APR 1 1992

Docket Nos. 50-498
50-499
License Nos. NPF-76
NPF-80

Houston Lighting & Power Company
ATTN: Donald P. Hall, Group
Vice President, Nuclear
P.O. Box 1700
Houston, Texas 77251

Gentlemen:

This refers to the meeting, open to public observation, conducted at our request in the Region IV office on March 13, 1992. This meeting related to activities authorized by NRC License Nos. NPF-76 and NPF-80.

This meeting was held to discuss South Texas Project essential cooling water system corrosion issues and Cooper-Bessemer emergency diesel generator reliability issues. The subjects discussed at this meeting are described in detail in the enclosed Meeting Summary.

It is our opinion that this meeting was beneficial and has provided a better understanding of the efforts that your staff has taken or plans to take to correct identified issues with the emergency diesel generators and the essential cooling water system.

In accordance with Section 2.790 of the NRC's "Rules of Practice," Part 2, Title 10, Code of Federal Regulations, a copy of this letter will be placed in the NRC's Public Document Room.

Should you have any questions concerning this matter, we will be pleased to discuss them with you.

Sincerely,

A. Bill Beach, Director
Division of Reactor Projects

Enclosure:
Meeting Summary w/attachments

cc w/enclosure: (see next page)

*RIV:PSD/DRP	C:PSD/DRP	D:DRP
DMGarcia;lt	ATHowell	ABBeach
3/ /92	4/1/92	3/1/92

*previously concurred

9204080004 920401
PDR ADOCK 05000498
P PDR

IE45

cc w/enclosure:
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ATTN: William J. Jump, Manager
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P.O. Box 289
Wadsworth, Texas 77483

City of Austin
Electric Utility Department
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Corpus Christi, Texas 78403

INPO
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1100 Circle 75 Parkway
Atlanta, Georgia 30339-3064

Mr. Joseph M. Hendrie
50 Bellport Lane
Bellport, New York 11713

Bureau of Radiation Control
State of Texas
1101 West 49th Street
Austin, Texas 78756

Judge, Matagorda County
Matagorda County Courthouse
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Bay City, Texas 77414

Licensing Representative
Houston Lighting & Power Company
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Three Metro Center
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[redacted]

bcc distrib. by RIV:

R. D. Martin
DRP
DRS
DRSS-RPEPS
IV File
RSTS Operator
D. Garcia
Resident Inspector
Section Chief (DRP/D)
MIS System
Lisa Shea, RM/ALF
R. Bachmann, OGC
Project Engineer (DRP/D)

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bcc to DMB (IE45)

bcc distrib. by RIV:

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RSTS Operator
D. Garcia

Resident Inspector
Section Chief (DRP/D)
MIS System
Lisa Shea, RM/ALF
R. Bachmann, OGC
Project Engineer (DRP/D)

MEETING SUMMARY

Licensee: Houston Lighting & Power Company (HL&P)

Facility: South Texas Project (STP)

License Nos.: NPF-76; NPF-80

Docket Nos.: 50-498; 50-499

Subject: MANAGEMENT MEETING CONCERNING ESSENTIAL COOLING WATER (ECW) SYSTEM AND EMERGENCY DIESEL GENERATOR (EDG) ISSUES

On March 13, 1992, representatives of HL&P met with Region IV personnel at the Regional offices to discuss the issues concerning the ECW system corrosion issues and Cooper-Bessemer EDG reliability issues at STP, Units 1 and 2. The staff found the meeting to be beneficial in providing pertinent information about licensee actions to resolve the issues that were discussed.

Attachments:
1. Attendance List
2. Licensee Presentation (NRC distribution only)

ATTACHMENT 1

ATTENDANCE LIST

Attendance at the management meeting between HL&P and NRC on March 13, 1992, in the Region IV office:

HL&P

D. P. Hall, Group Vice President, Nuclear
S. L. Rosen, Vice President, Nuclear Engineering
W. J. Jump, Manager, Nuclear Licensing
J. R. Lovell, Director, Nuclear Generation Projects
S. L. Wilson, Senior Engineer
G. R. Egan, President, Artech
M. Pacy, Project Manager, Diesel Generators

NRC

A. B. Beach, Director, Division of Reactor Projects (DRP)
D. D. Chamberlain, Deputy Director, Division of Reactor Safety (DRS)
A. T. Howell, Chief, Project Section D, DRP
J. I. Tapia, Senior Resident Inspector, STP, Project Section D, DRP
I. Barnes, Chief, Materials and Quality Programs Section, DRS
J. Rajan, Mechanical Engineer, Office of Nuclear Reactor Regulation (NRR)
G. Hornseth, Materials Engineer, NRR

State of Texas

G. Bynog, Chief Boiler Inspector

Other

M. T. Hardt, Director, Nuclear Division, CPSB
P. W. Colde, Manager, Joint Projects, City of Austin Electric Utility

ATTACHMENT 2

ESSENTIAL COOLING WATER SYSTEM

MEETING WITH NRC

MARCH 13, 1992

AGENDA

INTRODUCTION	D. P. HALL
ESSENTIAL COOLING WATER SYSTEM DESCRIPTION	J. R. LOVELL
ESSENTIAL COOLING WATER SYSTEM ISSUES	J. R. LOVELL
1. CURRENT STATUS	J. R. LOVELL
2. FLOODING, SPRAY, AND LOSS-OF-FLUID ANALYSIS	J. R. LOVELL
3. METALLURGICAL FAILURE ANALYSIS	S. L. WILSON
4. STRUCTURAL INTEGRITY ANALYSIS	G. R. EGAN
5. SUMMARY	J. R. LOVELL
6. STRATEGIC PLAN	J. R. LOVELL
CONCLUSION	D. P. HALL

ESSENTIAL COOLING WATER SYSTEM DESCRIPTION

The Essential Cooling Water System (ECWS) is designed to supply cooling water to various safety-related systems for:

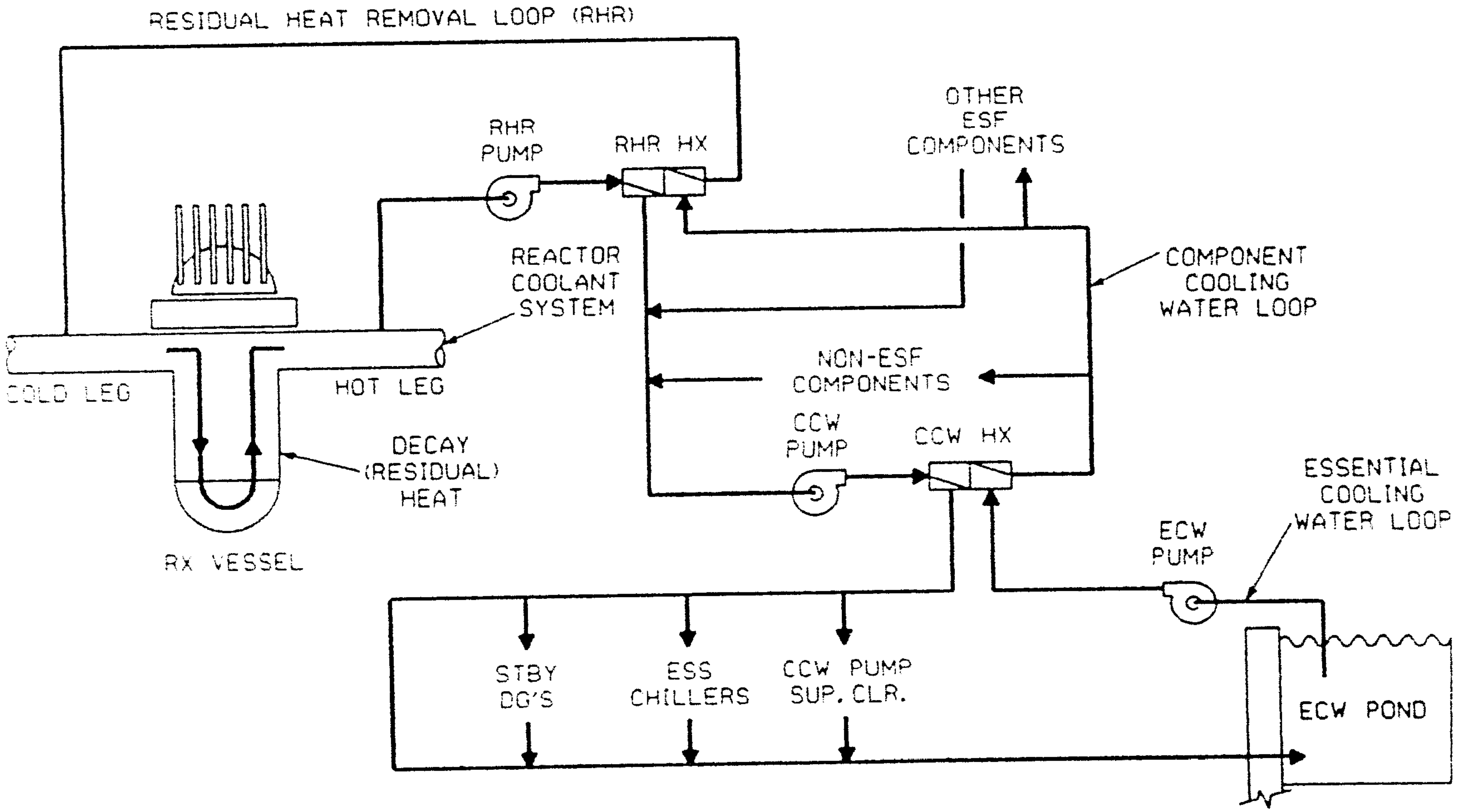
- **Normal plant operation**
- **Normal shutdown (one of three trains needed)**
- **During and after postulated design basis accidents (two of three trains needed)**

ECW is a low pressure, low temperature system (120 psig design, 41 psig operating)

Each train is powered from separate ESF supply and is capable of operating continually for a minimum of 30 days.

The underground portion of the system is continuously supported on concrete saddles and has compacted fill around it. This results in very low stresses.

ESSENTIAL COOLING WATER POND
IS THE
ULTIMATE HEAT SINK



BUTT WELDS

UNIT 1

FIELD WELDS WITH BACKING RINGS

	ABOVE GROUND	BELOW GROUND
30"	37	135
24"	3	0
14"	2	0
10"	45	64
8"	25	0
6"	134	0
4"	69	0
3"	74	0
TOTAL	389	199

UNIT 2

FIELD WELDS WITH BACKING RINGS

	ABOVE GROUND	BELOW GROUND
30"	38	140
24"	6	0
14"	13	0
10"	48	12
8"	31	0
6"	107	0
4"	47	0
3"	87	0
TOTAL	377	152

ESSENTIAL COOLING WATER SYSTEM ISSUES

1. CURRENT STATUS - WELDS

WELD CRACK POPULATION

LOCATION	DATE FOUND	STATUS
Unit 2 Train C 24"Line ECW Strainer Bypass	May 6, 1989	Repaired
Unit 2 Train B 30" Line Near CCW Heat Exchanger	July 13, 1991	Repaired Failure Analyzed
Unit 1 Train B 30" Line Near CCW Heat Exchanger	August 6, 1991	Repaired (Repair Cracked) Failure Analyzed
Unit 1 Train C 30" Line ECW Intake Structure	November 5, 1991	Scheduled 1RE04
Unit 1 Train A 30" Line MAB Supply Line	November 7, 1991	Scheduled 1RE04
Unit 1 Train B 30" Line Near CCW Heat Exchanger	December 13, 1991	Cut Out & Replaced
Unit 2 Train B 6" Line Essential Chiller Outlet	January 7, 1992	Repaired

Note: All Cracks were in Backing Ring Welds

WELDS - CURRENT PROGRAM

WELD MONITORING

- Monthly walkdown, with emphasis on backing ring welds.
- Leaks visually inspected daily.
- Leak rate determined daily.
- Best effort UT weekly if available, but not less than quarterly.
- Monthly walkdown of ground surface above underground piping

WELD REPAIRS

- Welds repaired to ASME Code Section IX, no later than 75% Critical Crack Size as estimated by structural integrity analysis, or 8 GPM leak rate in Mechanical Auxiliary Building, or 2.5 GPM per train in intake structure.
- Repair within train schedule, if practical.
- All leaks shall be repaired at next available outage greater than 30 days at the latest.
- Temporary repairs will be considered in future, to be followed by permanent code repairs during outage.
- 5 out of 7 cracks repaired to code requirements so far.

