

PHILADELPHIA ELECTRIC COMPANY

2301 MARKET STREET

P.O. BOX 8699

PHILADELPHIA, PA. 19101

(215) 841-4504

JOHN S. KEMPER
VICE-PRESIDENT
ENGINEERING AND RESEARCH

SEP 06 1984

Mr. A. Schwencer, Chief
Licensing Branch No. 2
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Docket Nos.: 50-352
50-353

Subject: Limerick Generating Station, Units 1 and 2
Information for Materials Engineering Branch (MTEB)
Regarding SER Confirmatory Issue No. 22 (Fracture
Toughness of Containment Pressure Boundary).

Reference: (1) Letter, J. S. Kemper (PECO) to A. Schwencer
(NRC), dated May 25, 1984.

Attachments: (1) Compliance with General Design Criterion
(GDC) 51.
(2) Certified Material Test Reports (CMTR).
(3) Stress Intensity Factor KI Calculation for
Assumed Flaws in 24-inch Feedwater Check Valve
Body Castings.

File: GOVT 1-1 (NRC)

Dear Mr. Schwencer:

Attachment (1) is submitted to confirm compliance of Limerick Generating Station Units 1 and 2 with the requirements of GDC 51, "Fracture Prevention of Containment Pressure Boundary". Attachment (2) provides the CMTRs for the containment pressure boundary components evaluated in Attachment (1). Attachment (3) is a fracture mechanics calculation summary which provides, in part, the results of the fracture mechanics evaluations performed at the 1180 psi maximum pressure during the 40°F lowest temperature operation experienced by the feedwater check valves when acting as a containment pressure boundary. This summary also includes information on the size and location of the assumed flaw, the stress direction, and a description of how the fracture mechanics analysis was performed. Reference (1) previously documented the fracture toughness capability of the Limerick Class 1 feedwater isolation check valves.

Sincerely,

Jw Ballyhoo
for
JS/Kemper

13001

8409130133 840906
PDR ADOCK 05000352
F PDR

JHA/gra/08318401

cc: See Attached Service List

| | |
|---|-----------------|
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| Judge Peter A. Morris | (w/o enclosure) |
| Judge Richard F. Cole | (w/o enclosure) |
| Judge Christine N. Kohl | (w/o enclosure) |
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Attachment (1)
Limerick Generating Station, Units 1 and 2
Compliance with General Design Criterion (GDC) 51

From June 21 to June 24, 1983, a compliance review was held at the offices of Bechtel and General Electric by Mr. J. Halapatz (NRC/MTEB) to assess compliance with GDC-51. The reviewer examined drawings, certified material test reports (Attachment 2), and heat treatment records of the reactor containment pressure boundary ferritic materials for compliance with GDC-51. The limiting components were identified. The metallurgical characterization of these materials, when correlated with the data presented in NUREG-0577 and the Summer 1977 Addenda of the ASME Code Section III, provides the technical basis for the staff's evaluation of the compliance with Code Class 2 requirements of these materials.

The following are the conclusions of the MTEB reviewer concerning permissible lowest service metal temperature (PLSMT).

1. Main Steam Isolation Valve (F028A typ., S/N 1-683 typ.)

- Body: SA 216 WCB by Quaker Alloy
Normalized: 4- $\frac{1}{4}$ " min design thk: NUREG-0577 Table 4.4 assigns a $(\overline{NDT} + 1.3\sigma)$ TNDT of +57°F. NUREG-0577 Fig. B2 would infer (because material is normalized) a TNDT in the population at or below the \overline{NDT} of +35°F (Table 4.4). S'77 Addenda CL-2 rules, assuming a TNDT of +35°F, would assign a PLSMT of +85°F to the material.
- Cover: SA 105 Gr II: Heat treated by Cann & Saul:
Normalized: 4- $\frac{1}{4}$ " min design thk: NUREG-0577 Table 4.4 assigns a $(\overline{NDT} + 1.3\sigma)$ TNDT of -5°F. S'77 Addenda CL-2 rules assign a PLSMT of +45°F.
- Poppet: SA 105 Gr II: Heat Treated by Cann & Saul:
Normalized: 5-7/8" min design thk: As with the cover, a $(\overline{NDT} + 1.3\sigma)$ TNDT is assumed to be -5°F. S'77 Addenda CL-2 rules assign a PLSMT of +55°F.
- Bolting: 2"SA 193 Gr-B7 and SA 194 Gr-2H:
NUREG-0577 Table 4.6 categorizes these materials as having the least susceptibility to brittle fracture.

