INSPECTION	TECHNIQUE, QUALITY CONTROL, FABRICATION	PROCEDURE AND PERFORMANCE QUALIFICATIONS	DESIGN	SAFETY, HUMAN & ORG. FACTORS
GROUP CHAIRMAN	**GROUP CHAIRMAN**	**GROUP CHAIRMAN**	**GROUP CHAIRMAN**	**GROUP CHAIRMAN**	**GROUP CHAIRMAN**
Jim O'Sullivan	Jack Couch	Rob Murray	Tom Reynolds	Anthony Harjo	Shawn T. Cullen
GROUP MEMBERS	**GROUP MEMBERS**	**GROUP MEMBERS**	**GROUP MEMBERS**	**GROUP MEMBERS**	**GROUP MEMBERS**
Tiny Von Rosenberg Jessie Grantham Bill St. Cyr, II Peter Szelagowski Iwan Pachniuk Jim Ibarra Felix Dyhrkopp	Cliff Anderson Mike Sammons K. Berard E. Klein Fon Stonum Graham Rand	Whitey Grubbs Duke Ogden Ron Rowland	Greg Cain Tom Payne Tom West Jesse Grantham P. D. Watson	Buddy Delaune Jr. Shelton Fortenberry Prof. K. Masubuchi John Steinmetz J. M. Sturrock Bryan Wood	Mike Blumenberg

AWS D3b Sub-Committee

(continued)

- The science, technology and applications of U/W Welding have come a long way since the World Wars.
- The demand for more comprehensive standards covering all forms of U/W Welding has grown significantly since the publication of the first Specification in 1979.

AWS D3b Sub-Committee

(continued)

- The Sub-Committee has worked hard to meet industry demands with each new publication of the Specification published in 1983, 1987 and 1993 respectively. The latest edition, currently in publication, will be made available in May of this year.

AWS D3b Sub-Committee

(continued)

- The Subcommittee has also worked hard to align the Specification with other underwater welding standards produced by organizations such as: ASME, U.S. Navy, International Institute of Welding, American Bureau of Shipping, Det Norske Veritas, Bureau Veritas and CEN.

AWS D3b Sub-Committee

(continued)

- Presently the Sub-Committee is actively working with the International Standards Organization (ISO) to ensure that requirements are consistent and uniform worldwide and that metric units of measure are readily available.

AWS D3.6 Specification for U/W Welding

- The Specification for U/W Welding includes:
  - General Provisions
  - Design
  - Workmanship
  - Technique
  - Qualification
  - Inspection, Testing and Quality

AWS D3.6 Specification for U/W Welding *(continued)*

- The 1999 edition of the Specification will offer the user a wealth of information, technical updates, forms and an easier to use format to include:
  - A commentary on all sections of the documents describing the basis for technical data, how some provisions evolved and useful guidelines.
  - Procedure and Welder Qualification example forms correlated to applicable sections of the Specification for ready access are also available.

AWS D3.6 Specification for U/W Welding *(continued)*

- The 2003 edition presently under development will offer still another leap forward in meeting industry needs going into the next Century.
- A non-mandatory appendix will be added on Human and Organizational Factors, as applied to U/W Welding operations, designed to aid in reducing inherent risks and improving safety.

AWS D3.6 Specification for U/W Welding *(continued)*

- Inspection and testing methods will be expanded to include new and special application testing, and inspection techniques.
- Processes will be expanded to include automatic and friction welding processes.

AWS D3.6 Specification for U/W Welding *(continued)*

- More provisions will be added to facilitate aligning criteria and technical requirements to International and other Standards such as ASME.
- The design section will be expanded to meet ANSI/AWS requirements to elevate the current Specification to a Code Standard.

AWS D3.6 Specification for U/W Welding *(continued)*

- A Specification is a standard that clearly and accurately describes the essential technical requirements for a material, product, system, or service. It indicates the procedures, methods, qualifications, or equipment by which it can be determined that the requirements have been met. A specification is intended to be mandatory when referenced by other mandatory documents.

AWS D3.6 Specification for U/W Welding *(continued)*

- A Code is a standard consisting of a set of conditions and requirements relating to a particular subject, and indicating appropriate procedures by which it can be determined that the requirements have been met. It is a standard that is suitable for adoption by a governmental authority as a part of a law or regulation, or as specified by other mandatory documents.

ISSUES

- Welder / Diver pre-screening qualification requirements
- Marine Welding Inspector qualifications
- U/W Welding Supervisor Qualifications
- International Standards Alignment

ISSUES

- Much of the Sub-Committee success to date is due in great part to industry input received through various committee presentations, domestic and international workshops, roundtables, publications and direct phone, mail or E-mail communication.

ISSUES

- The D3b Sub-Committee welcomes any input, concerns, questions, recommendations from a variety of Industries, Government Agencies, Owners, Contractors, Institutes, etc.

APPROACHES FOR IMPROVEMENT

- Review and evaluate the Specification and compare to industry needs.
- Redesign, update, add and delete items as needed
- Stay abreast of regulatory and international requirements and as they evolve and establish criteria
- Measure performance and audit for accuracy and completeness

SUMMARY

- Owner and Regulatory requirements for U/W Welding is a moving target
- Knowledge of U/W Welding Standard expectations is critical for compliance to specified requirements.
- Achieving compliance is a challenge.
- Considerable information is available to assist in compliance through the ANSI / AWS D3.6 Specification for U/W Welding.
- Aligning criteria with the International Standards can prove valuable to avoid common pitfalls when working in different parts of the world.

CONTACT INFORMATION

Should you have a question or wish to provide input to the D3 or D3b Committees you may contact the American Welding Society at:

- 550 N.W. LeJeune Road, Miami, FL 33126
- Tele: 1-800-443-9353 Fax: 305-443-7559
- E-Mail: info@aws.org
- Website: http://www.aws.org

  Attn: Mr. Len Connor - Secretary D3 & D3b Committees
- Rodger Holdsworth - Chairman

  Tele: 504-263-8700 Fax: 504-263-8701

Underwater Wet Welding

Regulatory Concerns

Tommy Laurendine, P.E.

Code of Federal Regulations (CFR)

Title 30

Subpart I - Platforms and Structures

Underwater wet welding is not included.

ANSI / AWS D3.6-93

MMS requires all underwater welding
(wet or dry)
comply with the D3.6-93 specification.

Regulatory Concerns

- EXISTING STEEL
- QUALIFIED WELDERS
- QUALIFIED PROCEDURES
- TEST SPECIMENS
- DUCTILITY
- FATIGUE
- FRACTURE

Existing Steel

What is the carbon equivalent (CE)?

Take sample send to lab.

If the steel is suitable for wet welding the MMS encourages the use of wet welding.

Qualified Wet Welders Qualified Procedures

Personnel and procedures should meet or exceed the requirements of

ANSI /AWS D3.6-93

"Specification for Underwater Welding"

Regulatory Concerns?

Are the same as any other engineered product. Show me with math and science that the solution is going to work.

Test Specimens

Underwater welding (wet or dry) requires fabrication of test specimens.

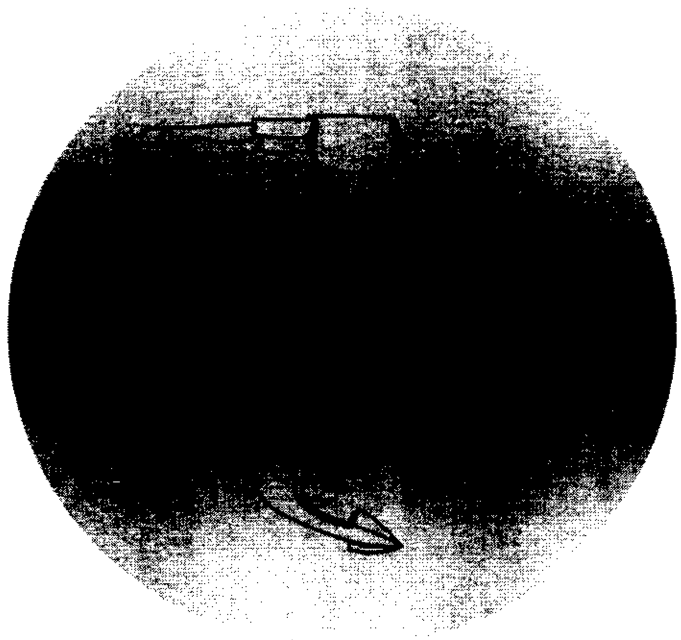
Ductility / Fatigue / Fracture

Wet welding has had a reputation of having problems with cracking due to brittleness.

Use the proper welding procedure.