CURRENT STATUS - CASTINGS

- Casting dealloying issue presented to NRC in May 1988
- Small Bore ($\leq$ 2"): Castings have been replaced
- Large Bore: 9 flanges, all with backing rings have leaked
  8 flanges have been replaced
  1 flange scheduled for repair
- Appropriate spare parts stocked
- All castings are above ground
- Estimated quantities
  Flanges - 311
  Fittings - 34
  Valves - 178
  Pumps - 6

MONITORING

- Walkdown inspections of backing ring locations quarterly, other castings every 18 months
- Leaks monitored biweekly
- Dealloying checks performed on two pumps at crevices. Depth of dealloying after two years - about 1/16".
- Flanges monitored for dealloying by sectioning
- Pumps monitored by grinding and etching at crevices

REPAIRS

- Castings with leaks replaced typically within 100 days

STRATEGIC PLAN - CASTINGS

- Monitoring indicates that castings are at low risk of leakage in the near future, except for flanges/fittings with backing rings.
- Continue to monitor and replace as described.
- Consider replacement of all flanges and fittings with backing rings in one or more outages with non-susceptible grades.
- Review and assess options for alternate materials for valves.
- Revisit long term replacement projections by December 1992.
- A program will be developed to track dealloying

CORRESPONDENCE WITH NRC

- Have provided two failure analysis reports.
- Relief Request in accordance with Generic Letter 90-05 filed January 17, 1992
- Relief Request from system Hydro requirements filed on March 5, 1992

- **Temporary Waiver of Compliance Status**

Sept. 1991	Repair of Unit 1 30" Line near CCW Heat Exchanger	Waiver prepared, but not used
Jan 1992	Repair of Unit 1 Standby Diesel Generator 6" flange and expansion bellows	Waiver prepared, but not used
March 1992	Repair of Unit 1 30" line near CCW Heat Exchanger	Waiver granted. Total outage time was 104 hours
March 1992	Repair of Unit 2 6" inlet and outlet lines to Essential Chiller	Waiver prepared, but not used

2. FLOODING, SPRAY, AND LOSS OF FLUID ANALYSIS

The following effects have been considered

- **Internal Flooding**
- **Spray Impingement**
- **Loss of Water**
- **Loss of Flow**

Internal flooding is limiting case. Administrative limits set are:

- **Mechanical Auxiliary Building** — **< 8 gpm**
- **Diesel Generator Building** — **< 1 gpm per cubicle**
- **ECW Intake Structure** — **< 2.5 gpm per cubicle**

Spray Impingement can be diverted and collected

Loss of water in ECW pond

- < 1/2 inch at maximum leak rate after 30 days

Loss of Flow

- Maximum leak rate is 0.06% of system flow

3. METALLURGICAL FAILURE ANALYSIS

4. STRUCTURAL INTEGRITY ANALYSIS

5. SUMMARY

- 7 cracks/leaks found in welds with backing rings
- 5 repaired to code requirements so far
- Root cause is corrosion and stress
- Failure is not due to hydraulic transients
- Good margins to limiting crack sites
- Welds replaced before margins are exceeded
- Large cracks required for failure with worst case stresses above ground. Larger margins below ground

6. STRATEGIC PLAN - WELDS

Develop strategic plan for inspection, detection of underground leakage, and long-term rehabilitation

Inspections

- Visually inspect accessible backing ring welds monthly
- Visually inspect ground for underground leaks monthly
- Destructive examination of cut-out welds
- Volumetric non-destructive examination not considered meaningful

Detection of Underground Leakage

Methods under consideration are:

- Acoustic Emission
- Tracers
- Leak Testing
- Non-Destructive Examination
- Visual

REHABILITATION METHODS

Options under review include:

- **Code weld repair upon detection**
- **Weld overlay**
- **Welded strap**
- **Remove backing ring, examine, and repair**
- **Coatings and linings**

Any options other than code repair are subject to structural integrity justification and prior NRC approval

STANDBY DIESEL GENERATORS

MEETING WITH NRC

MARCH 13, 1992

AGENDA

INTRODUCTION	D. P. HALL
STANDBY DIESEL GENERATOR DESCRIPTION	M. PACY
STANDBY DIESEL GENERATOR ISSUES	M. PACY

1. DIESEL GENERATOR RELIABILITY IMPROVEMENT PLAN
2. FUEL OIL/LUBE OIL ISSUES
3. FUEL INJECTOR PUMP ISSUES
4. MECHANICAL ISSUES
5. RELAYS AND ELECTRICAL ISSUES
6. LONG TERM ISSUES

CONCLUSION	D. P. HALL

STANDBY DIESEL GENERATOR DESCRIPTION

- 6 Standby Diesel Generators, 3 per Unit
- Supplied by Cooper - Bessemer
- Each 20-cylinder turbo-charged diesel drives a 5500 kw generator
- Function
  - Provide electrical power to Engineered Safety Features buses in the event of loss of offsite power

1. DIESEL GENERATOR RELIABILITY IMPROVEMENT PLAN

- Proactive response to solve recurring issues
- Goal is to maintain high reliability and availability
- Task Force to review:
  - Operating and Maintenance Procedures
  - Engineering and Design Issues
- Current reliability is above target of 0.975

  Trigger Values:

  3 valid failures in 20 demands
  4 valid failures in 50 demands
  5 valid failures in 100 demands

  Trigger values based on Initiative 5A of NUMARC 87-00.

- **Current Status**

Unit 1: last 20 demands - 0 valid failures
last 50 demands - 0 valid failures
last 100 demands - 3 valid failures

Unit 2: last 20 demands - 0 valid failures
last 50 demands - 0 valid failures
last 100 demands - 0 valid failures

…BE OIL ISSUES

… HOLDER AND NOZZLE TIP HOLDER

…acked delivery valve holders
…racked nozzle holders

…semer installation method causes high material

…

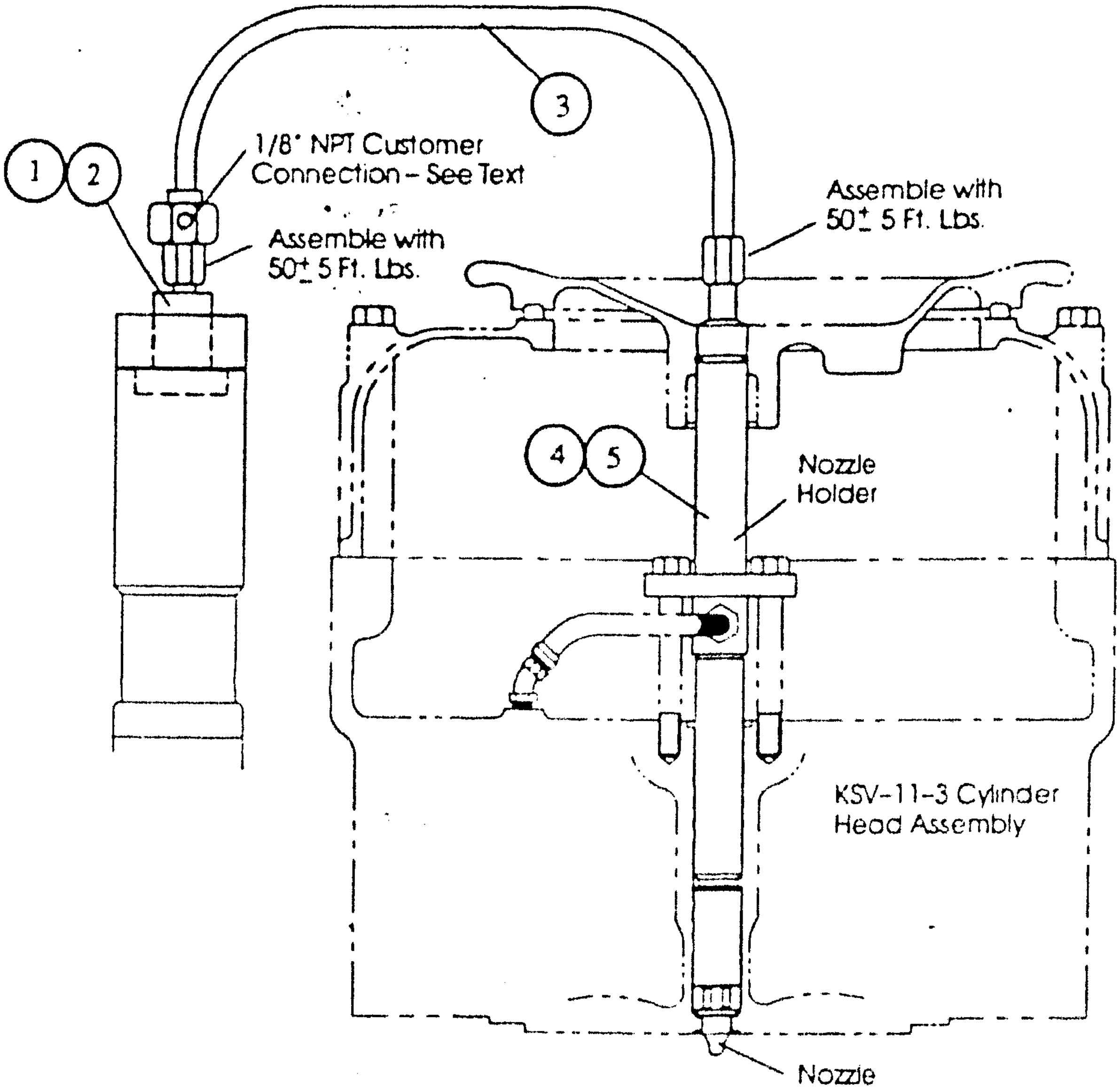
Revised method of installation reduces torque

- New swaged delivery valve holder, fuel line and nozzle holder to be installed 1RE04, 2RE03

2. FUEL OIL/LUBE OIL ISSUES

A. CRACKED DELIVERY VALVE HOLDER AND NOZZLE TIP HOLDER

- Since 1989: 13 cracked delivery valve holders
  4 cracked nozzle holders
- Cooper-Bessemer installation method causes high material stresses
- Revised method of installation reduces torque
- New swaged delivery valve holder, fuel line and nozzle holder to be installed 1RE04, 2RE03



Item	Name	Part Number	Qty. Req'd.
1.	Injection Pump	2-50F-049-005	One, Not Both Required
2.	Delivery Valve Holder	2-50F-049-143	
3.	Fuel Line	2-50F-062-001	One Req'd.
4.	Fuel Injection Nozzle (Holder Plus Tip)	KSV-13-5A#1	One, Not Both Required
5.	Nozzle Holder (Holder Only)	2-50F-061-001	

FIG. 1 KSV – NEW HIGH PRESSURE FUEL LINE ASSEMBLY

B. FUEL NOZZLE TIP FAILURES

Chronology:

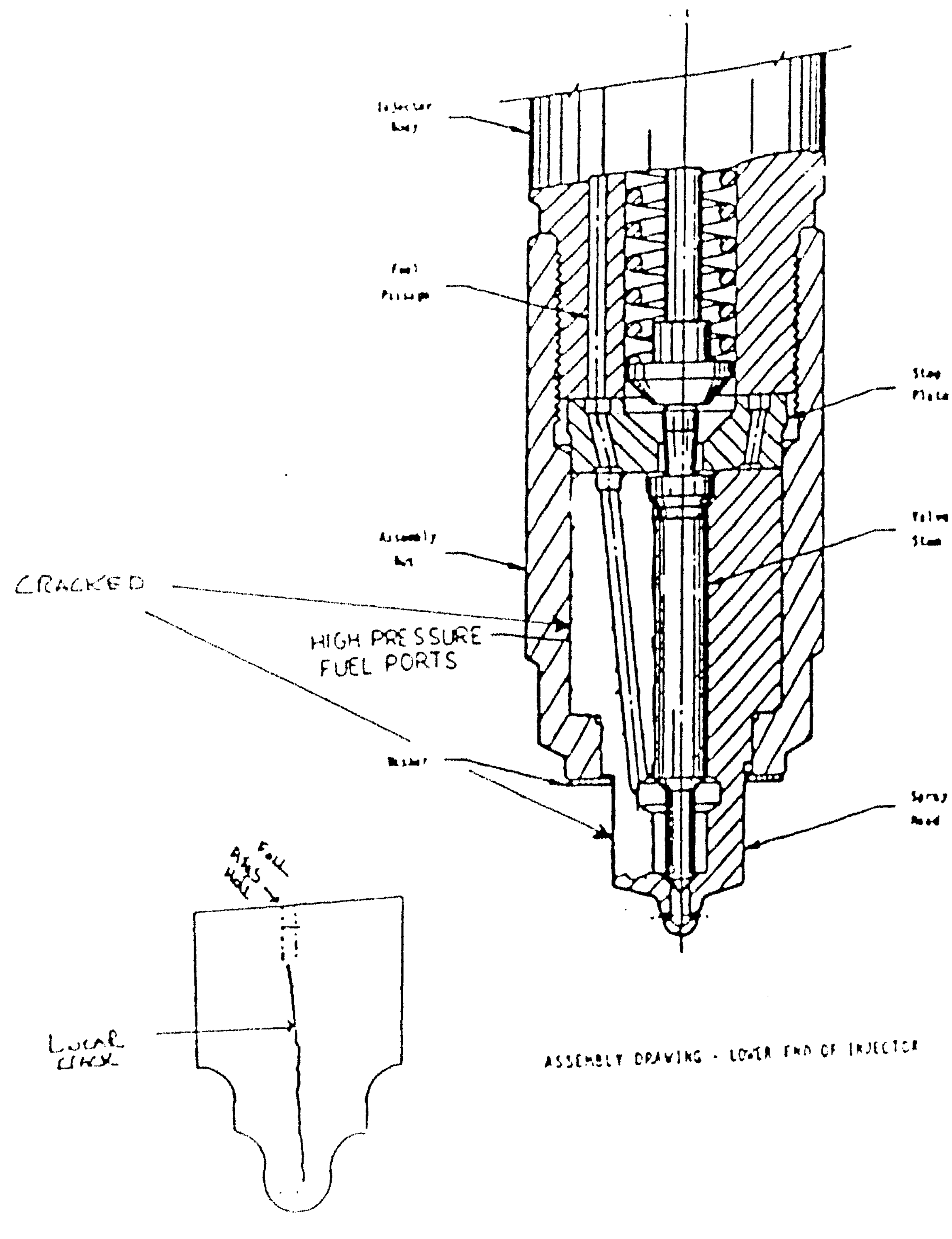
- 1987 - STP found lot 001124 with 20 cracked tips
- 1988 - Cooper-Bessemer notified STP of bad lot 150008 at Commonwealth Edison
- 1991 - STP found cracked tips in lots 150010 and 150006
- Lots 150006, 8, 10 manufactured by Bendix