2. Main Steam Flued Head (Process pipe is integral within flued head)

SA 105 Gr II and SA 350 Gr. LF2: Quenched and tempered: 5 in. axial thickness: NUREG-0577 Table 4.4 assigns a TNDT of -28°F to normalized material. The materials are both categorized as C-MN, quenched and tempered, and, therefore, could be assumed to have a TNDT below -28°F . Assuming a TNDT of -28°F , S'77 Addenda CL-2 rules assign a PLSMT of $+27^{\circ}\text{F}$.

3. Feedwater Flued Head (Process pipe is integral within flued head)

SA 350 Gr. LF2: 8" Axial Thk: Normalized: NUREG-0577 Table 3.2 categorize material as C-MN comparable to SA-105. NUREG-0577 Table 4.4 assigns a $(\overline{\text{NDT}} + 1.3\sigma)$ TNDT of -5° to normalized SA 350 LF2: S'77 Addenda CL-2 rules assign a PLSMT of $+67^{\circ}\text{F}$.

4. Feedwater Isolation Valve (F074A typ.)

Body: SA 352 Gr LCB: Quaker Alloy: Normalized (interrupted quench): 6 hrs @ $1630/1650^{\circ}\text{F}$; Furnace Cool $1440/1460^{\circ}\text{F}$, for 2 hrs; $1420-1430^{\circ}\text{F}$, for 40 min; SA 352 Gr. LCB is categorized as similar to SA 216.

NUREG-0577 Table 4.4 assigns a $(\overline{\text{NDT}} + 1.3\sigma)$ TNDT of $+57^{\circ}\text{F}$. NUREG-0577 Fig. B-2, however, would assign a TNDT in the population below $\overline{\text{NDT}}$ of $+35^{\circ}\text{F}$ (Table 4.4). Based on assuming TNDT of $+35^{\circ}\text{F}$, S'77 Addenda CL-2 rules would assign a PLSMT of $+80^{\circ}\text{F}$.

Cover: SA 350 Gr LF2 (by Cann & Saul): Normalized and tempered: 5" min design thk: SA 350 Gr LF2 is categorized as C-MN (per NUREG-0577 Table 3.2) comparable to SA 105: NUREG-0577 Table 4.4 assigns a $(\overline{\text{NDT}} + 1.3\sigma)$ TNDT of -5°F ; S'77 Addenda CL-2 rules assign a PLSMT of $+50^{\circ}\text{F}$.

Disc: SA 352 Gr LCB: Quaker Alloy: 3.75" min Thk. Normalized: NUREG-0577 Table 4.4 assigns a $(\overline{\text{NDT}} + 1.3\sigma)$ TNDT of $+57^{\circ}\text{F}$. However, S'77 Addenda CL-2 rules based on Fig. B2 data for normalized material assign a PLSMT of $+85^{\circ}\text{F}$, assuming a TNDT $+35^{\circ}\text{F}$ (Table 4.4).

Bolting: SA 193 B7: SA 194 2H: NUREG-0577 Table 4.6 categorizes these materials as having the least susceptibility to brittle fracture.

5. Flued Heads - General

Flued heads identified are limiting materials, SA 105 (X-8 penetration) was specified but SA 350 Gr LF-2 was applied. Normalized, quenched and tempered: 3" max Thk: NUREG-0577 Table 4.4 would assume a TNDT of -28°F : S'77 Addenda CL-2 rules assign a PLSMT of $+2^{\circ}\text{F}$.

6. Penetrations

All penetration sleeves apply per Bechtel Spec. 8031-C-2 Rev.
10: SA 516 Gr 60 or Gr 70, Normalized; or SA 333 Gr 1: SA 537
Gr B is identified, but not applied.