- Class A - Comparable to above-water welding
- Class B - For less critical applications
- Class C - Where load bearing is not a primary consideration
- Class O - To meet the requirements of another designated code or specification

PEMEX - IMP
UNDERWATER WET WELDING SEMINAR
26 FEBRUARY 1999



CERTIFICATION AND QUALITY ASSURANCE

CERTIFICATION & QUALITY ASSURANCE

- REVIEW OF EXISTING CERTIFICATION SCHEMES
- DISCUSSION OF QC/QA ASPECTS
- SUMMARY

CERTIFICATION SCHEMES

- ABS
  - GUIDE FOR UNDERWATER WELDING
- AMERICAN WELDING SOCIETY
  - ANIS/AWS D3.6, SPECIFICATION FOR UNDERWATER WELDING
- BUREAU VERTIAS
  - UNDERWATER WELDING, GENERAL INFORMATION AND RECOMMENDATIONS

CERTIFICATION SCHEMES

- DET NORSKE VERITAS
  - RP B604, UNDERWATER WELDING
- DEPARTMENT OF DEFENSE
  - MIL-STD-1692, UNDERWATER WELDING REQUIREMENTS FOR NAVAL FACILITIES
- DEPARTMENT OF THE NAVY
  - TECH MANUAL: S9086-CH-STM-010, CHAPTER 074, WELDING AND ALLIED PROCESSES

CERTIFICATION SCHEME BASIS

- INTERNATIONAL INSTITUTE FOR WELDING
  - IIW DOC SCUW 124, STANDARD GUIDELINES FOR SPECIFICATION FOR UNDERWATER FUSION WELDING

CERTIFICATION SCHEME BASIC ELEMENTS - IIW

- APPROVAL OF WELDING PROCEDURE
  - ESSENTIAL VARIABLES
  - QUALIFICATION TESTING
- APPROVAL OF JOB PARAMETERS
- QUALIFICATION OF WELDERS
  - TRAINING
  - TESTING

EXPANDED ELEMENTS

- QUALITY MANAGEMENT SYSTEM
- CONTROL OF WELDING PROCEDURES
- CONTROL OF WELDERS
- UNDERSTANDING THE JOB
- INSPECTION OF THE WORK

SCHEME COMPARISON - QA

DOC	SYSTEM
ABS	X
AWS	O
BV	O
DNV	O
DOD	X
NAVY	O

SCHEME COMPARISON - WELDING

DOC	WPS	WELD	TRAIN
ABS	X	X	X
AWS	X	X	X
BV	X	X	O
DNV	X	X	O
DOD	X	X	X
NAVY	X	X	O

SCHEME COMPARISON - JOB

DOC	GUIDE	LIMITS	CONF
ABS	X	X	X
AWS	O	O	X
BV	X	O	X
DNV	O	X	X
DOD	X	O	O
NAVY	X	X	X

SCHEME COMPARISON - NDT

DOC	FINAL	NDT	TRAIN
ABS	X	X	O
AWS	X	X	O
BV	X	X	X
DNV	O	O	O
DOD	X	X	X
NAVY	X	X	X

CERTIFICATION ELEMENTS

- QUALITY MANAGEMENT SYSTEM
- CONTROL OF WELDING PROCEDURES
- CONTROL OF WELDERS
- UNDERSTANDING THE JOB
- INSPECTION OF THE WORK

QUALITY MANAGEMENT SYSTEM

- MANAGEMENT STRUCTURE
- CORPORATE QUALITY POLICIES
- INTERNAL AUDITING PRACTICES
- NCR & CORRECTIVE ACTION PRACTICES
- PURCHASING PRACTICES
- RECORD RETENTION

QUALITY MANAGEMENT SYSTEM

- SPECIAL PROCESS CONTROL
- CALIBRATION PRACTICES
- INSPECTION PRACTICES
- TESTING PRACTICES
- PERSONNEL QUALIFICATIONS
- SUBCONTRACTED SERVICES
- DESIGN PRACTICES

WELDING PROCEDURES

- CLASS OF WELD
- WELDING PROCESS
- JOINT DESIGN
- BASE METAL & CE
- FILLER METAL
- POSITION OF WELDING

WELDING PROCEDURES

- HEAT TREATMENT
- ELECTRICAL CHARACTERISTICS
- TECHNIQUE & SEQUENCE
- ENVIRONMENT
- INTERMEDIATE INSPECTIONS
- FINAL INSPECTIONS

CONTROL OF WELDERS

- TRAINING
  - FORMALIZED AND DOCUMENTED
- EXPERIENCE
  - WORK RECORDS
- WELDER QUALIFICATION

WELDER QUALIFICATION

- WELDING PROCESS
- ELECTRODE CLASSIFICATION
- STEEL HEAT TREATMENT
- SHIELDING GAS
- WELDING POSITION
- PIPE DIAMETER, WALL THICKNESS
- DIRECTION OF VERTICAL TRAVEL

WELDER QUALIFICATION

- OMISSION OF BACKING
- DEPTH
- DIVER FACTORS
  - DIVING SUIT
  - DEPTH
  - VISIBILITY
  - THERMAL ENVIRONMEMT
  - DIVER SUPPORT

UNDERSTANDING THE JOB

- TYPE OF REPAIR
  - ACCESS, TIMING, JOINT FITUP
  - REDESIGN
- LIMITS ON CLASS/PROCESS
- BASE METAL IDENTIFICATION
- CONFIRMATION TESTS
- FEEDBACK

INSPECTION OF THE WORK

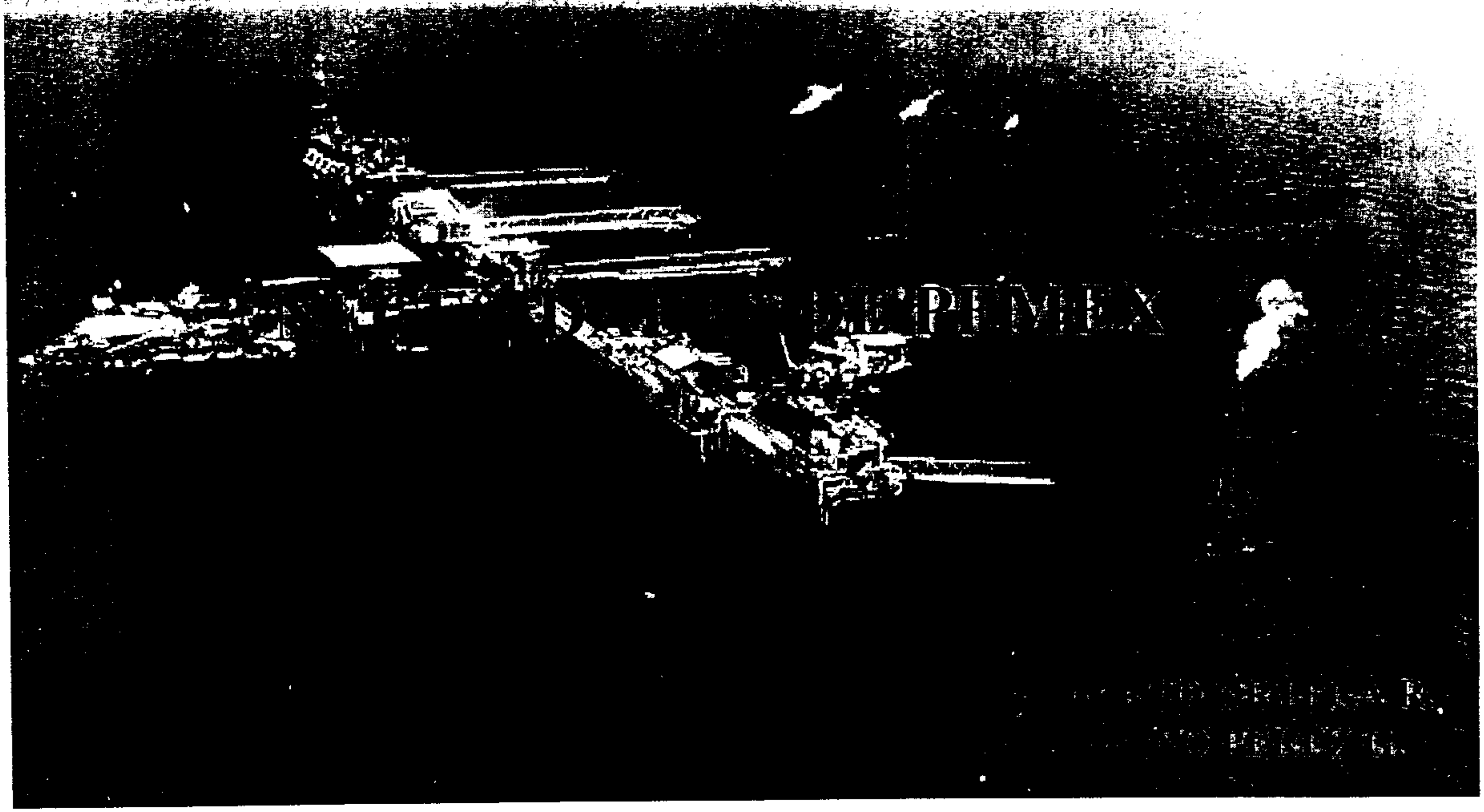
- SELECTION OF NDT METHOD
  - SURFACE, INTERNAL
- APPROVED PROCEDURES
- QUALIFIED INSPECTORS
- EXTENT OF INSPECTION
  - TIMING OF INSPECTION
- DESIGN RELATED CRITERIA
  - CODES, ANALYSIS

SUMMARY

- EXISTING CERTIFICATION SCHEMES
- QUALITY MANAGEMENT SYSTEMS
- PERSONNEL
- UNDERSTANDING THE JOB

PEMEX

EXPLORACION Y PRODUCCION



PARTICIPACION DEL IMP

El Instituto Mexicano del Petróleo en apoyo a Petróleos Mexicanos, desde 1982 viene participando activamente en las actividades de inspección y mantenimiento de plataformas de la siguiente forma:

- Emite manuales de inspección
- Realiza la evaluación y retroalimentación de los reportes de inspección
- Realiza la evaluación estructural de plataformas dañadas
- Emite recomendaciones de reparación y reforzamiento

PARTICIPACION DEL IMP

Actualmente el IMP desarrolla para PEP RMNE los proyectos siguentes:

- Actualización de la filosofía de inspección
- Proyectos de desarrollo tecnológico

  - **Detección, evaluación y reparación de grietas por fatiga en nodos de subestructuras y superestructuras de plataformas marinas.**

  - **Técnicas de aplicación de soldadura submerina en instalacioneses marinas**

El Seminario de Soldadura Húmeda ha sido considerado como parte de este último proyecto