Status:

- All lots 1500XX series now purged
- Haynes lots LCH-1, LCH-19, LC001091 now in use
- Testing of new lots required

FACILITY NAME (1)	DOCKET NUMBER (2)	LER NUMBER (6) YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	PAGE (3)
South Texas, Unit 1	0 5 0 0 0 4 9 8	9 1	— 0 0 9 —	0 0	0 8 OF 0 8

Figure 2
<u>SDG 13 Fuel Injector Nozzle Crack</u>

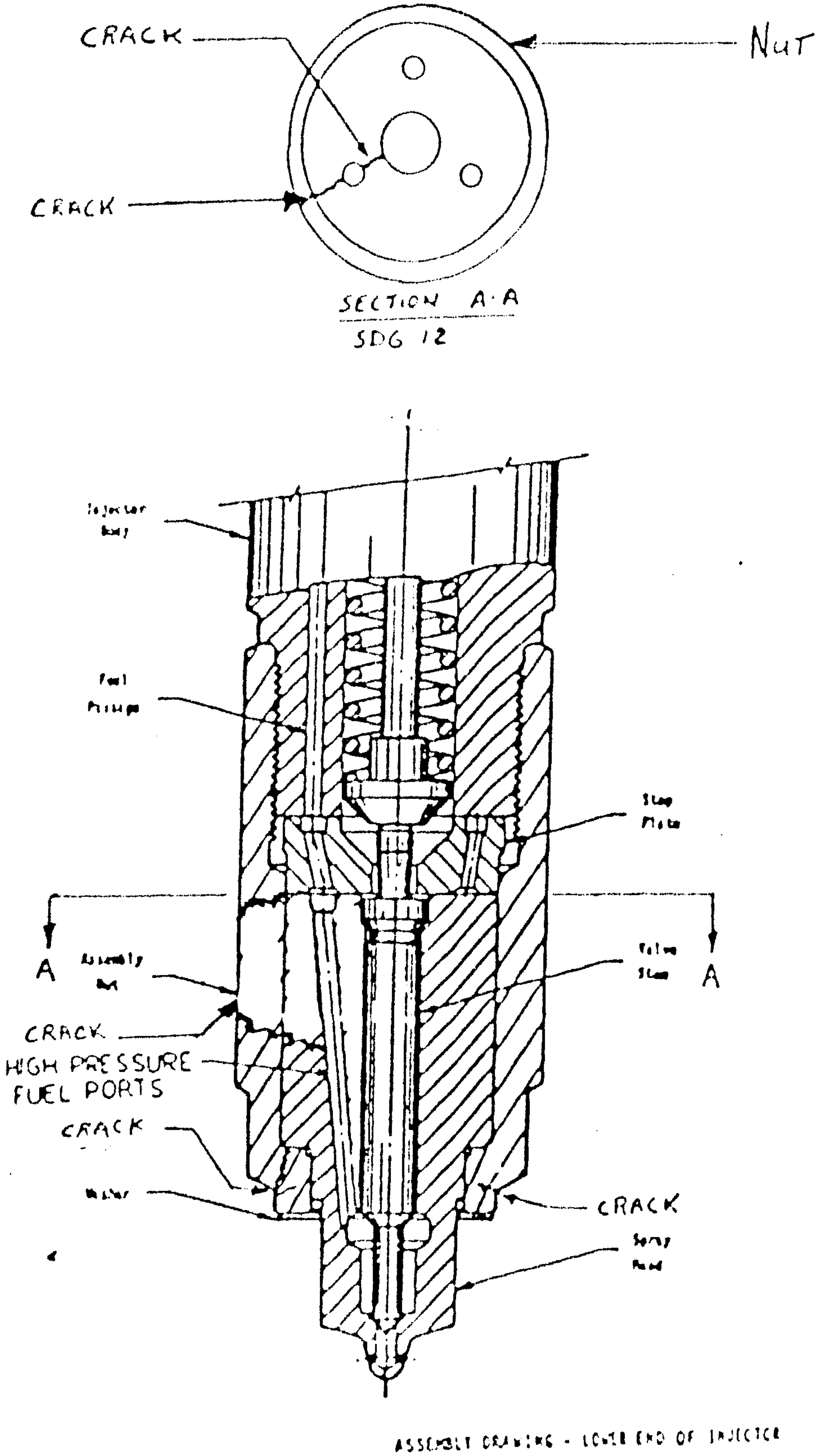


FACILITY NAME (1)	DOCKET NUMBER (2)	LER NUMBER (6) YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	PAGE (3)
South Texas, Unit 1	0 5 0 0 0 4 9 8	9 1	— 0 0 9 —	0 0	0 7 OF 0 8

TEXT (If more space is required, use additional NRC Form 366A's) (17)

Figure 1

SDG 12 Fuel Injector Nozzle Crack



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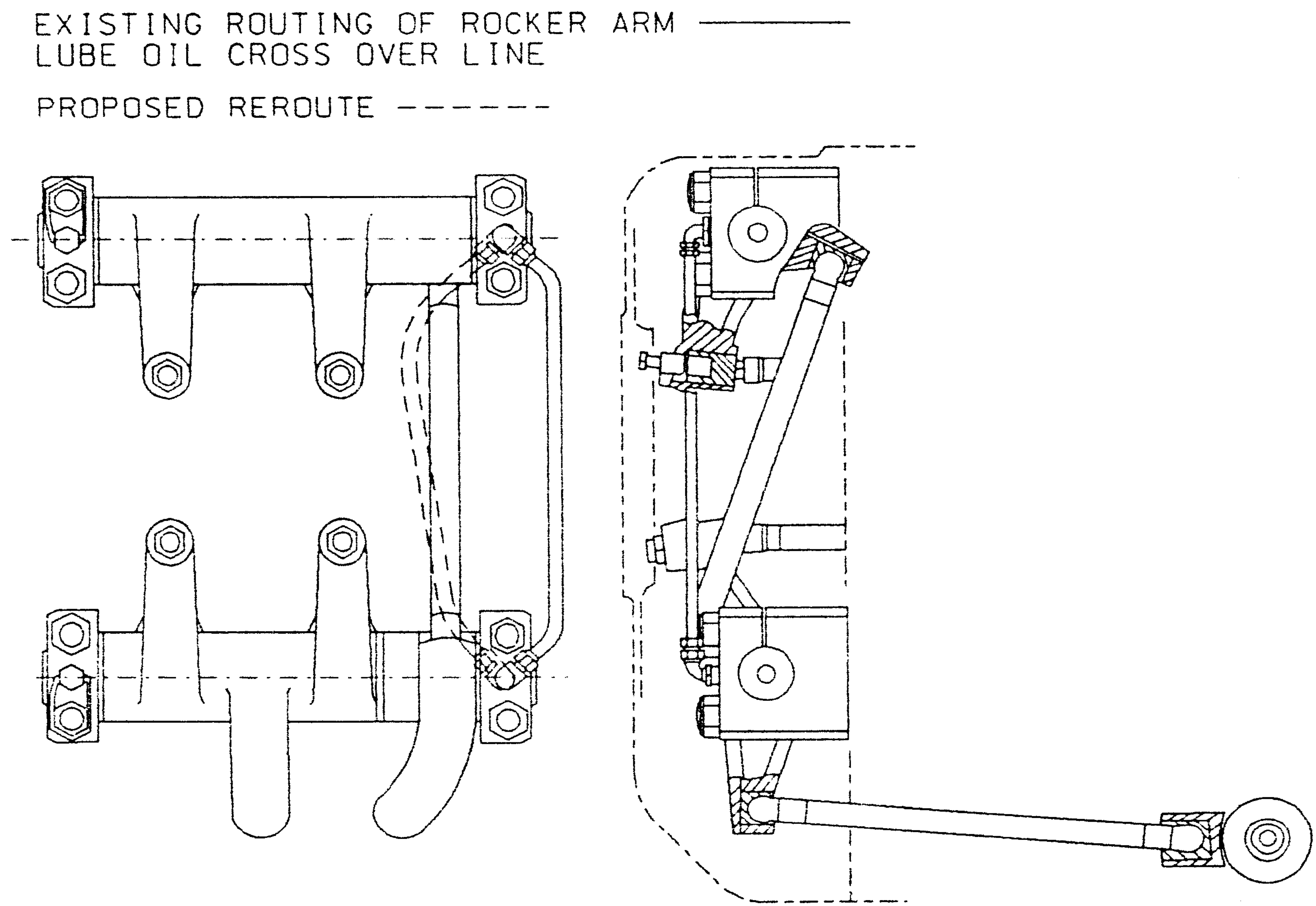
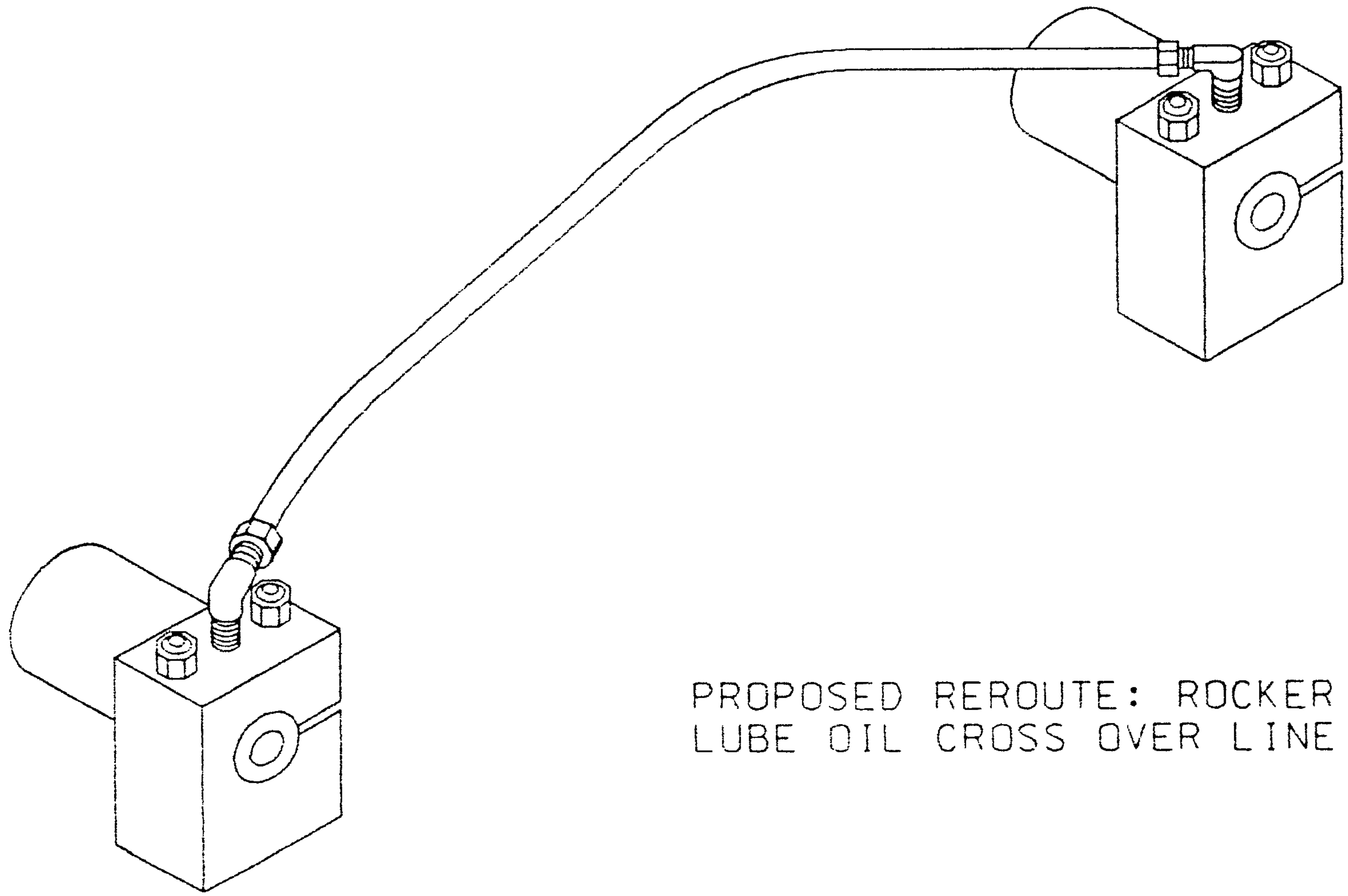
C. ROCKER ARM CROSSOVER LUBE OIL LINE FAILURE

- One failure to date
- High cycle fatigue
- Misalignment and tight bend radii contribute
- Replace with 0.062" wall thickness tube and better bend radii
- Will try prototype on one cylinder for proposed refit


EXISTING ROUTING OF ROCKER ARM
LUBE OIL CROSS OVER LINE
PROPOSED REROUTE



PROPOSED REROUTE: ROCKER ARM
LUBE OIL CROSS OVER LINE

3. FUEL INJECTOR PUMP ISSUES

A. FUEL INJECTOR PUMP SEIZURE

- One pump had seized at STP in 1989
- Silica/Sand contamination found by Cooper-Bessemer
- Other utilities have had seizures

B. FUEL INJECTOR PUMP HOLLOW STUD FAILURES

- 7 failures since 1987
- Generally attributed to overtorquing and installation method
- Revised method of installation