PEN X. 9A/B: SA 516 Gr 60: 1- $\frac{1}{2}$ " Thk: S'77
(Limiting) Addenda CL-2 rules assign a TNDT of 0°F and a
PLSMT of +30°F.

X-11: SA 333 Gr 6: 0.812" Thk: NUREG-0577
(Limiting) Table 4.4 assigns a (NDT +1.30°) TNDT of 67°F;
S'77 Addenda CL-2 rules assign a PLSMT of 97°F.
However, the material was Cv tested at -50°F to
criteria consistent with S'77 Addenda CL-2 rules
given the design LMST of 65°F.

X-15 Typ: SA 420 WPL 1: Applying SA 516 Gr 70 and A350 LF1:
Pipe Caps Limiting Thk is 1.156" WL x 18": Cv tested at
-50°F to Cv criteria consistent with S'77 Addenda
CL-2 rules given the design LMST of 65°F.

7. Equipment Hatch/Personnel Airlocks

69-3 SA 516 Gr 60: 3" Thk: quenched and tempered.
(Typ. Door and barrel reinforcement is identified as
Limiting) limiting. S'77 Addenda CL-2 rules assign a TNDT
-10°F and a PLSMT of +30°F.

MK-70-7: SA 516 Gr 60: 1" thk door assembly.
(Limiting) Normalized: S'77 Addenda CL-2 rules assign a
TNDT of 0°F and a PLSMT of +30°F.

162-1 SA 516 Gr 70: 3" thk. Quenched and tempered.

The above data was compared by the applicant with system design
data to determine if the lowest service metal temperature (LMST)
for any system was below the PLSMT for the equipment in that
system. The LMSTs are identified in Table 1.

The ambient air temperature was assumed to equal the LSMT for
those identified components that are part of the primary
containment. The ambient air temperature was conservatively
calculated by postulating failure of the Reactor Enclosure Air
Supply System and all heating under those conditions cited in
GDC-51. The reactor enclosure was calculated to maintain ambient
temperature above 65°F.

Fluid temperatures were assumed to equal the LMST for those identified components in intimate contact with the fluid. One mode of the feedwater system results in a LMST of 42°F due to HPCI injection from the condensate storage tank. For this mode, four items associated with the feedwater system appeared as potential problems because this LMST was below the NRC-calculated PLMST provided earlier. These four items are the feedwater flued head and the cover, disk, and body of the outboard feedwater isolation check valve.

Subsequent to the June 1983 review, the applicant reviewed these components with the following dispositions:

- . Feedwater Flued Head - the actual thickness of the flued head is 8". This is considerably larger than the minimum design thickness of less than 2.5" and yields a PLMST of 25°F.
- . Feedwater Valve Cover - the actual thickness of the valve cover is 5". This is considerably larger than the minimum design thickness of 2.75" and yields a PLMST of 30°F.
- . Feedwater Valve Disk - Under the limiting condition, HPCI is injecting into the vessel and, therefore, the disk does not have a pressure retaining function in this case.
- . Feedwater Valve Body - The evaluation of PLMST and a fracture mechanics analysis has been provided in a report transmitted by letter, J. S. Kamper to A. Schwencer, dated May 25, 1984. The report calculates a PLMST of 30°F.

The results of these evaluations are summarized in Table 1.

Conclusion

The materials of the reactor containment pressure boundary under the conditions of operation, maintenance testing, and a postulated accident will not fail in brittle fracture and the probability of a rapidly propagating fracture is minimized.

DEFINITIONS

General Design Criteria 51

The reactor containment pressure boundary shall be designed with sufficient margin to assure that under operating, maintenance, testing and postulated accident conditions (1), its ferritic materials behave in a non-brittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures and other conditions of the containment boundary material during operation, maintenance, testing and postulated accident conditions, and the uncertainties in determining (1) material properties, (2) residual, steady state and transient stresses, and (3) size of flaws.