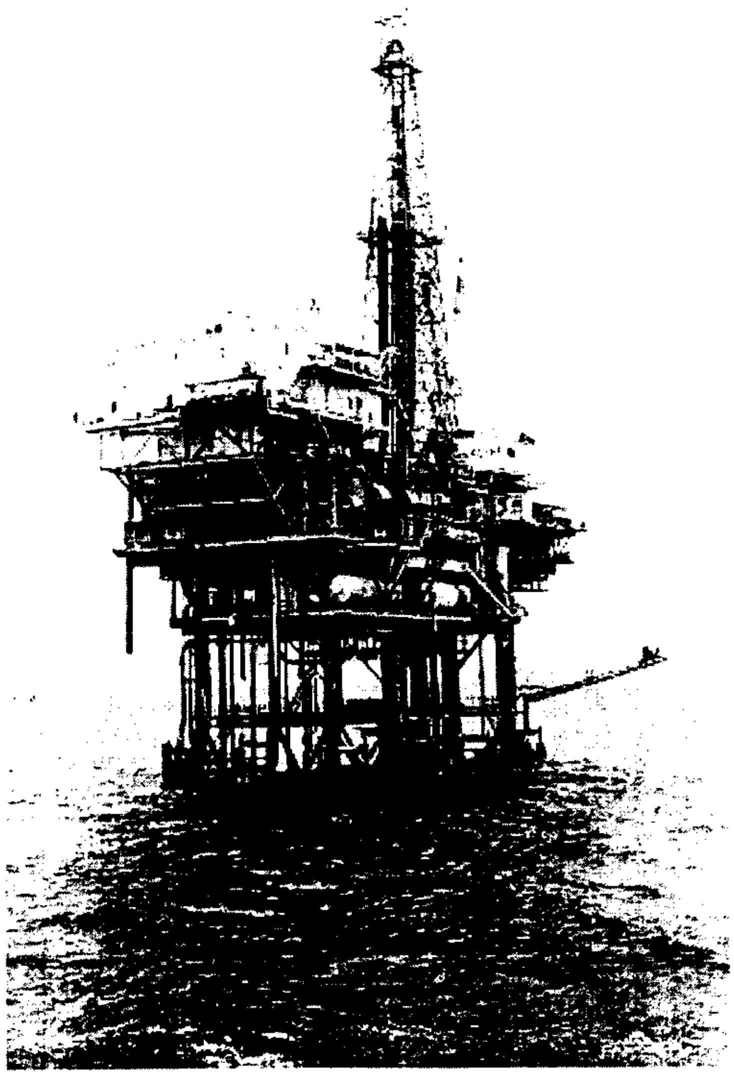
PARTICIPACION DEL IMP

Para ofrecer los servicios antes mencionados PEMEX y el IMP han participado en proyecto de copatrocinio con universidades y compañias extranjeras, entre las que destaca:

Universidad de Londres (1987 - 1999)

- FATIGA (1987-1994)
- RISC (1991 - 1997)
- ACFM (1994)
- LEADIR (1995 -1999)
- EDICS (1995 -1999)

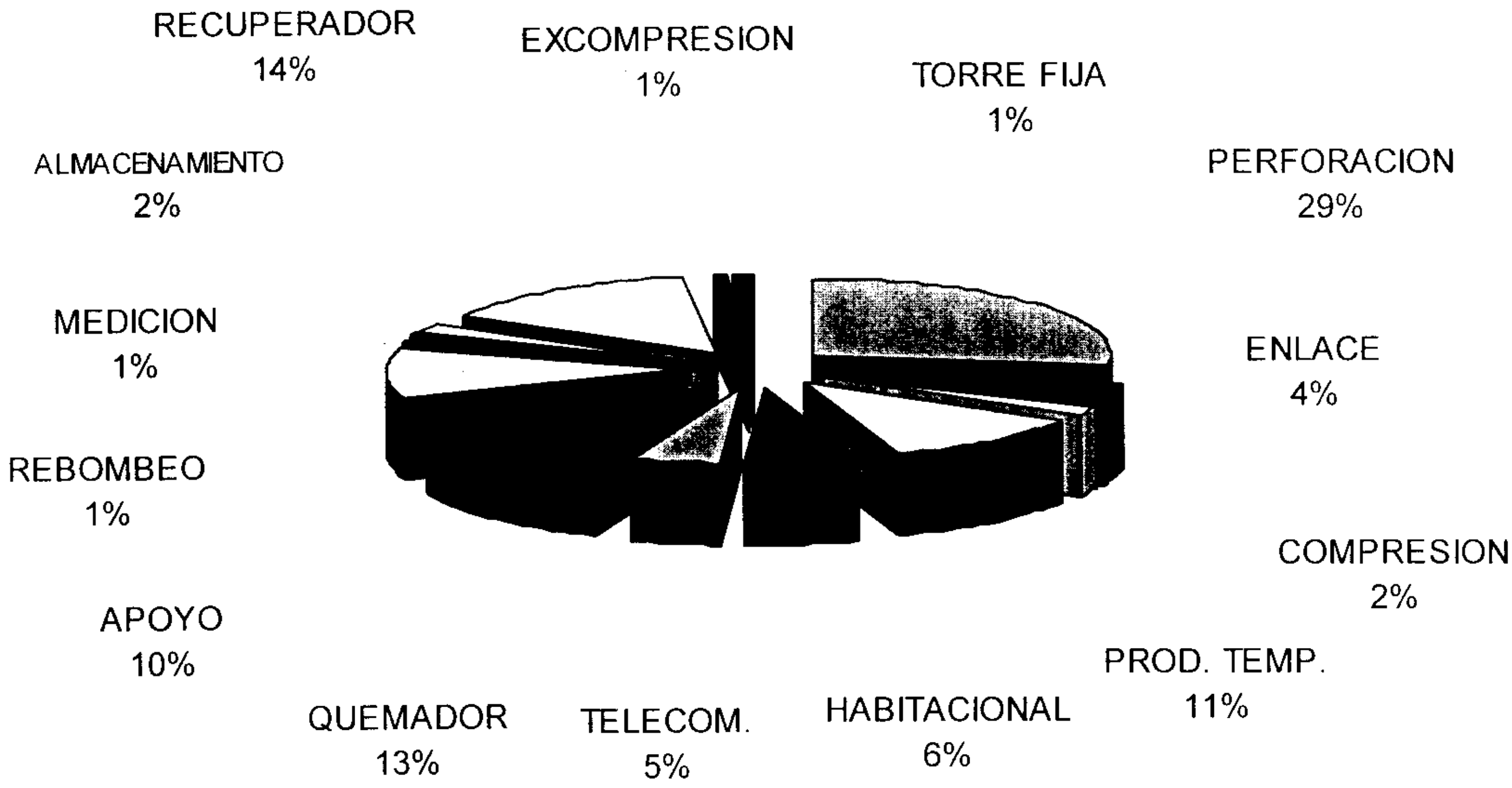
PLATAFORMAS DE PEMEX RMNE



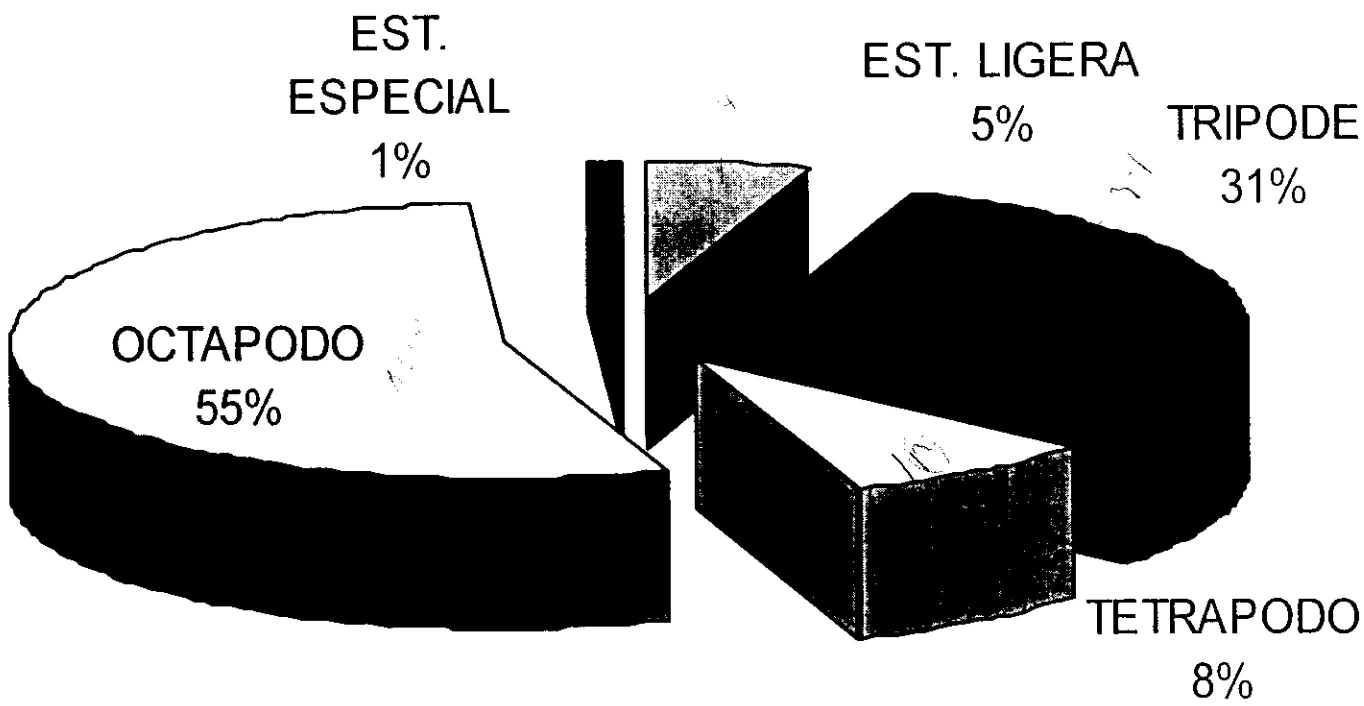
100 Plataformas para los servicios:

- Perforación
- Enlace
- Compresión
- Producción
- Habitacional
- Rebombeo
- Medición
- Telecom
- Apoyo
- Recuperadores

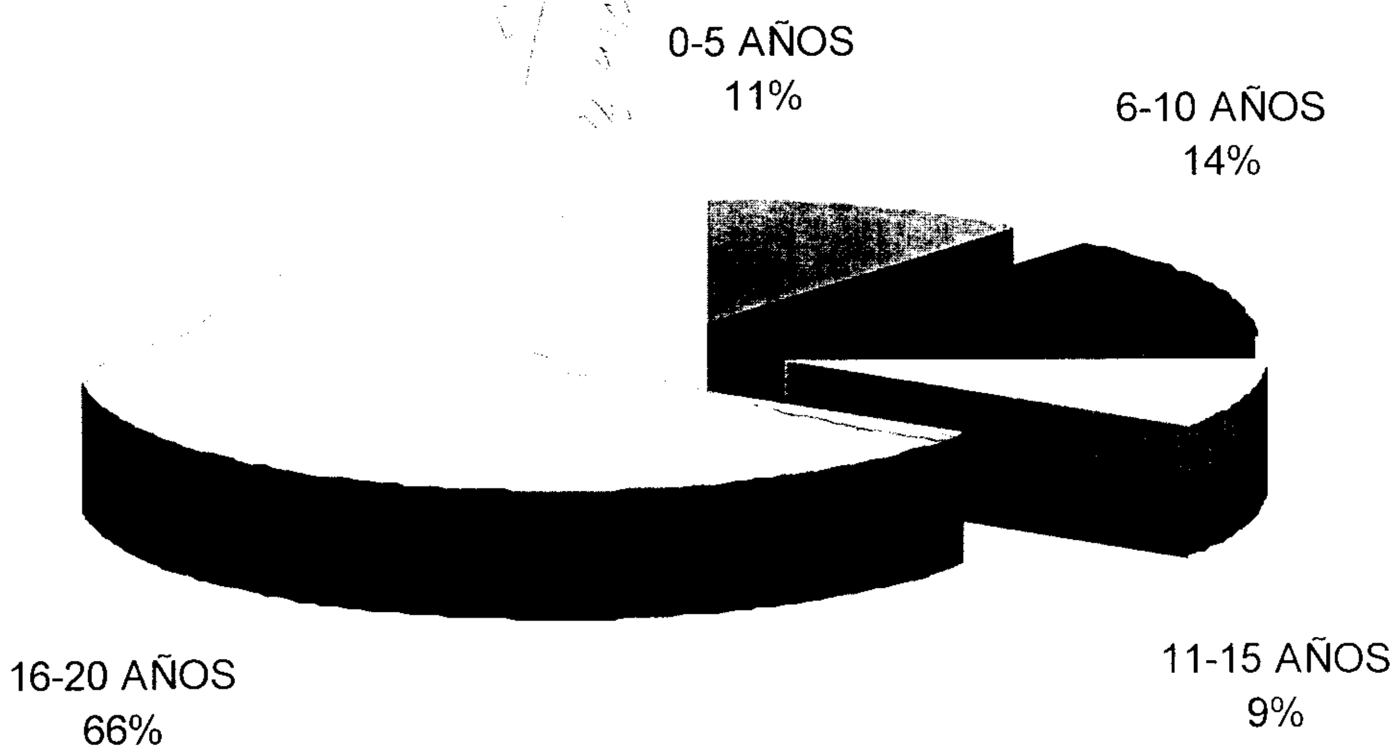
SERVICIOS DE LAS PLATAFORMAS



TIPO DE PLATAFORMAS



EDAD DE LAS PLATAFORMAS

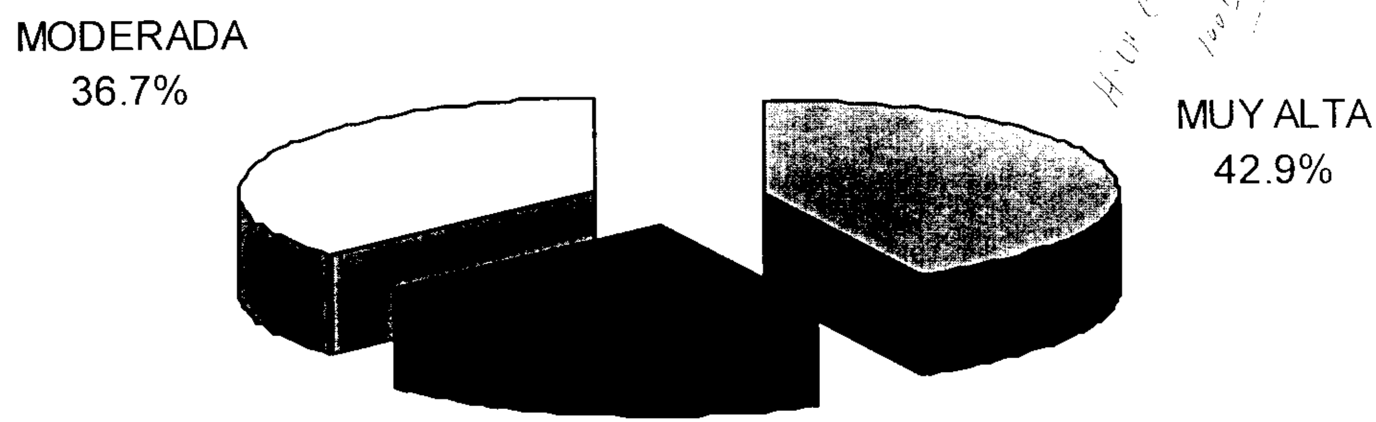


RIESGOS DE LAS PLATAFORMAS

Por el medio en están instaladas, por el servicio que prestan y por las operaciones marinas las plataformas son susceptibles de los daños siguientes:

- **Grietas**
- **Fracturas**
- **Desprendimientos**
- **Corrosión**
- **Abolladuras**
- **Pandeos**
- **Tallones**
- **Cortes**
- **Orificios**