FOR PARTS ORDERING INFORMATION
SEE SECTION 2 OF THIS MANUAL

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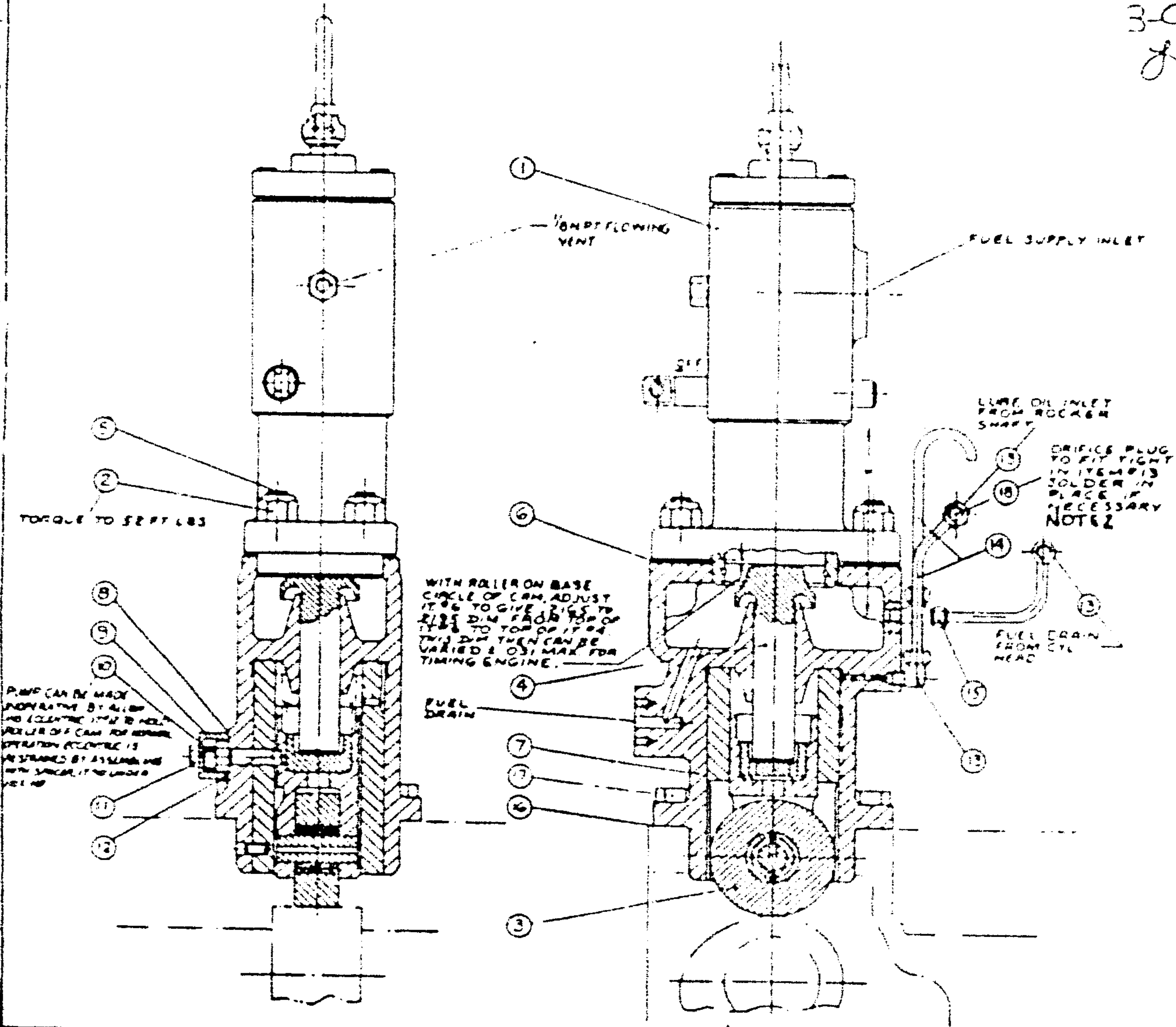
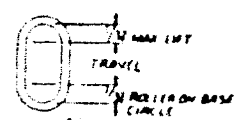
QTY	NAME	PART NO	MAT'L	REMARKS
1	PUMP - INJECTION	2-50F-030-001	COML	
4	NUT (5/8-11)	1-07F-019-040	STL	
1	CROSSHEAD (SUB-ASSEMBLY)	2.25-1-2 #9	—	
1	ROD-PUSH	KSV-18-14	STL	
4	STUD-TAP END (BELOW)	KSV-18-18	STL	
1	SHIM-PUMP	W11D-1 #13	BRS	
1	PEDESTAL - FUEL PUMP	KSV-18-D #3	C I	
1	GASKET	FW-19-[illegible]	FBR	
1	COVER	W13D-[illegible]	BRZ	
1	SPACER	KSV-18-C	STL	
2	BOLT (5/16-18 × 1¾)	1-07-001-018-012	STL	
1	ECCENTRIC	[illegible]	STL	
3	ELBOW (1/4 OD × 1/8 PT)	2-02T-086-005	STL	
1	TUBING (1/4 OD)	3F-385-6-003	SST	
1	TEE (1/4 OD × 1/8 PT)	2-02T-087-004	STL	
1	GASKET	W16B-32 #21	FBR	
4	BOLT (5/8-11 × 1½)	1-07F-015-040-0[illegible]	STL	
1	ORIFICE (1/16)	2-02T-136-007	BRS	

B/M PER CYLINDER





NOTE #1 - AT ORIGINAL ASSEMBLY SELECT SHIMS (ITEM #6) SO PUMP SCRIBE LINE TRAVEL IS CENTERED IN TIMING (VIEW A) WINDOW. THEN SET INJECTION TIMING BY ROTATING FUEL CAM ON CAMSHAFT. WHEN REPLACING PUMP (ITEM #1) DUE TO WEAR OR DAMAGE, TIME NEW PUMP BY ADJUSTING SHIM PACK ONLY. SEE INSTRUCTION BOOK FOR PRESCRIBED INJECTION TIMING

NOTE 2 - See Page 231A for additional installation details

HC - STP FCR-HBM-01421

~~FOR INFORMATION ONLY~~ mae 9/1/89

~~CURRENT REVISIONS OF DRAWINGS~~

~~ARE MAINTAINED IN DCO~~

NUCLEAR STANDBY

INSPECT AT ASSEMBLY PER QCP-12-12

FUEL INJECTION PUMP

COOPER-BESSEMER

KSV-18-4

14

4. MECHANICAL ISSUES

A. PISTON SCUFFING

- One piston and rings in DG-12 replaced in 1991
- Liner was acceptable
- Likely cause is cracked injector nozzle
- Rapid loading contributes to this problem
- Monthly lube oil analysis and boroscope inspect cylinders every refueling
- Susquehanna and Bryon: Same type of problem
- Riccardo Report

B. ECW WATERHAMMER IN DG BRANCH LINES

- Leaking of intercooler mechanical expansion joints (MEJ)
- Trip of ECW pump causes column separation
- Mechanical fatigue of MEJ
- Vacuum breaker added in ECW line to reduce transient

5. RELAYS AND ELECTRICAL ISSUES

RELAYS AND PREPOSITIONING BOARD

- Replaced all but 10 Agastat relays. Service Request exists to complete work.
- Over age was the concern
- Prepositioning Board Problems
  - Replaced 4 of 6 to date
  - Evaluation of gold contacts
- Evaluation of Hermetically Sealed Relays

DROPPING RESISTOR IN WOODWARD GOVERNOR

Chronology:

- 1989 Fluctuating speed in DG12
- Dropping resistor failure
- Two resistors in parallel - when one fails erratic governor performance
- I&E Notice 90-51
- Change out to single resistor, robust design
- Refit complete

6. LONG TERM ISSUES

- Longer run time and loading time
- Vendor Manual update
- Spare Parts issues

STRUCTURAL INTEGRITY ANALYSIS

- Introduction
- Potential Failure Modes
- Analysis Methods
- Fracture Mechanics
- Limit Load
- Analysis Models

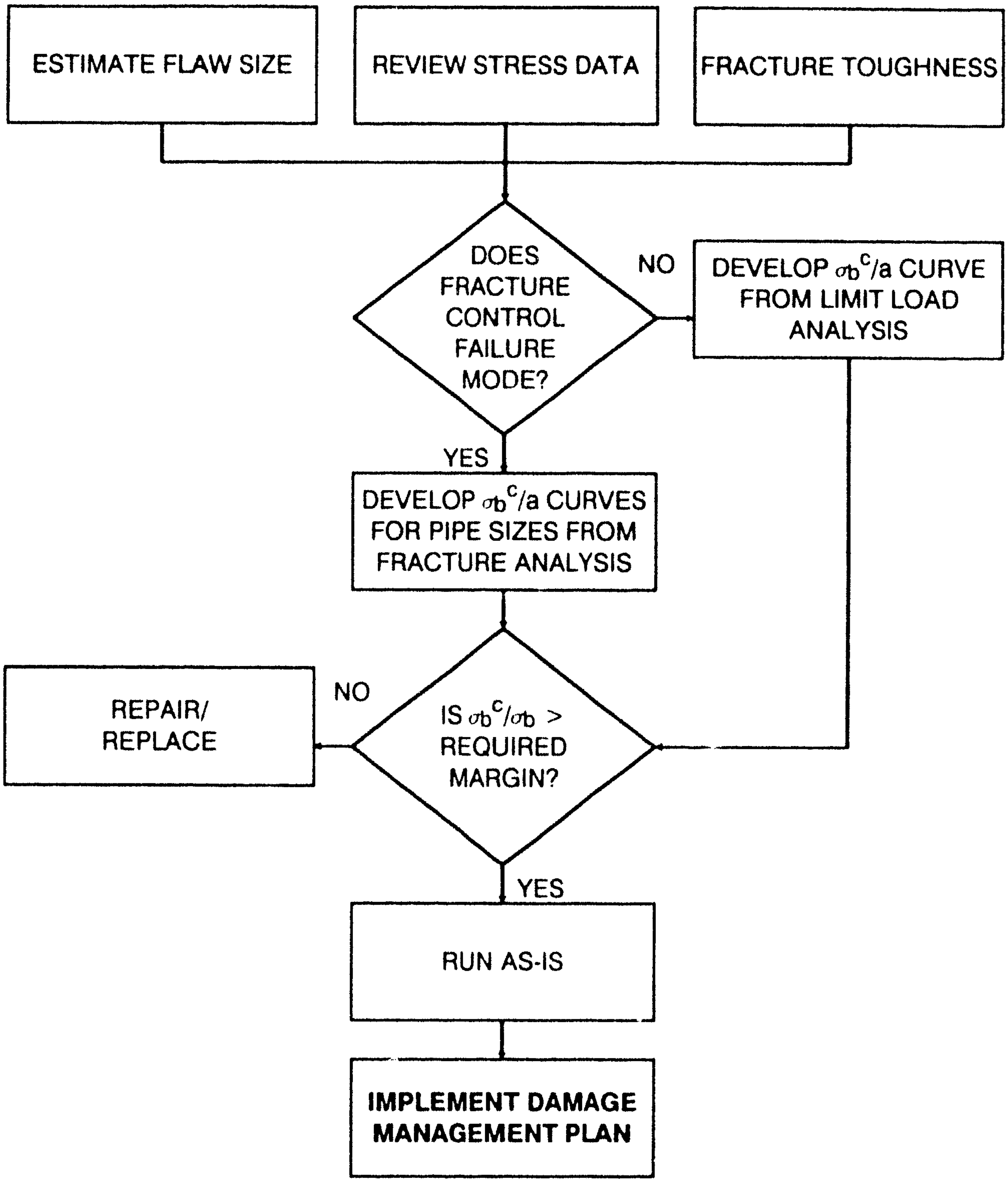
STRUCTURAL INTEGRITY ANALYSIS (Continued)

- Materials Data
  - Fracture Toughness
  - Strength
- Stress Inputs
- Results — Failure Margins
  - Specific-Existing Leaks
  - Generic-Limiting Flaws

POTENTIAL FAILURE MODES FOR ALUMINUM-BRONZE

- Fracture — Controlled by Geometry, Flaw Size (a, 2c) Stresses and Fracture Toughness
- Limit Load — Controlled by Flaw Area, Stresses, and Flow Stress

ANALYSIS STRATEGY – EXISTING LEAKS



ANALYSIS METHODS — THROUGH-WALL FLAWS

Fracture Toughness Screening

$$K_I = (\sigma_m F_m + \sigma_b F_b)\sqrt{\pi a} = K_{Ic}$$

where

K_I is the Applied Stress Intensity Factor

σ_m AND σ_b are Membrane and Bending Stress, Respectively

F_m and F_b are Constants

a is Characteristic Flaw Dimension

K_{Ic} is the Fracture Toughness

Hence the Critical Bending Stress, σ_b^c, is

$$\sigma_b^c = \frac{K_{Ic}}{F_b\sqrt{\pi a}} - \sigma_m \frac{F_M}{F_b}$$

ANALYSIS METHODS — THROUGH-WALL FLAWS

Limit Load

Based on ASME Section XI, Appendix H:

$$\sigma_b^c = \frac{2}{\pi} \sigma_f (2 \sin\beta - \sin\theta)$$

where

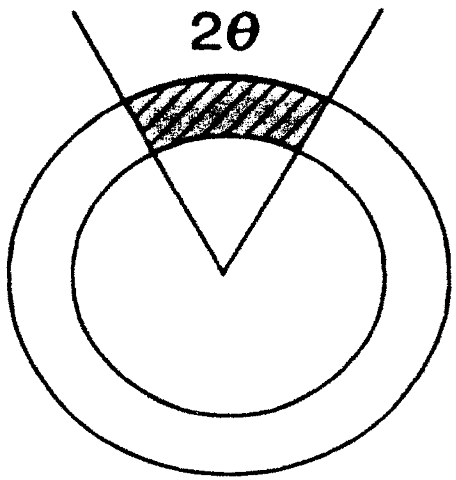
σ_b^c is Critical Bending Stress,

$$\beta = \frac{\pi}{2}\left(1 - \frac{\theta}{\pi} - \frac{\sigma_m}{\sigma_f}\right)$$

and

σ_f is the Flow Stress Taken as the Average of the Yield and Ultimate Strengths

ANALYSIS MODELS - THROUGH CRACK



- Crack Subjected to Pressure Stress and Bending
- Crack Placed in Positive Bending Moment