Reactor Containment Pressure Boundary

The reactor containment pressure boundary as addressed in the NRC licensing review process, consists of those ferritic steel parts of the reactor containment system which sustain loading and provide a pressure boundary in the performance of the containment function under the operating, maintenance, testing and postulated accident conditions. These include equipment hatches, personnel airlocks, drywell head, containment penetration sleeves, process pipes, end closure caps, flued heads and penetrating-piping systems connecting penetration process pipes extending to and including the system outboard isolation valves.

Lowest Service Metal Temperature (LSMT)

The lowest service metal temperature (LSMT) is defined as the minimum temperature of the fluid or metal whenever the component must perform its pressure retaining function under operating, maintenance, testing, and postulated accident conditions.

Permissible Lowest Service Metal Temperature (PLSMT)

The permissible lowest service metal temperature (PLSMT) as defined by the ASME Code Section III NC-2311, is the sum of the temperature (T_{NDT}) and the value of A which is equal to or less than $(LSMT - T_{NDT})$ as shown in Figure NC-2311(A)-1 corresponding to the thickness of the material. To insure fracture toughness, the PLSMT of the limiting ferritic steel components of the reactor containment pressure boundary must be less than or equal to the LSMT under operating, maintenance, testing and postulated accident conditions.

SUMMARY
TABLE 1

| Limiting Item* | Part | MTL | Thickness (in) | | PLSMT* (°F) | Limiting Condition | LMST (°F) | Remarks |
|------------------------------|---------------------------|-----------------------------|-------------------|--------------|----------------------------|------------------------|--------------|--|
| Main Steam | | | | | | | | |
| Flued Hd. MSIV | X-7A(Typ) F028(Typ) | SA350 Gr. LF2 | 5.0 (Axial) | | 27°F | Maint. & Test | 120°F | The reactor, MSIV's, flued head, and piping water hydrotested at 120°F. |
| Body | | SA216WCB | 4.25 | | 85°F | " | " | |
| Cover | | SA105 Gr II | 4.25 | | 45°F | " | " | |
| Poppet | | SA105 Gr II | 5.88 | | 55°F | " | " | |
| Feedwater | | | Min. Req. Thk | Actual Thk | (Using Min. Req.Thk) | | | PLSMT based upon material thickness re- quired to per- form its pres- sure retaining function. |
| Flued Hd. Isolation Valve | X-9A/B(Typ) F074A(Typ) | SA350 Gr LF2 | <2.5 | 8.00 (Axial) | 25°F | Postulated Accident | 42°F | |
| Body# | | SA352 Gr LCB | 1.18 | 2.31 | 30°F | " | " | |
| Cover | | SA350 Gr LF2 | 2.75 | 5.00 | 30°F | " | " | |
| Disc**** | | SA352 Gr LCB | 2.78 | 3.75 | NA | NA | NA | |
| Flued Heads (Gen) | X-8(Typ) | SA350 Gr LF2 SA105 Gr II | 3.00 | | 2°F | Postulated Accident | 65°F | |
| Sleeves | | | | | | | | |
| Feedwater*** | X-9A/B(Typ) | SA516 Gr. 60 | 1.50 (wall) | | 30°F | " | " | |
| Steam to HPCI | Pen X-11 | SA333 Gr. 6 | 0.81 | | **65°F | " | " | |
| Spare Pen & Pipe Caps | X-15(Typ) | SA420 WPL1 | 1.16 | | **65°F | " | " | |
| Equip. Hatch | 69-3 Door/barrel Assy. | SA516 Gr 60 | 3.00 | | 30°F | Maint. & Testing | 65°F | Postulated loss of re- actor enclo- sure air sup- ply and heat- ing system |
| | 70-7 (Door Assy) | SA516 Gr 60 | 1.00 | | 30°F | " | " | |
| Personnel Air Locks | 162-1 | SA516 Gr 70 | 3.00 | | 30°F | " | " | |

NOTES: * Defined by the NRC.

** Use Lowest Metal Service Temp. (LMST)

*** Categorized by the NRC as a Sleeve.

**** Disc does not have a pressure retaining function under limiting condition.

For evaluation of PLSMT see report submitted by letter, J. S. Kemper (PECo)
to A. Schwencer (NRC), dated 5/25/84.