CATEGORIAS DE EXPOSICION

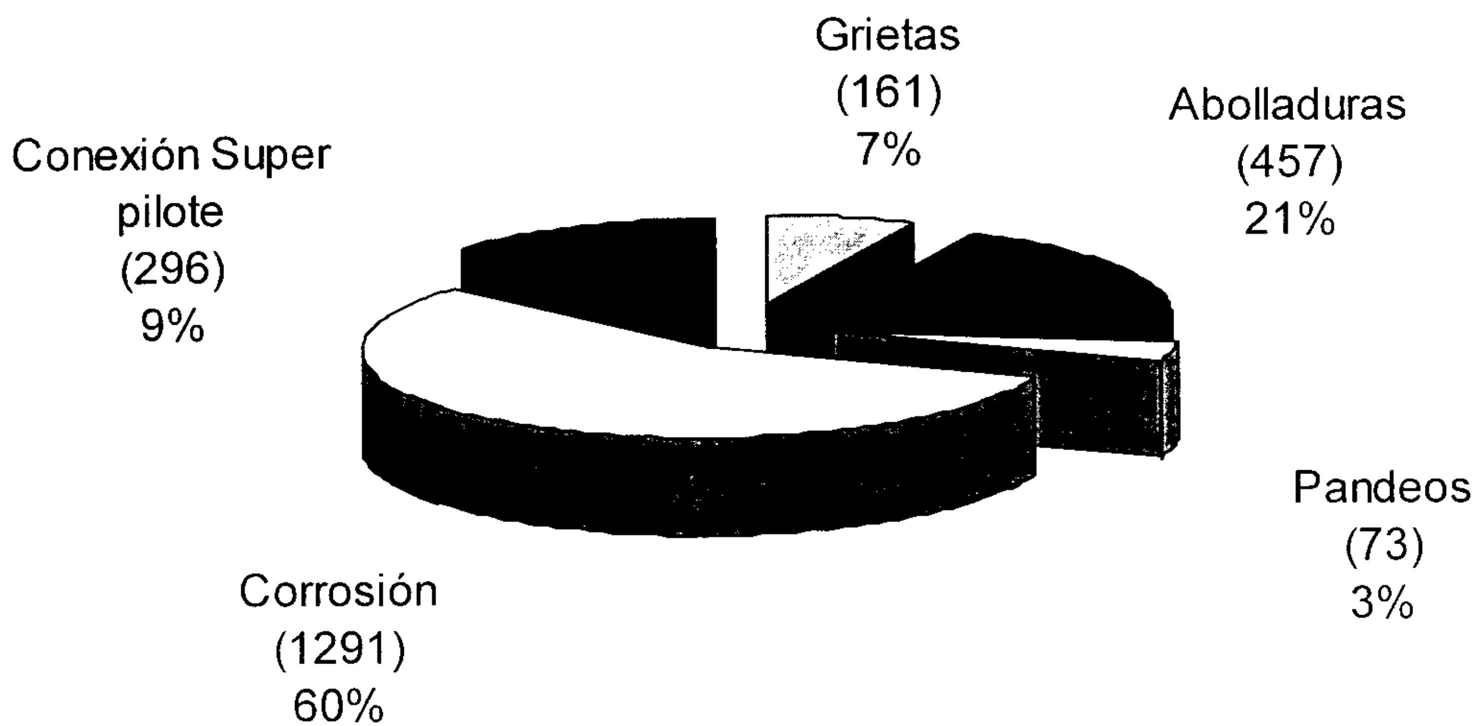


RIESGOS DE LAS PLATAFORMAS

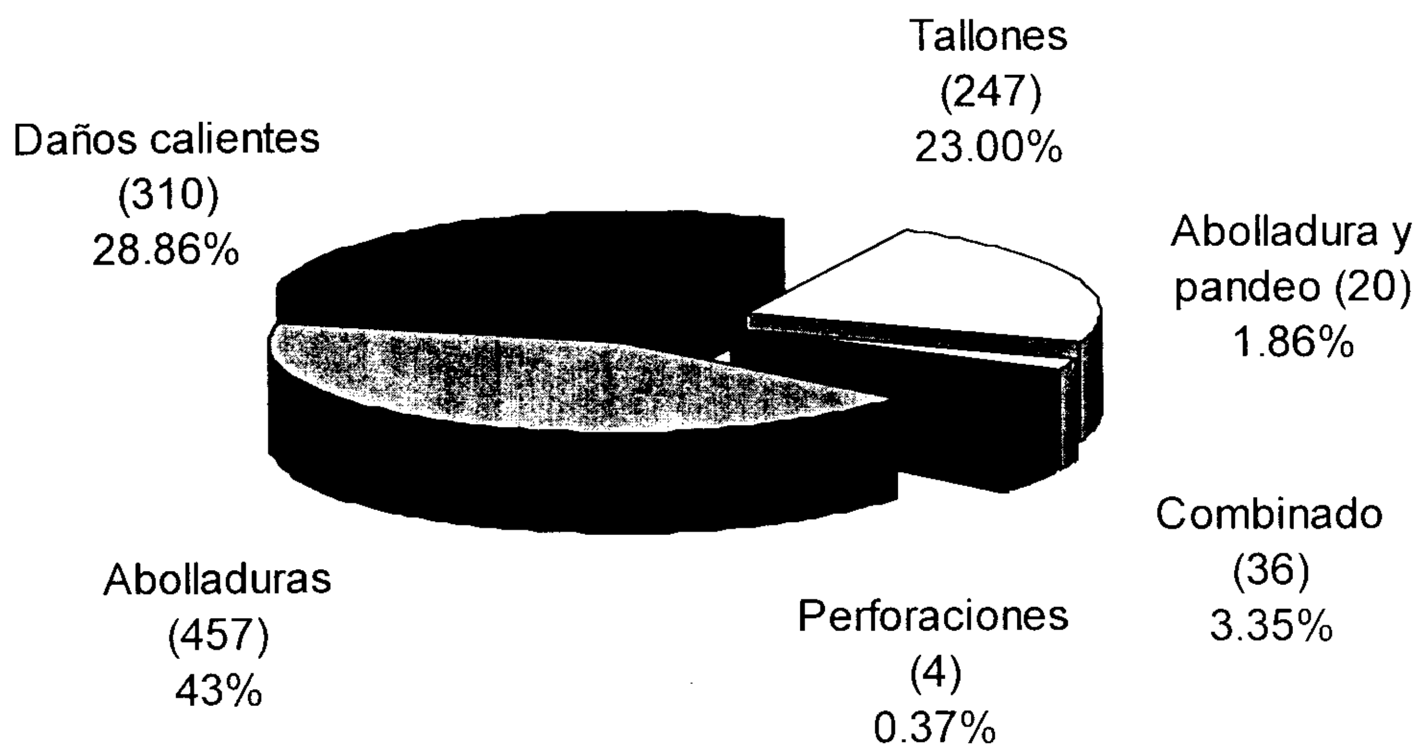
Los daños puede ser causados por:

- **Impactos de embarcaciones**
- **Caída de objetos**
- **Equipo de corte**
- **Fatiga**
- **Corrosión**
- **Sobrecargas de oleaje**
- **Crecimiento marino**