FRACTURE TOUGHNESS DATA

Weld Metals

- Tests Performed on Brown & Root Welds in Previous Program
- Bounding Value of $K_{Ic} = 120\ ksi\sqrt{in}$ (2 standard deviations from mean)

FRACTURE TOUGHNESS ESTIMATION FOR AL-BRONZE WELD METAL

COD Test Data

Specimen Number	Temp. (°F)	E (ksi X 10^3)	σ_y (ksi)	σ_u (ksi)	σ_f (ksi)	δ (in)	Computed K_c (ksi $in^{1/2}$)
B1	40	11.4	28.3	79.3	53.8	0.0253	136.5
B2	40	11.4	28.3	79.3	53.8	0.0222	127.2
B3	40	11.4	28.3	79.3	53.8	0.0259	138.1
B4	40	11.4	28.3	79.3	53.8	0.0267	140.2
C1	70	17.7	37.4	84.2	60.8	0.0254	181.1
C2	70	17.7	37.4	84.2	60.8	0.0242	176.8
C3	70	17.7	37.4	8.42	60.8	0.0248	179.0
D1	70	17.0	33.7	82.5	58.1	0.0181	146.5
D2	70	17.0	33.7	92.5	58.1	0.0215	159.6
D3	70	17.0	33.7	82.5	58.1	0.0182	146.9
E1	70	16.7	35.6	79.2	57.4	0.0320	191.9
E2	70	16.7	35.6	79.2	57.4	0.0300	185.8
F1	70	14.6	34.4	77.7	56.1	0.0330	180.0
F2	70	14.6	34.4	77.7	56.1	0.0330	180.0
F3	70	14.6	34.4	77.7	56.1	0.0290	168.8

FRACTURE TOUGHNESS ESTIMATION FOR AL-BRONZE WELD METAL (Continued)

Mean K_c: $\overline{K}_c = 162.6$ ksi in$^{1/2}$
Standard Deviation: $S = 21.4$ ksi in$^{1/2}$

$$K_{Ic}^{-} \approx \overline{K_c} - 2S \cong 120 \text{ ksi in}^{1/2}$$

$$K_{Ic}^{-} = \text{Conservative Bound}$$

STRESS REVIEW

1. Above Ground Piping

2. Below Ground Piping

ABOVE-GROUND STRESS ANALYSIS REVIEW RESULTS

- Review Covered All Pipe Sizes

- All Stress Components Considered:

  - Pressure
  - Weight
  - Seismic
  - Thermal
  - Settlement
  - Transients

ABOVE-GROUND STRESS ANALYSIS REVIEW RESULTS (Continued)

- **Bounding Case for 30-Inch Pipe Summarized Below (stresses in psi):**

			Equation				
Calc.	Pipe Size	SLP Design	8	9B	9D	10	Max. Stress
RC967	30	3510	4484 (414)*	6564 (829)*	4544 (829)*	9946 (777)*	13500

*Denotes Node Number in Calc.

BURIED ECW PIPING

For 30-Inch Pipe
(stresses in psi)

		Code Equation			Unconcentrated Stress	
Equation	Location	Stress	Allowable	SIF	Axial	Bending
9D	D	40756	43200	8.81	1590	5972
10	BCDEF	12970	27000	11.31	0	1147

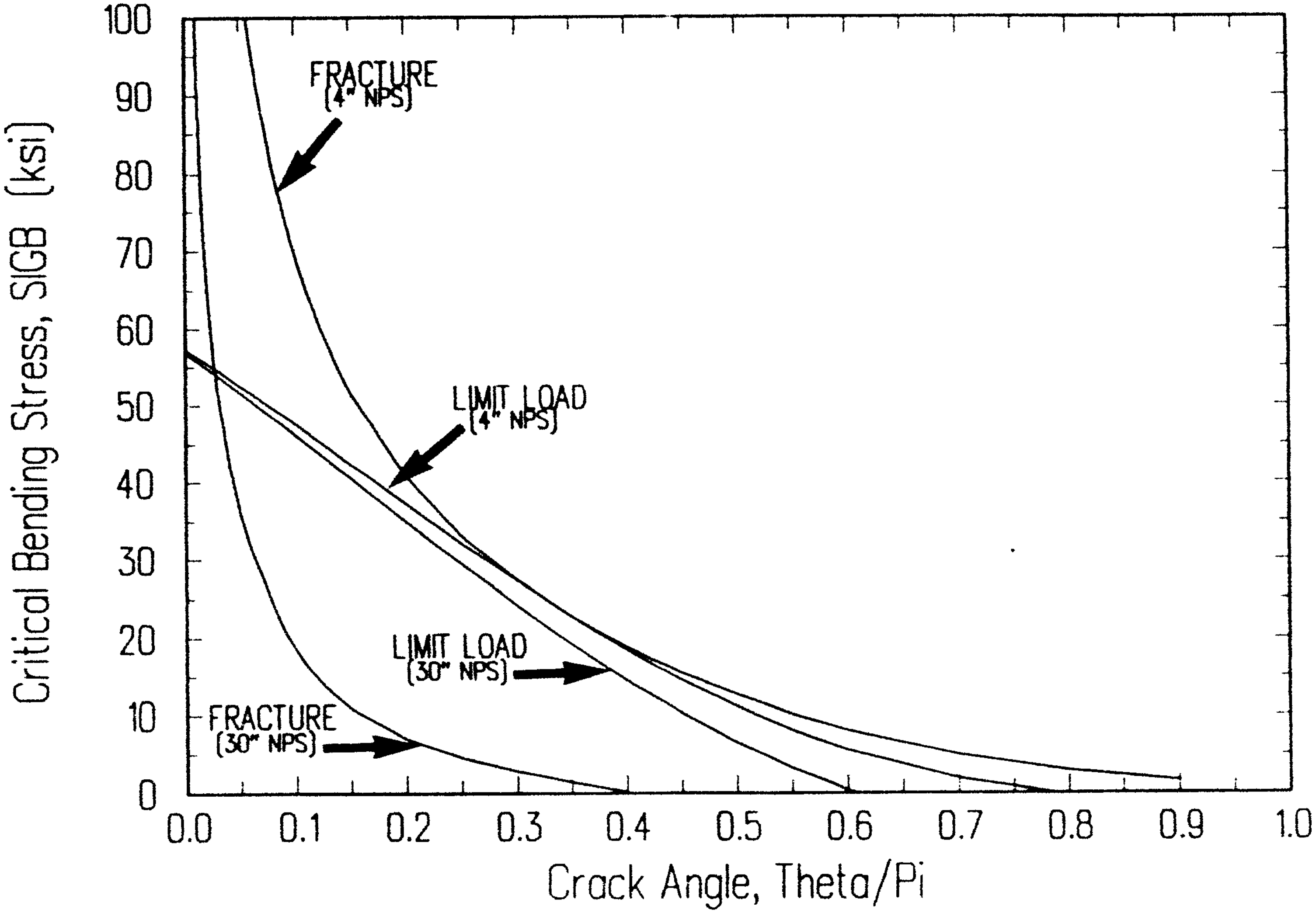
For 10-Inch Pipe
(stresses in psi)

		Code Equation			Unconcentrated Stress	
Equation	Location	Stress	Allowable	SIF	Axial	Bending
9D	D	17088	43200	8.81	317	2538
10	HIJ	5833	27000	2.605	0	2239

WATER HAMMER ANALYSIS REVIEW

- Objective — To Assess Impact of Water Hammer Loads on Critical Flaw Size Calculations
- Method — Screening Analysis Using Bechtel Water Hammer Results at Selected Locations
- Results of Walkdown and Drawing Review:
  - Cracks Not Caused by Water Hammer:
    - Many in Areas Not Subject to Major Water Hammer Levels
    - No Support System Damage
  - Buried Piping Less Susceptible to Water Hammer Damage Than Above-Ground Piping

CRITICAL BENDING STRESS - THROUGH-WALL CRACK



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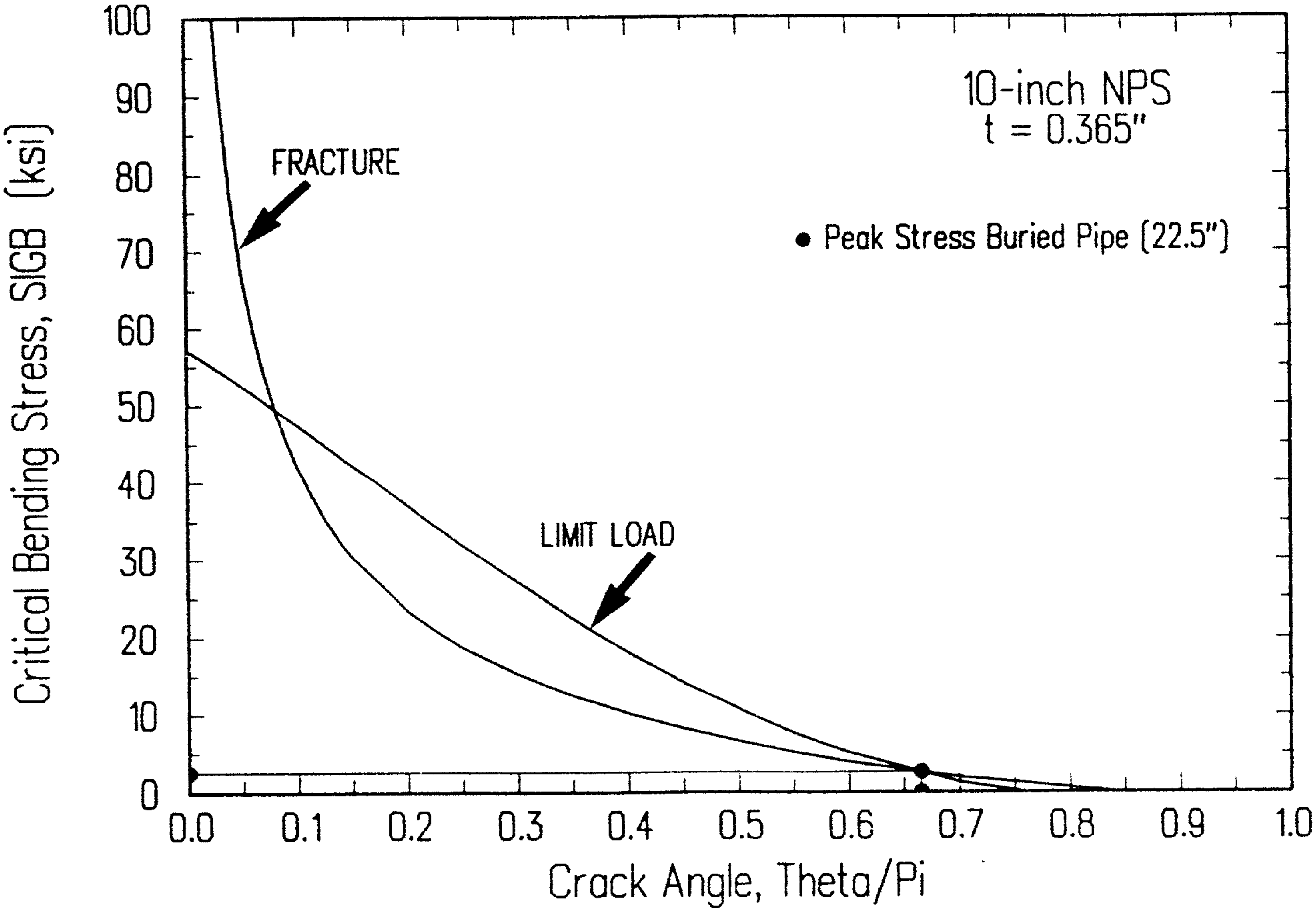
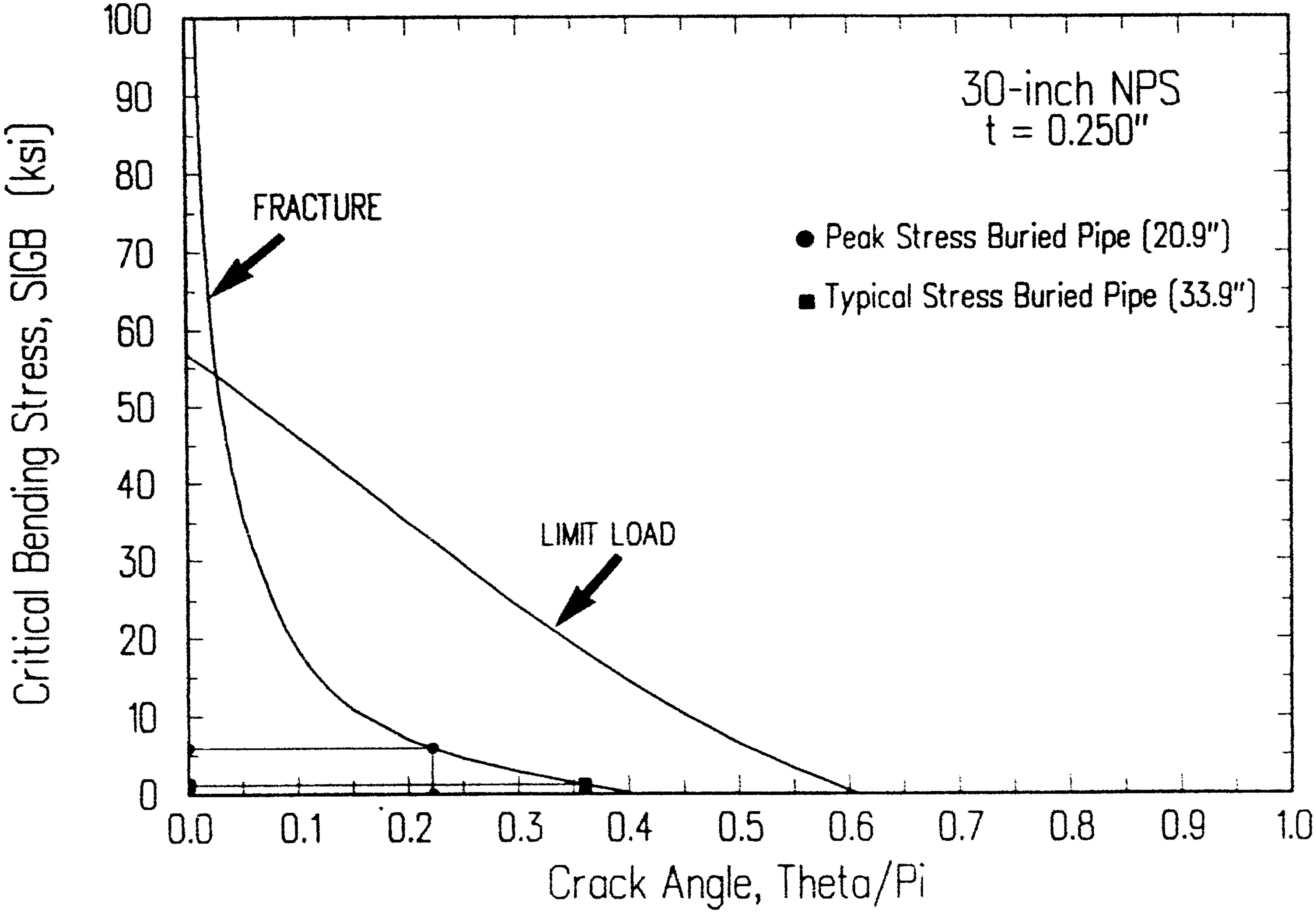
CRITICAL BENDING STRESS - THROUGH-WALL CRACK