ATTACHMENT
2 : Index for Attached CMTRs (Sh 1/2)

| <u>Limiting Item - Part</u> | | <u>MHI Heat No</u> |
|-----------------------------|-----------------------------|--|
| Main Steam Penetrations | X-7A 7B 7C 7D | 44736 - 8 ↓ - 6 - 6 - 8 <div> <div>FLUED HEAD</div> <div>(TYP.) HEAT No:</div> <div>2L2574</div> </div> |
| Feedwater Penetration | x-9A x-9B | B3596 ↓ <div> <div>(flued heads)</div> <div>No: K-5073</div> </div> |
| Penetration (Gen) | X-8 X-11 X-15 | 68328 (flued head heat No. is 326N077) N31420 X5996 |
| Equip Hatch | 69-3 70-7 | 66B094 67A756 |
| Airlock | 162-1 | C8676 |
| Feedwater Isolation Valve | 1F074A/B | |
| Body | ↓ | F6137/F6152 |
| Cover | | 213643/213643 |
| Disc | | F6589/F6589 |

INDEX FOR ATTACHED CMTRS (SH 2/2)

LIMITING ITEM — PART

MATERIAL HEAT NO.

MAIN STEAM

ISOLATION VALVE — IF028A (TYP.)

BODY

8816

COVER

219222

POPPET

219727

Penetration X-7A
7B
7C
7D

Heat No: U4736-8
↓ -6
-6
-8

MATERIAL HEAT NUMBER SHEET

Material Types:

1. Welded Assemblies
2. Non-Welded Code Matl.
3. Non Code Matl.

SHIPMENT # 60 UNIT # 1

Q-2-F 1100-1

| Piece-Mark | Serial No. | STR REF. NO. | Material Heat No. | Matl. Type | Piece-Mark | Serial No. | STR REF. NO. | Material Heat No. | Matl. Type |
|----------------------|------------|--------------|--------------------|------------|------------|------------|--------------|-------------------|------------|
| (1) | | | 312-A ~ INERT ASSY | | | | | 4 ~ CONCRETE | |
| (1) 313-2 | -1- | 211 | B3666 | 1 1 | | | | ANCHORAGE ASSY | |
| (1) 313-2 | - | 131 | 51622431 | A36 3 | (4) 76-7 | - | 90 | 68B423 | A36 3 |
| (2) 313-4 | -2- | 80 | U4736 | 8 1 | (16) 76-12 | - | 85 | 72B418 | A36 3 |
| (3) 313-4 | - | 131 | 51622431 | A36 3 | (4) 76-12 | - | 85 | 70B182 | A36 3 |
| (2) 313-5 | - | 131 | 51622431 | A36 3 | (2) 316-3 | -1- | 116 | 6610579 | A36 3 |
| (1) 313-6 | - | 131 | 51622431 | A36 3 | (2) 316-4 | -1- | 116 | 6610579 | A36 3 |
| (1) 315-7 | - | 374 | 9059 | A36 3 | (2) 316-5 | -1- | 116 | 6610579 | A36 3 |
| (15) 313-8 | - | 114 | 51622545 | A36 3 | (2) 316-6 | -1- | 116 | 6610579 | A36 3 |
| (15) 313-9 | - | 114 | 51622545 | A36 3 | (2) 315-2 | -1- | 96 | U4736 | 6 1 |
| (2) 314-2 | -2- | 80 | U4736 | 8 1 | | | | | |
| (2) 315-1 | -1- | 96 | U4736 | 6 1 | | | | | |
| (16) 314-12 | - | 53 | 74B232 | A36 3 | | | | | |
| (8) 314-3 | - | 53 | 74B232 | A36 3 | | | | | |
| (16) 314-4 | - | 53 | 74B232 | A36 3 | | | | | |
| (2) 314-6 | - | 53 | 74B232 | A36 3 | | | | | |
| (2) 314-7 | - | 53 | 74B232 | A36 3 | | | | | |
| (2) 314-8 | - | 53 | 74B232 | A36 3 | | | | | |
| (2) 314-9 | - | 53 | 74B232 | A36 3 | | | | | |
| (2) 314-10 | - | 53 | 74B232 | A36 3 | | | | | |
| (4) 314-11 | - | - | L2424816 | A36 3 | | | | | |
| (2) 315-2 | - | 53 | 74B232 | A36 3 | | | | | |
| (2) 315-3 | - | 53 | 74B232 | A36 3 | | | | | |
| (2) 315-4 | - | 53 | 74B232 | A36 3 | | | | | |
| (2) 315-5 | - | 53 | 74B232 | A36 3 | | | | | |
| (2) 315-6 | - | 53 | 74B232 | A36 3 | | | | | |
| (2) 315-7 | - | 53 | 74B232 | A36 3 | | | | | |
| (2) 316-1 | -1- | 128 | 47903711 | A36 3 | | | | | |
| (2) 316-2 | -1- | 128 | 47903711 | A36 3 | | | | | |
| (4) 316-7 | -1- | 85 | 72B418 | A36 3 | | | | | |
| (4) 76-7 | -1- | 128 | 47903711 | A36 3 | | | | | |
| (12) 76-7 | - | 85 | 72B418 | A36 3 | | | | | |