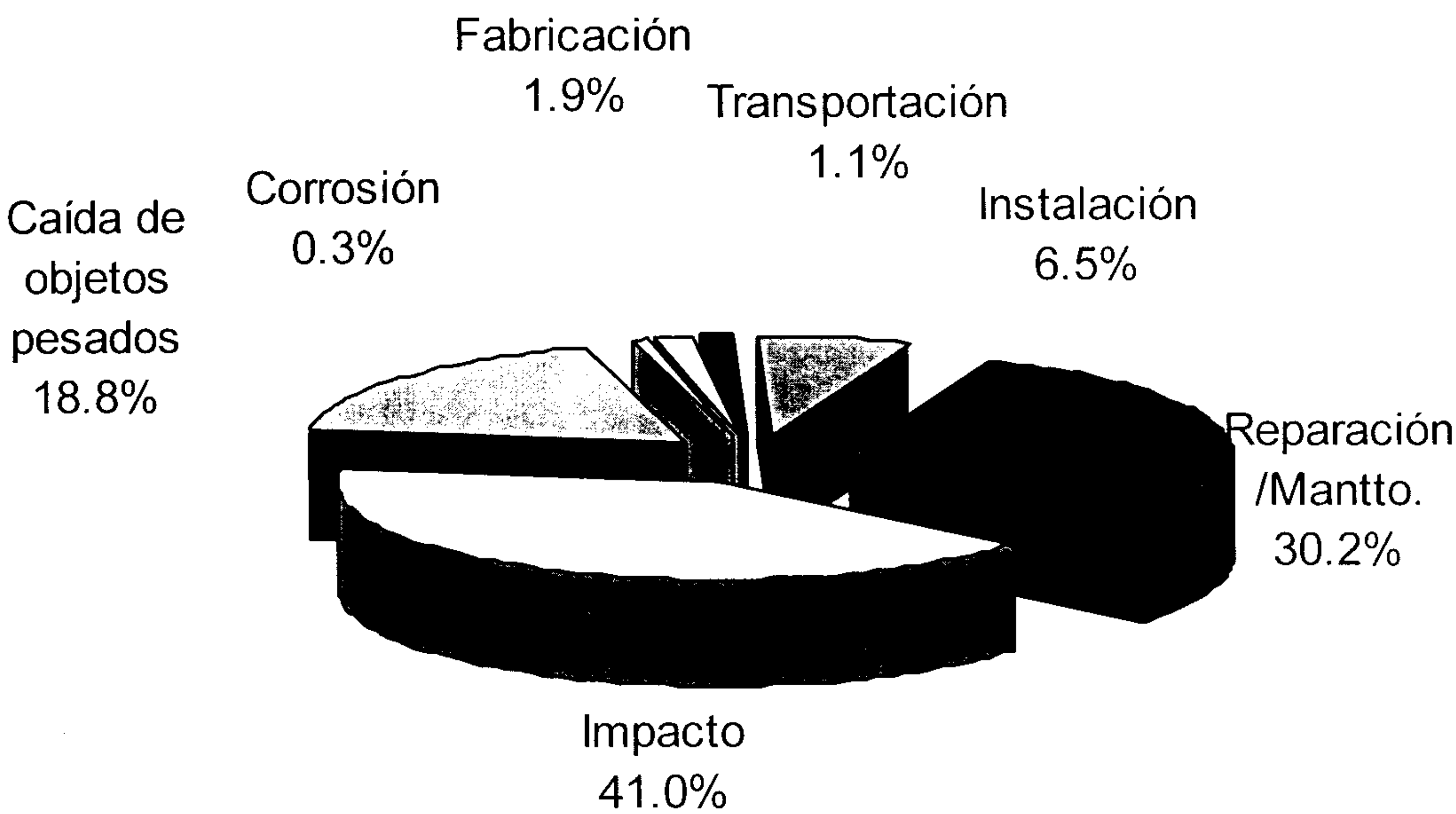
DAÑOS GENERALES EN LAS PLATAFORMAS



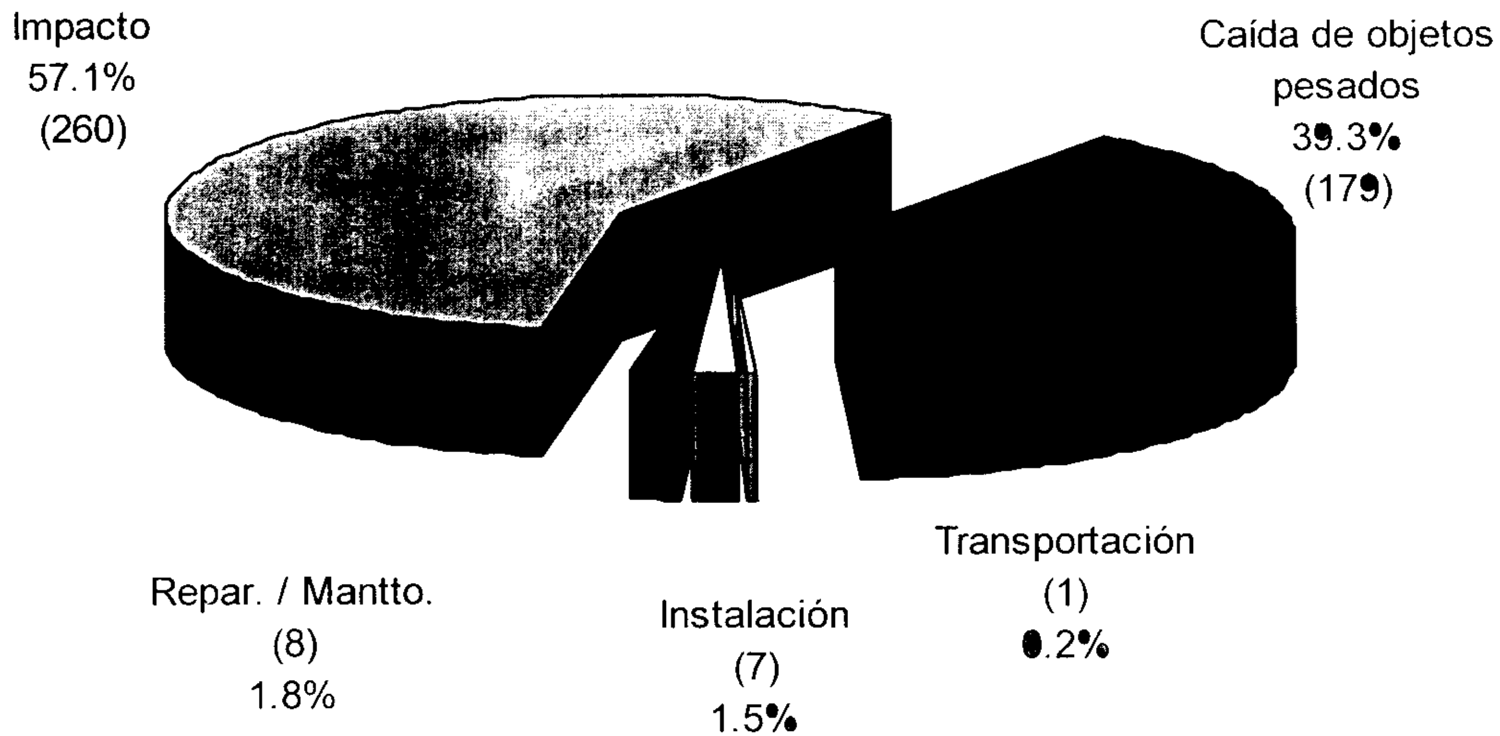
DAÑOS MECÁNICOS



CAUSAS DE LOS DAÑOS MECÁNICOS

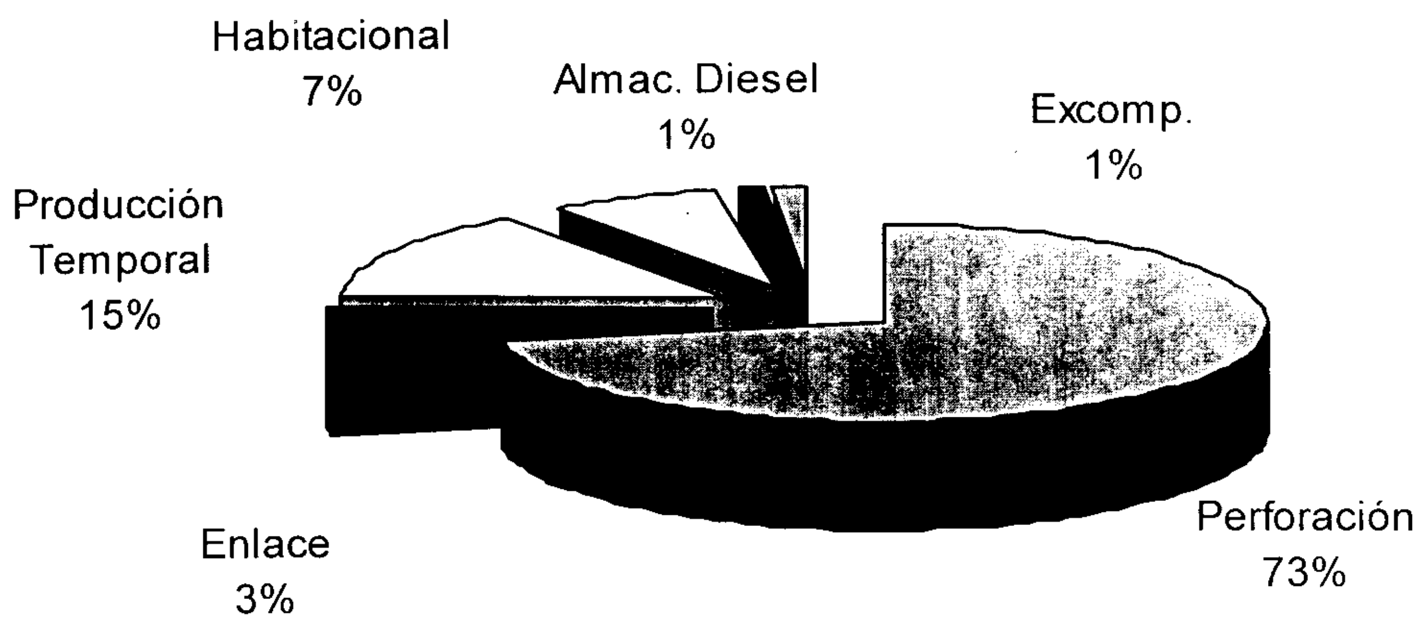


CAUSAS DE LAS ABOLLADURAS

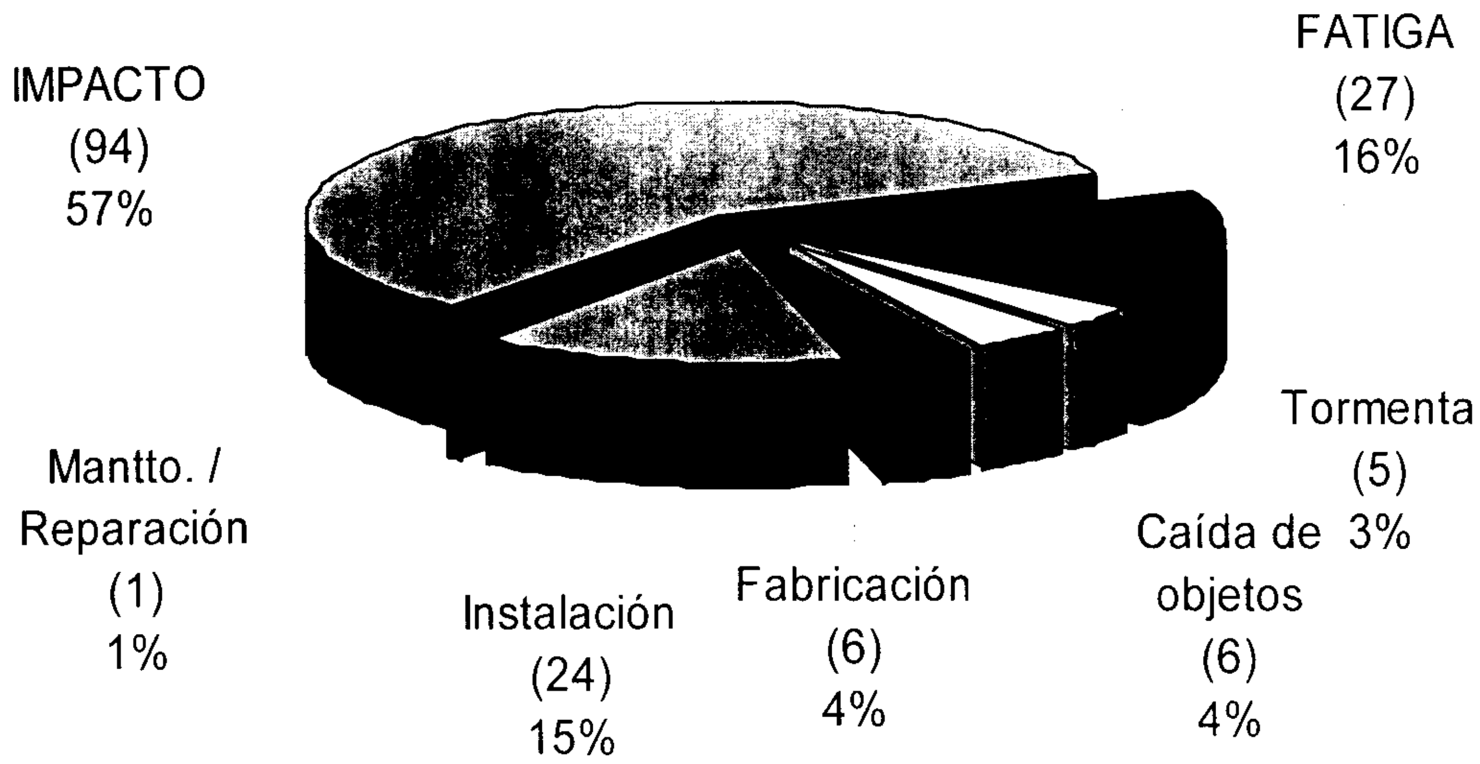


ABOLLADURA POR IMPACTO DE EMBARCACION

GRIETAS POR TIPO DE SERVICIO



CAUSAS DE LA GRIETAS



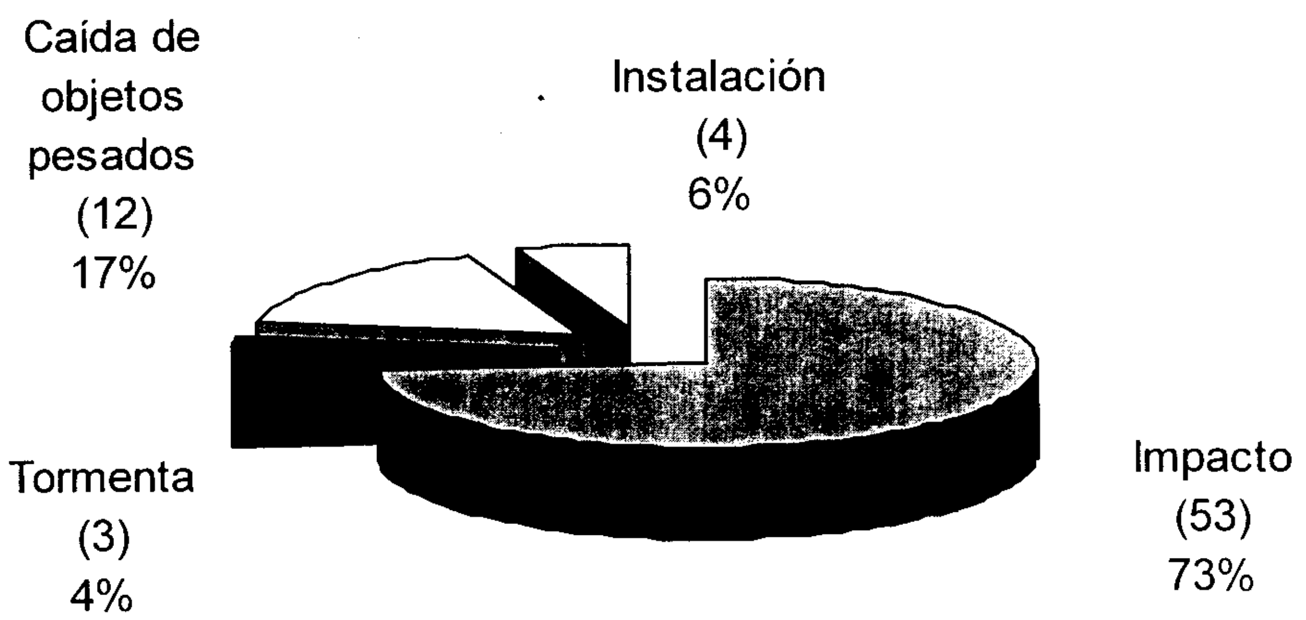
DAÑOS POR IMPACTO DE EMBARCACIONES

DAÑOS POR FATIGA

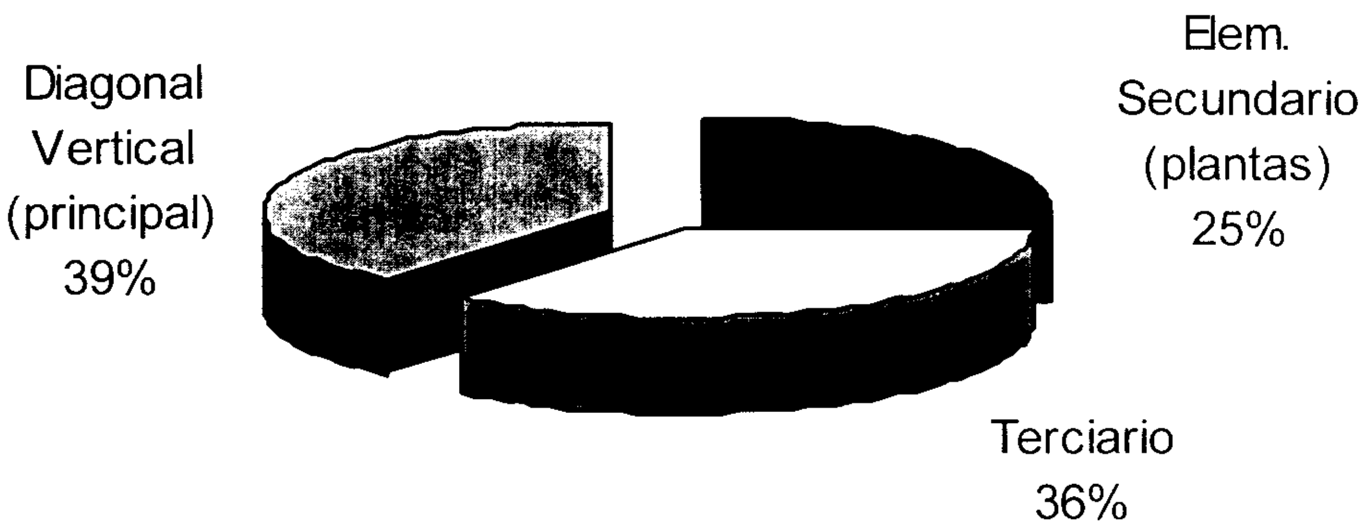
DAÑOS POR SOBRECARGAS

DAÑOS POR FATIGA Y OLEAJE DE TORMENTA

CAUSAS DE LOS PANDEOS