![APTECH ENGINEERING SERVICES, INC.]

CRITICAL BENDING STRESS - THROUGH-WALL CRACK



RESULTS — GENERIC ANALYSIS

Pipe Size (in)	Location	Wall Thickness (in)	Peak Applied Bending Stress (psi)	Critical Flaw Size (% Circ.)	Critical Flaw Size (in)
30	Above Ground	0.25	13,500	12.5	11.8
30	Below Ground	0.25	5,927	22.2	20.9
30	Below Ground	0.25	1,147*	36.0	33.9
10	Below Ground	0.365	2,538	66.5	22.5

*Typical Value

RESULTS

Existing Cracks

Summary of Flaw Evaluation Results for Four Aluminum-Bronze Welds

Weld Numbers	Pipe Size (in)	Thickness (in)	Maximum Crack Length 2a (in)	Percent Circumference	Applied Membrane Stress σ_m (psi)	Applied Bending Stress σ_b (psi)	Critical Bending Stress σ_b^c (psi) Fracture	Critical Bending Stress σ_b^c (psi) Limit Load	Failure Margin (σ_b^c/σ_b)
EW1302-FW0032	30	0.25	5.50	5.58	3600	6721	26,406	50,667	3.93
EW1102-FW0032	30	0.25	4.372	4.68	3600	6247	22,153	51,966	3.55
EW1205-FW0043	30	0.25	10.375	11.1	3600	8296	14,960	44,948	1.80
EW2208-FS3452	6.625	0.375	1.0	5.09	1060	1650	83,544	52,343	31.7

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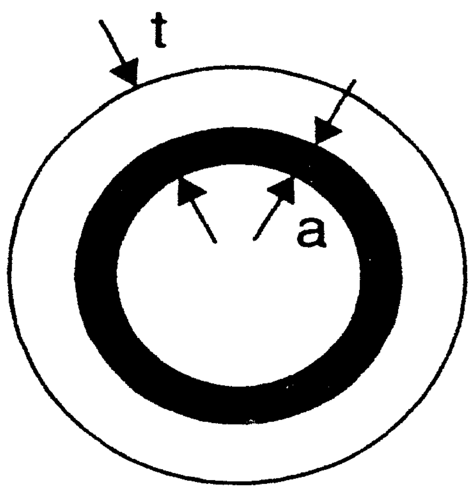
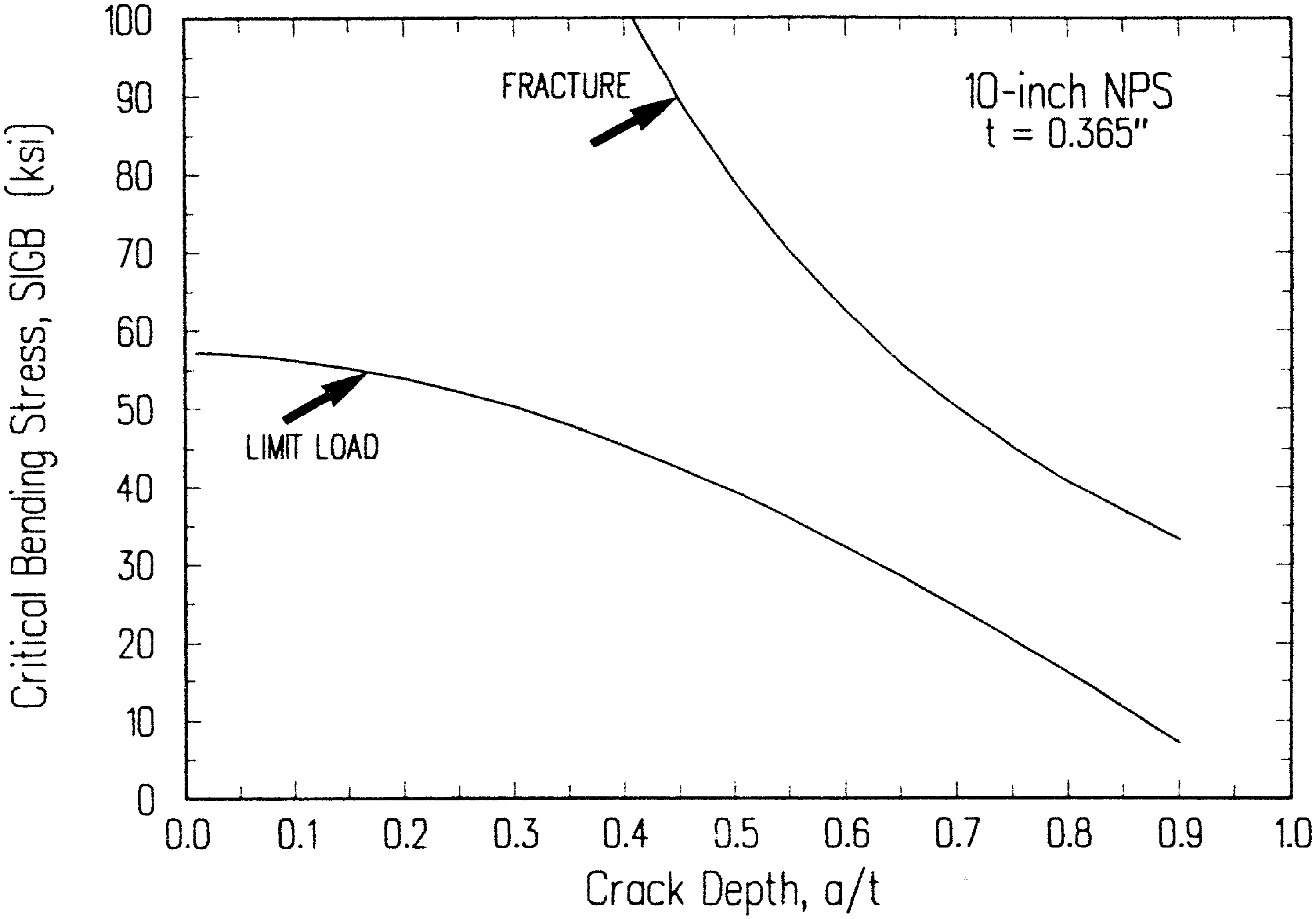
ANALYSIS MODELS - PART-THROUGH CRACK

Assumed 360°



CRITICAL BENDING STRESS - PART-THROUGH CRACK



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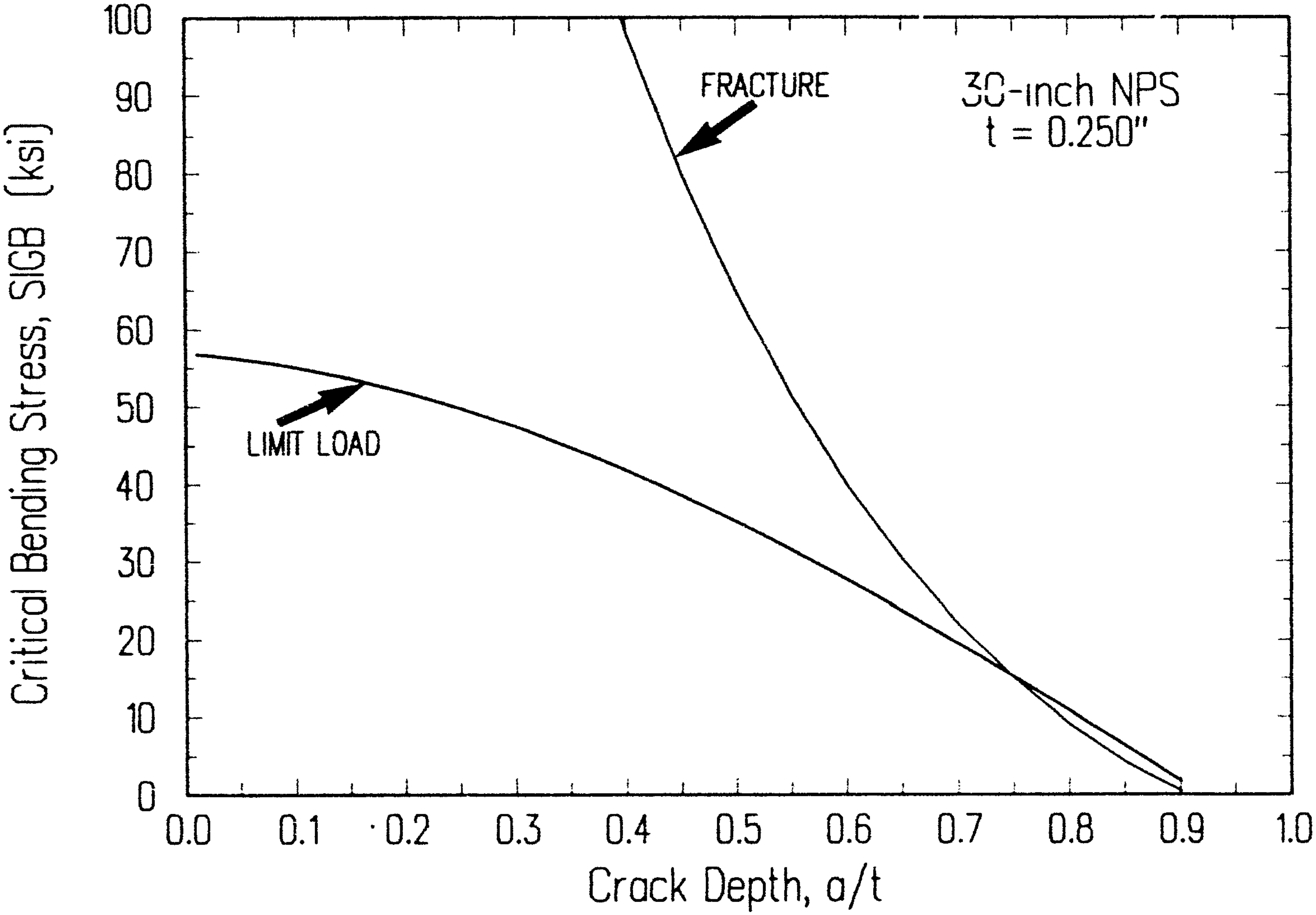
CRITICAL BENDING STRESS - PART-THROUGH CRACK



CONCLUSIONS

- Analysis Shows That Large Flaws in Large Pipes are Controlled by Fracture Failure Mode
- Small Flaw Controlled by Limit Load
- For Typical Flaws Large Margins Exist in Terms of Stresses of Flaw Sizes
- For Generic Analysis at Peak Bending Stress for Above Ground Piping Large Flaws May be Safely Tolerated (~12 Inches)
- Below Ground Piping More Tolerant to Flaws Because of Lower Stresses