LIMERICK GENERATING STATION, UNIT 1
PHILADELPHIA ELECTRIC COMPANY
SPEC. 8091-C-2
CBI 70-7198

*Don't
Bother
3*

Data taken from applicable CBI records.

CBI Shop QA *10-11-75*

Date *3-1-75*

Revisions

By

Chkd

Date

10005

Reviewed (for material covered by code):

Authorized Inspector:

Date

4-7-75

Contract No.

70-7198

No. *60*

Sh. *1* of *1*

PURCHASER: **08**
Chicago Bridge & Iron Co.
6 Pur. Dept.

LUKENS STEEL COMPANY

COATESVILLE, PA. 19320

TEST CERTIFICATE

DATE: **6-3-71**
CONSIGNEE:

FILE NO: **1540-03-05**

MILL ORDER NO.

CUSTOMER P.O.

50018-3

70-7198U-23

RG 6171 LK

SPECIFICATIONS:

SA-516 Gr. 60 CB & I MS-603B Rev. 0 DTD 3/9/70 Sect. 111 Winter 68 Addenda CB & I GP3 516
Rev. 4 DTD 2/25/70

BEND TEST

O.K. HOMOGENEITY TEST

CHEMICAL ANALYSIS

| MELT NO. | C | Mn | P | S | Cu | Si | Ni | Cr | Mo | V | Ti | Al | B | Grain Size |
|---|----|------|-----|-----|----|----|----|----|----|---|----|----|---|---------------|
| U4736 | 14 | 1.02 | 012 | 028 | | 29 | | | | | | | | 7 - 8 |
| LIMERICK GENERATING STATION, UNIT 1 PHILADELPHIA ELECTRIC COMPANY SPEC. 8031-C-2 CBI 70-7198 | | | | | | | | | | | | | | |
| Affirmed and subscribed before me this day of JUN 3 1971 <i>Phillip A. Romandino Jr.</i> | | | | | | | | | | | | | | Notary Public |