TIPOS DE ELEMENTOS CON PANDEOS



PANDEO POR IMPACTO DE EMBARCACION

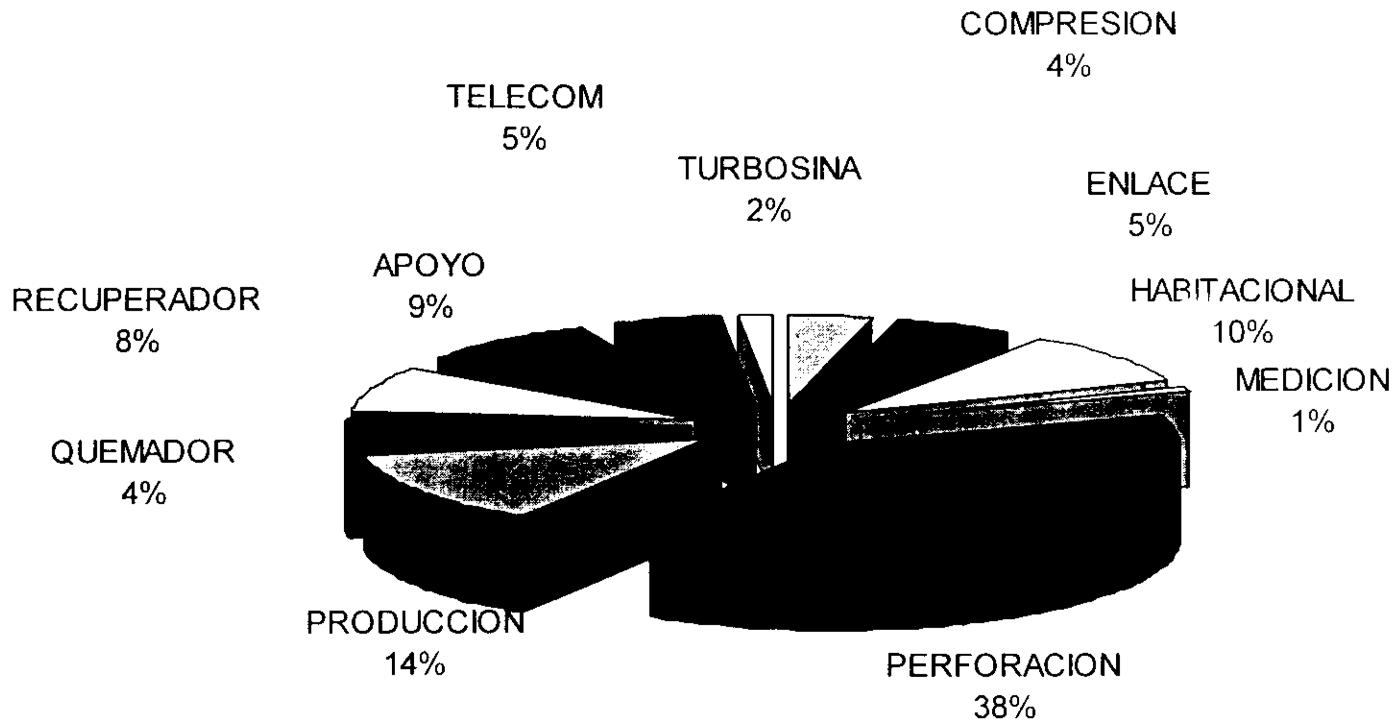
INSPECCION DE PLATAFORMAS

Para detectar los daños se realizan inspecciones periódicas bajo el agua a elementos estructurales y accesorios

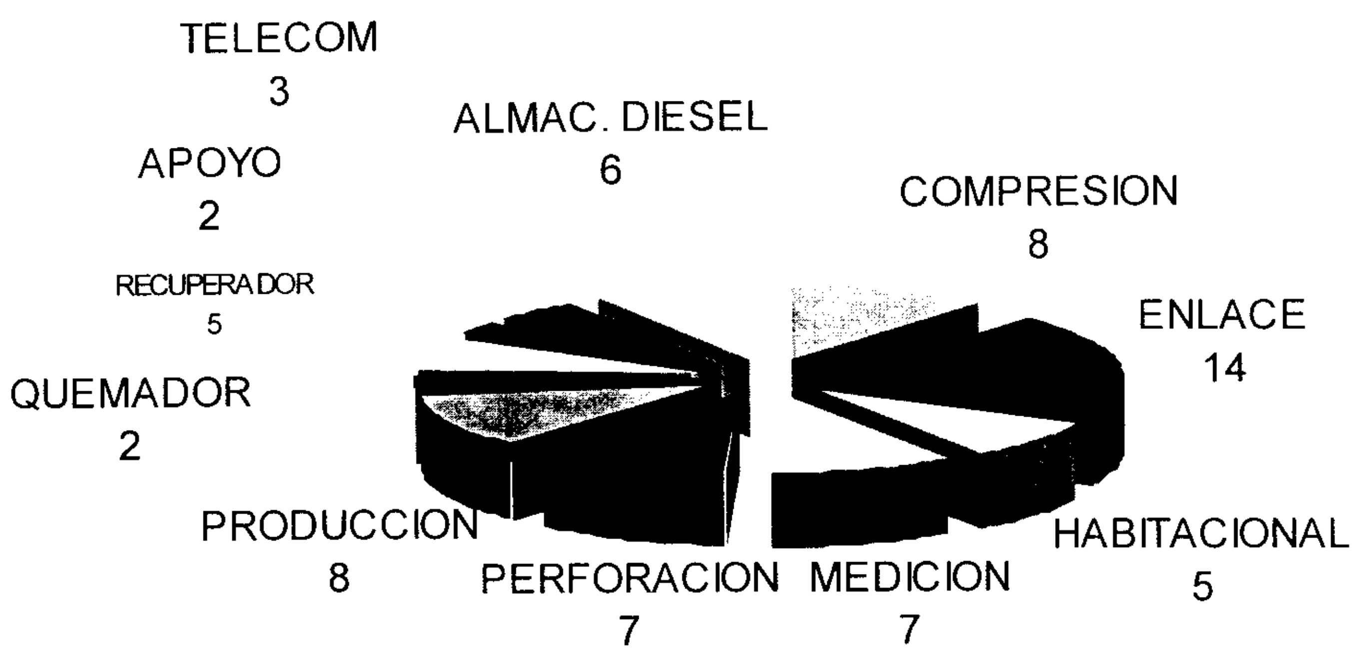
- **Visual general**
- **Visual detallada**
- **Pruebas no destrucitvas**
    - Patículas magnéticas
    - Ultrasonido
    - ACFM

Por medio de buzos y ROV para trípodes de quemador

MAS DE 500 INSPECCIONES REALIZADAS



DURACION DE LAS INSPECCIONES (Días)



DAÑOS POR SOBRECARGAS

¿COMO CORREGIR LOS DAÑOS?