METALLURGY AND FAILURE ANALYSIS OF ALUMINUM BRONZE WELDS FROM STP ECW SYSTEM

I. Background on Aluminum Bronze Metallurgy

II. Results and Conclusions of Failure Analysis

ALUMINUM BRONZES

Copper alloys of 5 - 15% Aluminum (+Fe, Ni) having good general corrosion resistance, high strength and not susceptible to stress corrosion cracking in the ECW environment

ALUMINUM BRONZE ALLOYS UTILIZED IN THE SYSTEM

- Wrought Alloy (CA-614)
  Pipe, fittings, backing rings, flanges,
  CCW heat exchanger, pump column

- Cast Alloys (CA-952, CA-954, CA-955)
  Flanges, valve bodies, pump impellers

- Filler Metal (AWS ERCUAL-A2)
  Butt welds

MICROSTRUCTURE AND ALUMINUM CONTENT

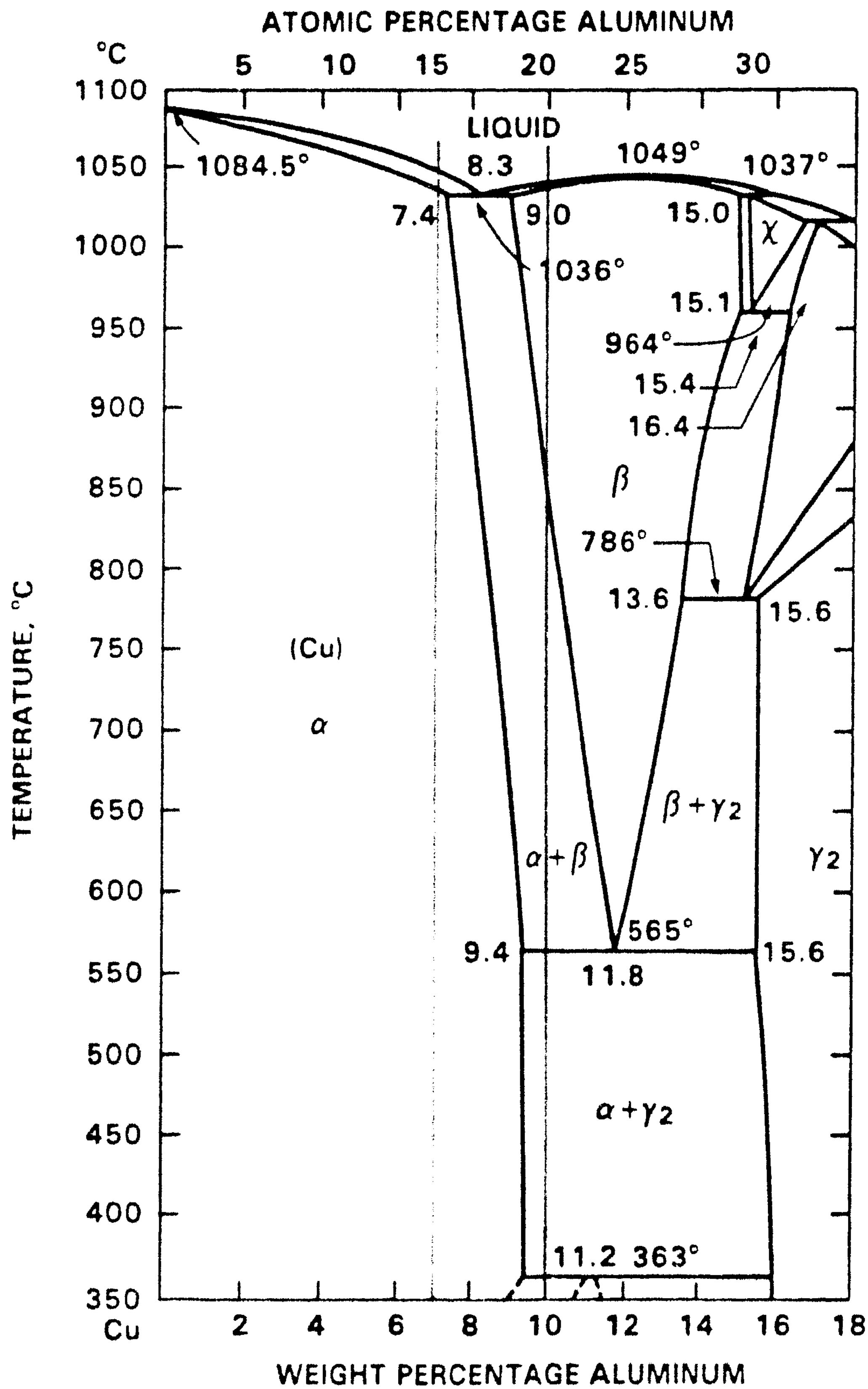
- Single Phase Alloys (CA-614)

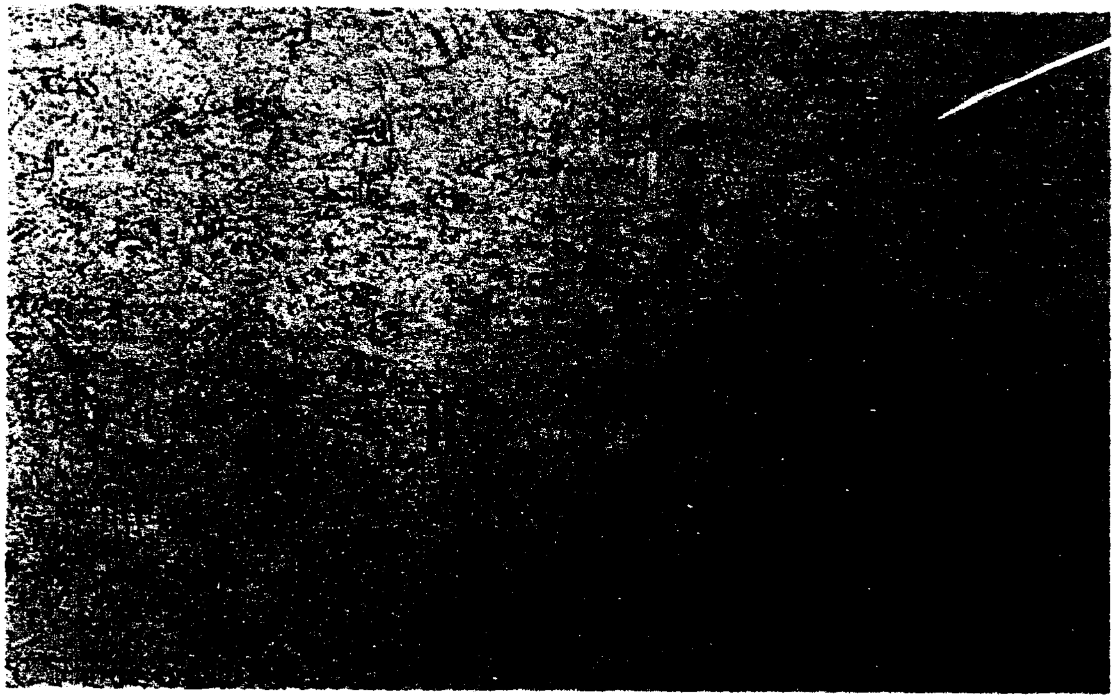
  6 - 8% Aluminum, consist of alpha phase

- Dual Phase Alloys (CA-9XX AND ERCUAL-A2)

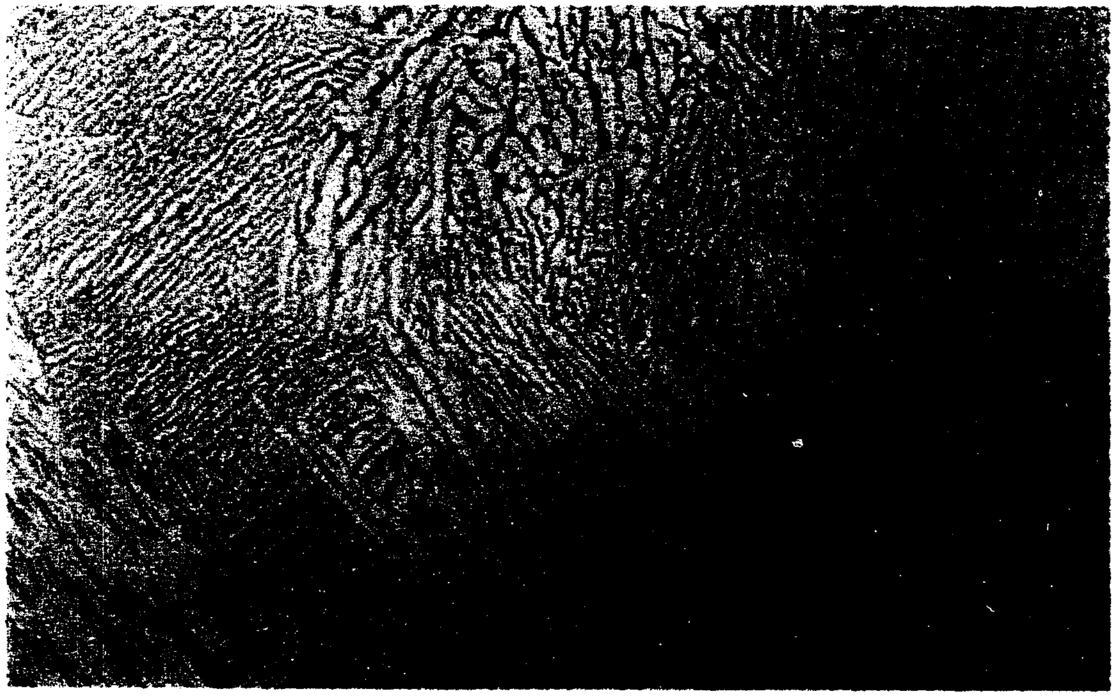
  8.5 - 11.5% Aluminum, consist of mixture of alpha and beta phases

PHASE DIAGRAM OF ALUMINUM-COPPER BINARY ALLOY





ALPHA PHASE
(CA-614)



ALPHA + BETA PHASE
(ERCuAl-A2)

DEALLOYING MECHANISM

- Dissolution of higher aluminum phases

- Reprecipitation of elemental copper (porous)

- Dealloyed metal retains some tensile strength

- Crevice conditions accelerate phenomenon by increasing [Cl^-] and decreasing pH locally

DEALLOYED ERCuAl-A2 MICROSTRUCTURE

FIRST CRACK ANALYSIS

- 4" crack in weld joining elbow to CCW heat exchanger nozzle (Unit 1)

- Weld history revealed previous weld was "cut-out" during construction

- Crack initiated at tip of weld root defect (lack of fusion) 8.4" long

- Dealloying confined along crack length

- Crack path was interdendritic (i.e., through the beta phase regions)

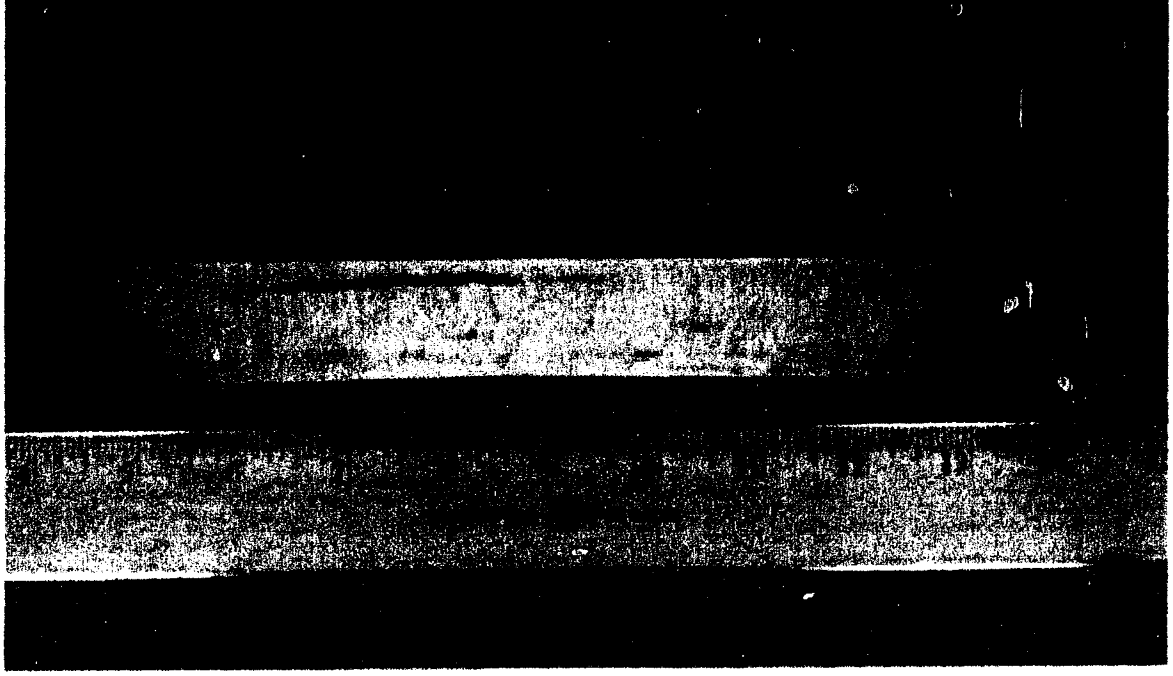


Figure 5. Photograph taken of the dye penetrant indication on the outside surface of the weld showing the through wall portion of the crack. (Magnification: 0.5X)