PHYSICAL PROPERTIES

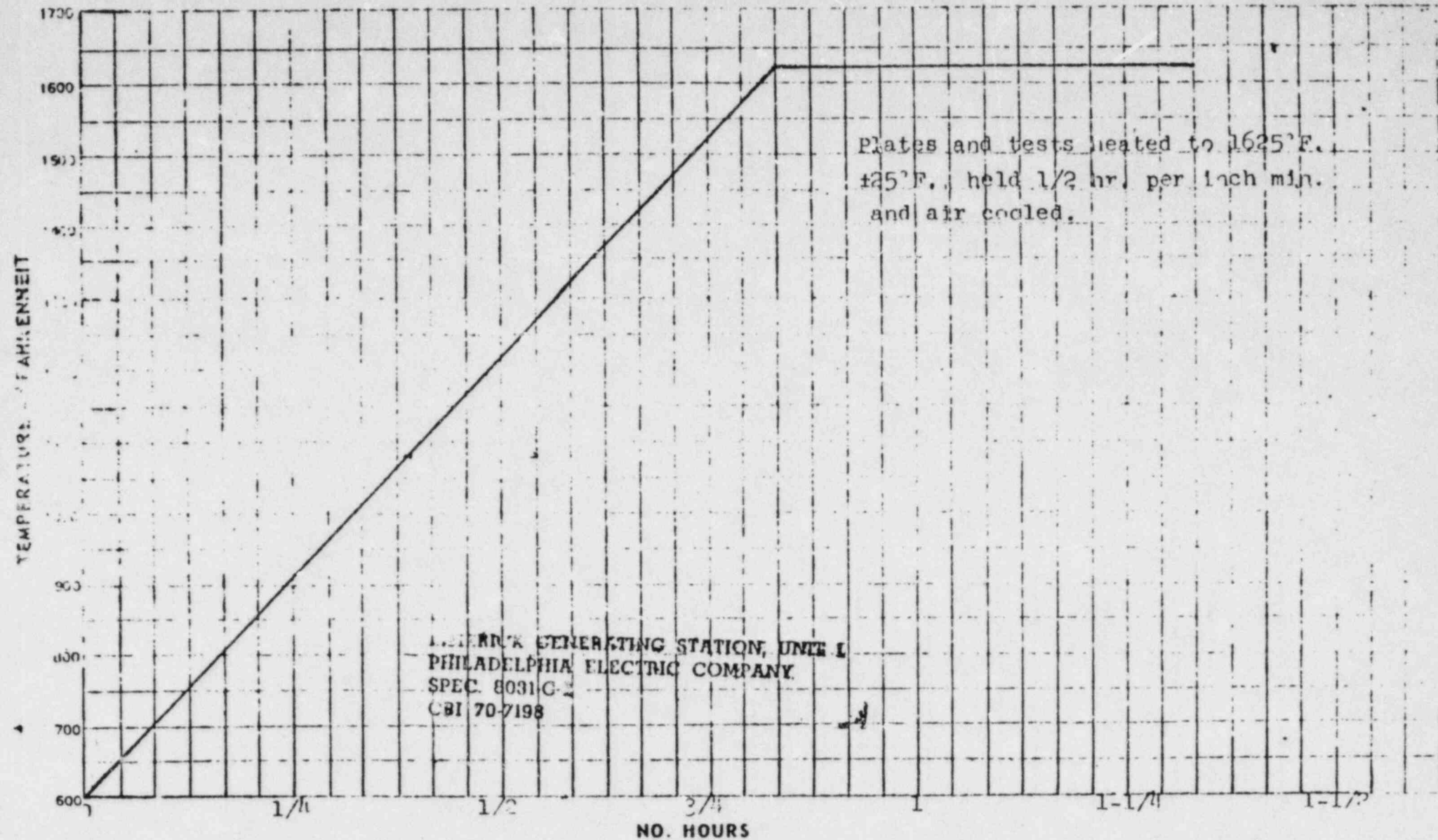
| MELT NO. | SLAB NO. | YIELD PSI X100 | TENSILE PSI X100 | % ELONG IN | % R.A. | BHN | Long. IMPACTS V-Notch -30°F. | Fracture Appearance % Shear | My Commission Expires April 1, 1972 DESCRIPTION |
|---|----------|----------------|------------------|------------|--------|-----|------------------------------|-----------------------------|---|
| U4736 | 8 | 505 | 709 | 29 | | | 63 - 56 - 63 | 50-50-50 | 1-280 x 129-3/4 x 1" |
| Lateral Expansion in Inches | | | | | | | .054 .058 .056 | | |
| " | 7 | 477 | 713 | 28 | | | 66 - 58 - 55 | 50-50-50 | 1-322 x 129-3/4 x 1" |
| Lateral Expansion in Inches | | | | | | | .047 .050 .059 | | |
| Plates and tests heated to 1625°F. ±25°F., held 1/2 hr. per inch min. and air cooled. | | | | | | | | | |
| We hereby certify that the above material has been manufactured according to SA-516 Gr. 60 CB & I MS-603B Rev. 0 DTD 3/9/70 Sect. 111 Winter 68 Addenda CB & I GP3 516 Rev. 4 DTD 2/25/70 and that we have complied with all the requirements of these specifications. | | | | | | | | | |

We hereby certify the above figures are correct as contained in the record of Lukens Steel Company

SUPERVISOR TESTING

08

LUKENS STEEL COMPANY
COATESVILLE, PA.