- Abrazaderas mecánicas
- Abrazaderas Cementadas
- Remoción
- Soldadura hiperbárica
- Remoción de grietas
- Soldadura húmeda

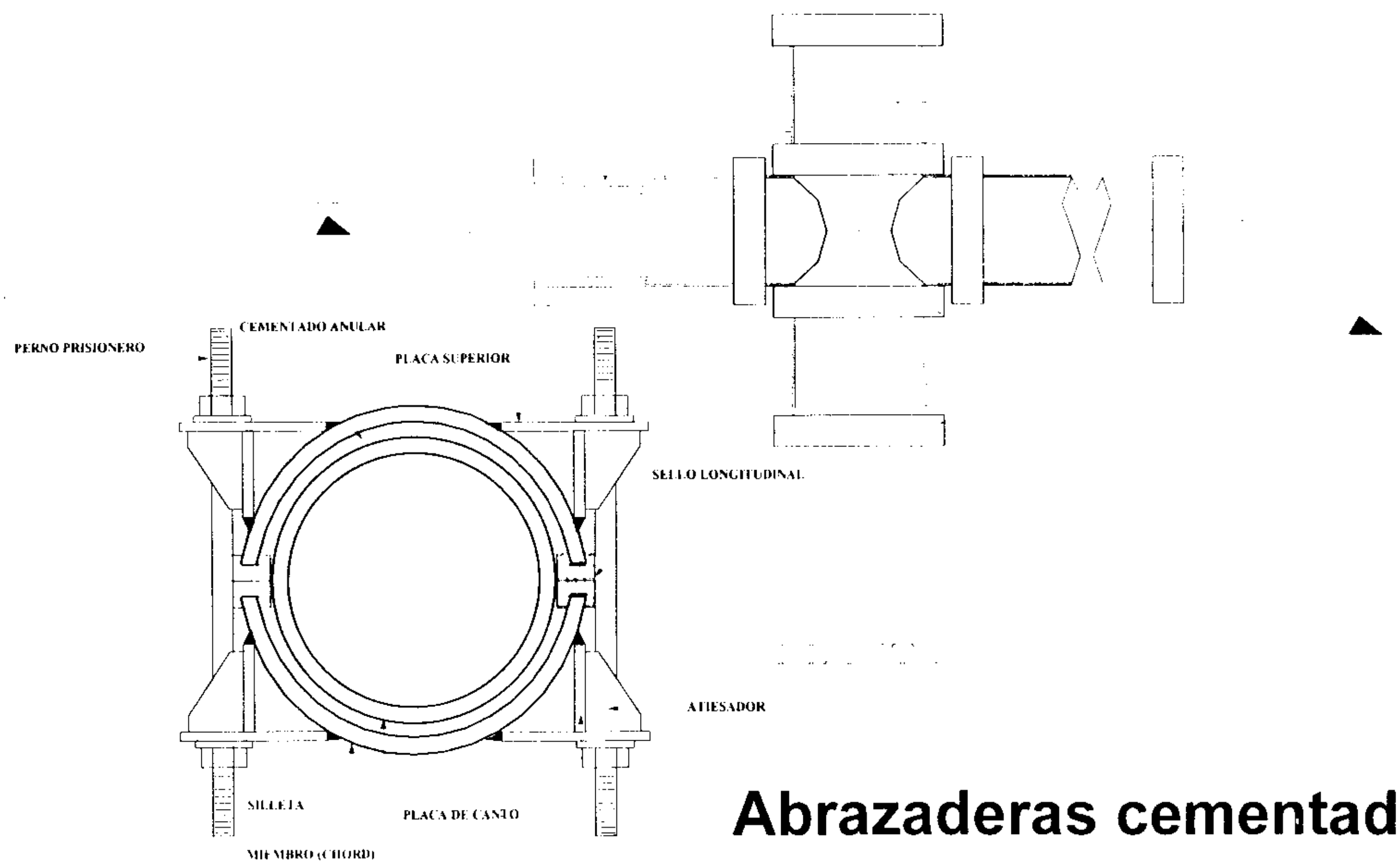
CORRECCION DE DAÑOS

Abrazaderas

- Desventajas
  - –No son funcionales en juntas complejas
  - –Pueden resultar muy pesadas
  - –Presentan problemas de ajuste
  - –Requieren control de temperatura para evitar deformaciones

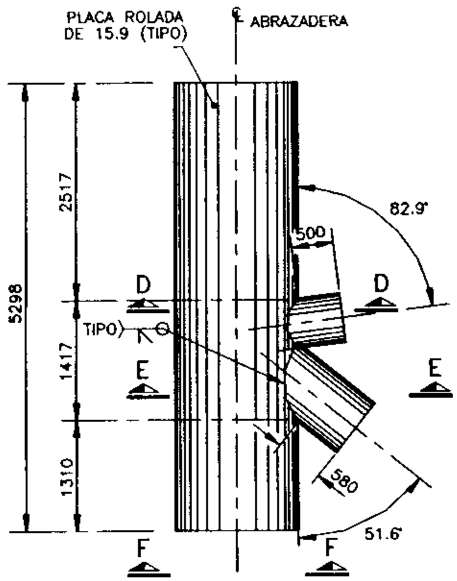
- Ventajas
  - –Son funcionales en juntas simples (T e Y)
  - –Son económicas en juntas simples
  - –Fácil instalación en juntas simples

CORRECCION DE DAÑOS



Abrazaderas cementadas

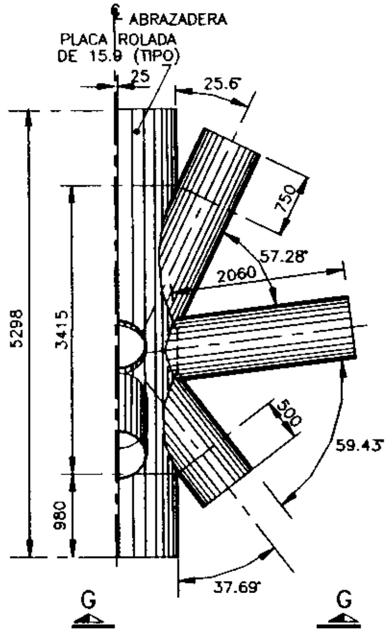
CORRECCION DE DAÑOS



(D-1) ELEVACION

DETALLE 1.-ABRAZADERAS 1 Y 2 (INVERSA)

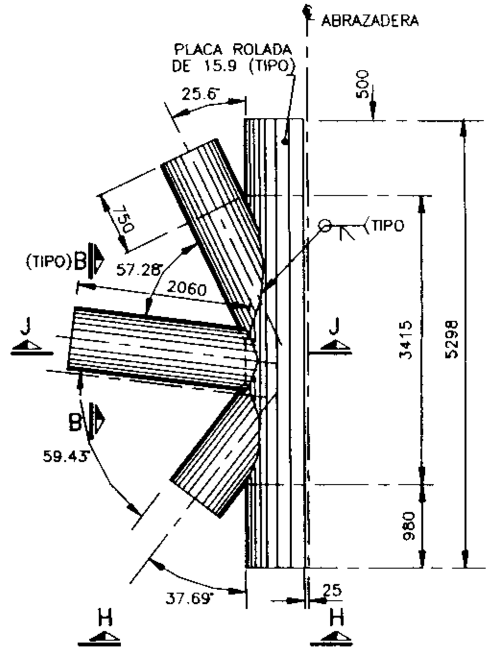
PIEZA A ESC. 1:50



(D-2) ELEVACION

DETALLE 2.-ABRAZADERAS 1 Y 2 (INVERSA)

PIEZA C ESC. 1:50



(D-3) ELEVACION

DETALLE 3.-ABRAZADERAS 1 Y 2 (INVERSA)

PIEZA B ESC. 1:50

Abrazaderas cementadas

CORRECCION DE DAÑOS

Remoción de elementos

Cuando los elementos estructurales son secundarios y tienen daños se han removido

Ejemplo, el arreglo estructural para guías de conductores de la primera planta bajo el nivel medio del mar en plataformas de perforación

CORRECCION DE DAÑOS

Soldadura hiperbarica

–Es costosa
–Es difícil su aplicación en juntas tubulares
–El habitat puede causar otros daños

CORRECCION DE DAÑOS

Remoción de grietas por esmerilado

Se aplica a grietas causadas por fatiga con profundidades menores al 50% del espesor del elemento

–Requiere de personal de buceo capacitado
–Una reparación inadecuada puede acelar el crecimiento de la grieta
–No se ha empleado esta técnica en PEMEX

CORRECCION DE DAÑOS

Soldadura húmeda

La soldadura húmeda se ha aplicado en:

La fijación de ánodos

- La reparación de grietas

Problemas:

- No se logra la continuidad estructural fácilmente
- Personal altamente calificado
- Porosidad
- Agrietamiento
- Etc.

CONCLUSIONES

- Existen varios daños en elementos estructurales y accesorios que deben repararse
- La soldadura húmeda es una alternativa viable para varios casos
- La soldadura húmeda ha sido aplicada con éxito en el Golfo de México y en el Mar del Norte
- Para una aplicación exitosa de la soldadura húmeda en la Sonda de Campeche hay que seguir las recomendaciones de los expertos aquí presentadas