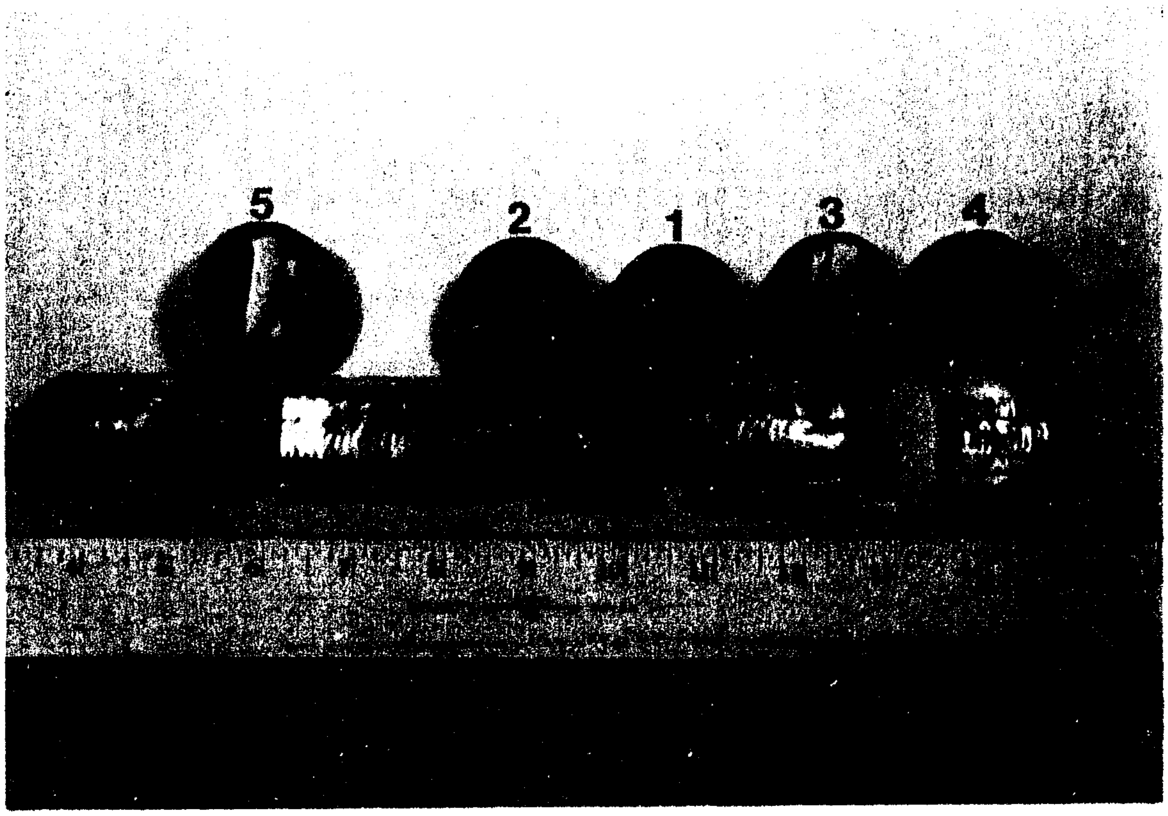


Figure 6. Photograph of the sectioned specimen. Note fracture surface specimens and locations of metallurgical cross sections. (Magnification: 0.5 X)

Figures 12 and 13. Photomacrographs of cross section #2 also in the through wall portion of the crack. Pre-existing defect includes lack of fusion with weld crack. (Magnifications: 2.2 and 10X, Ammonium Persulfate Etchant, MM 2477)

Figure 14. Higher magnification photomacrograph of cross section #2. Lower arrow shows extent of lack of fusion. Upper arrow shows estimated extent of pre-existing defect. (Magnification: Ammonium Persulfate Etchant, MM 2477)

MT-3512A

SECOND CRACK ANALYSIS

- 5-3/4" crack in pipe to pipe weld near CCW heat exchanger (Unit 2)
- Weld history showed extensive repairs during construction where crack was located
- Crack growth monitored after leakage was found
- Initiation at weld root where lack of fusion and possible pre-existing weld cracks were found
- Dealloying along crack length (much less than in Unit 1)
- Crack path was within beta phase regions
- Intergranular corrosion attack of base metal in small area

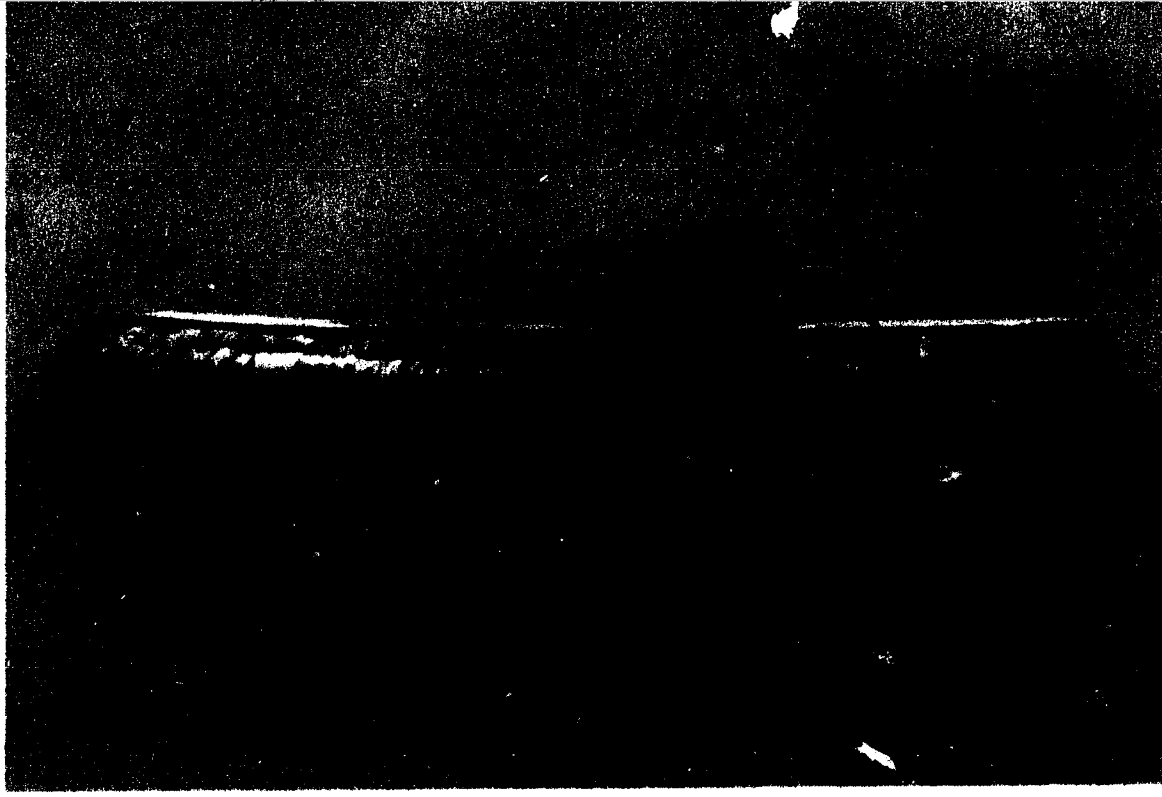


Figure 1. Photograph of the as-received specimen. Outer black lines indicate extent of ultrasonic testing indication. Small black lines at edge of specimen indicate boundary of the through - wall crack as noted on 08/06/91. (Magnification: 0.6X)

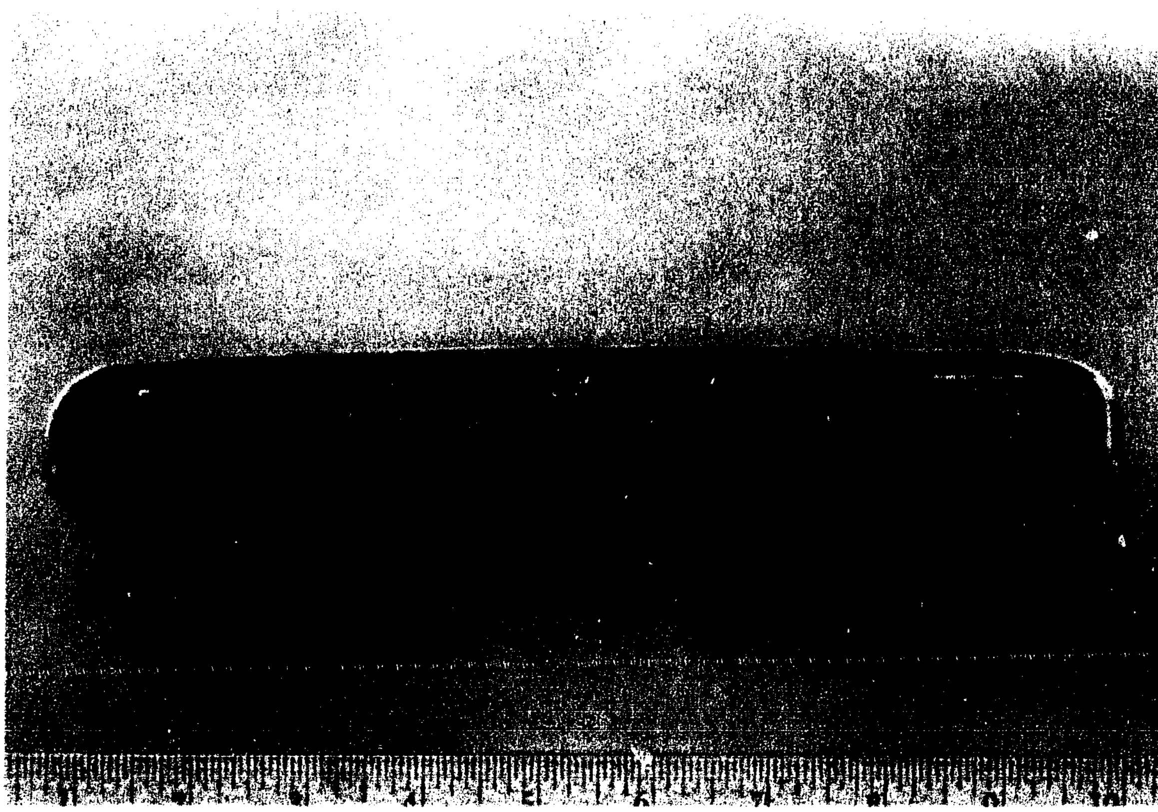
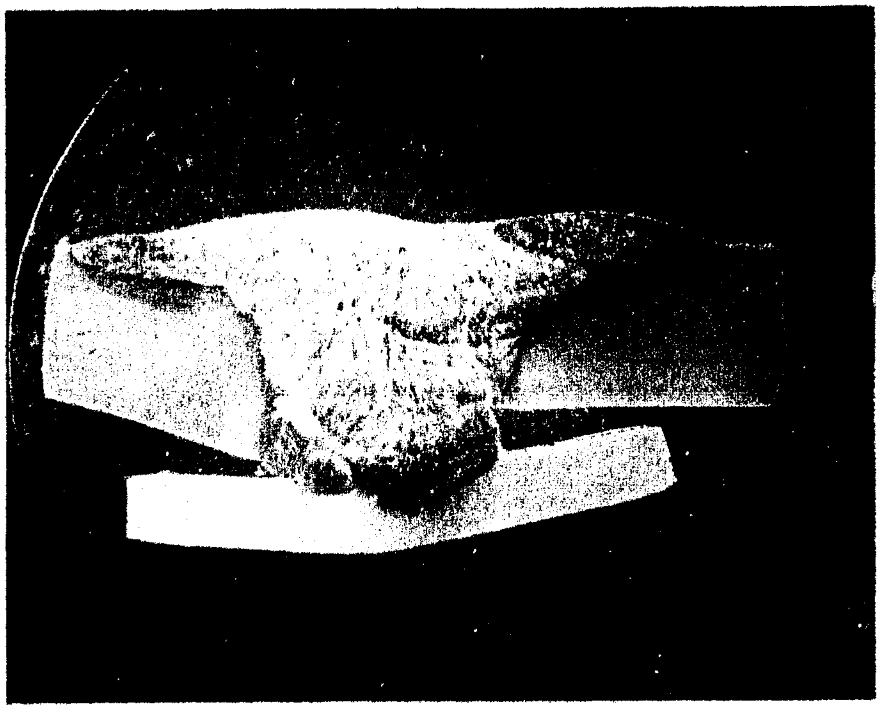


Figure 2. Photograph showing the inside diameter surface of the as-received specimen. Corrosion products can be seen coming out from under the backing ring (arrow). (Magnification: 0.6X)



Figures 8 and 9. Photomacrographs of the cross section #1 taken outside the top end of the through-wall crack in an area of in service propagation. Optics of the microscope reverses the higher magnification image horizontally. (Magnification: 2.5X and 10X, Ammonium Persulfate Etchant, MM-2511)

Figure 10. Higher magnification photomacrograph of cross section #1 showing the crack. Arrows show the boundaries of maximum lateral dealloying. (Magnification: Ammonium Persulfate Etchant, MM-2511)

MT-3512B

CONCLUSIONS

- Cracks initiated at weld defects (lack of fusion or cracking)
- Crack propagation due to combined effects of dealloying and stresses at crack tip
- Dealloying due to crevice effects of backing ring and defect
- Stress needed for propagation = residual + operating stresses