Order # 50012-3 Contract _____ Furnace 200' Date 5-9-71

Heat No. 04736-7 Original Charts are available for customer verification

- 8

H. J. Klein 80

80000

MAIN STEAM PENETRATION X-7A

FLUED HEAD (TYP.)

HEAT NO. 2L2574



NATIONAL FORGE COMPANY

TEST CERTIFICATION

Limerick Flued Head

CUSTOMER: The M. W. Kellogg Company

NATIONAL FORGE CO. ORDER: 60-4875

CUSTOMER ORDER NO.: N-8774-11

SPECIFICATION: ASME-SA 350-LF2, ES-11 and
ES-151, Addendum "A"

ITEM-SERIAL NO.

DESCRIPTION:

G.E. Spec. 21-A-1556 & 21-A-9416

and ASME Code, Section III, NE2310 and NE2321

02-001

42" OD Flued Head Fittings

N42

Drawing 131-C-7525-2, Rev. 2, Part No. 2-EE

MARK: Item 15

| ITEM-SERIAL | HEAT NO. | C. | Mn. | P. | S. | Si. | Ni. | Cr. | Mo. | V. |
|-------------|----------|-----|------|------|------|-----|-----|-----|-----|-----|
| 02-001 | 2L2574 | .23 | 1.03 | .014 | .014 | .23 | | | | .04 |

| TEST | ULTIMATE TENSILE STRENGTH (P.S.I.) | YIELD PT (P.S.I.) | % ELONGATION | % REDUCTION OF AREA | MAXIMUM % Shear | Charpy IMPACT (FT-LBS.) @ 0°F | Lat. Exp. |
|--|--|-------------------------|-----------------|------------------------------|-------------------------------|--|----------------------|
| 02-001 | 84,250 | 72,000 | 32.0 | 72.3 | 59% 57% 63% | 109.0 95.0 113.0 | .078 .070 .081 |
| QUENCHED @ TEMPERED @ GRAIN SIZE FREE OF MERCURY CONTAMINATION ROUND FLUTED INGOT MOLD TENSILE SPEC. 505 TESTED LONGITUDINAL GAGE LENGTH 2" | 1580°F for 6 hrs. in water 1220°F for 6 hrs. 8-9 | | | | | | |

M. W. KELLOGG CO.
M.T.R. APPRO'D
J/M DATE 4/9/73

HEAT TREAT PROCEDURE HT-60-A-4875-OA 10/27/72
IMPACT PROCEDURE LT-60-A-4875-OA, Rev. A 1/22/73

State of Pennsylvania }
Warren County } ss:

Before me, a Notary Public in and for above County, personally appeared N. C. Baxter, Jr.
of the National Forge Company, who being duly Sworn according to Law, deposes and says that the above Report is a true and
correct copy of tests as contained in the records of the Company.

Subscribed and Sworn to
14th March 73
at its day of 19.

Kathleen J. Harvey
My Commission expires.....

Embossed Hereon is My
Irvine, Warren County, Pennsylvania, Notary Public
My Comm.....



1/12/73

FW Fined Head
Penetration X-9A/B

Heat No. B3596

GO 810 REV DEC

PURCHASER:

E71
 Chicago Bridge & Iron Co.
 Pur. Dept.

LUKENS STEEL COMPANY

COATESVILLE, PA. 19320

TEST CERTIFICATE

DATE: 9-23-71

FILE NO 1540-03-06

CONSIGNEE:

MILL ORDER NO.

CUSTOMER P.O.

52474-2

71-7198U-40

RG 91571 DR

SPECIFICATIONS:

MS-603-B Rev. 0 DTD 3/9/70 SA-516-69 Gr. 60 Sect. III thru Winter 1968 Addenda

BEND TEST

O.K.

HOMOGENEITY TEST

CHEMICAL ANALYSIS

| MELT NO. | C | Mn | P | S | Cu | Si | Ni | Cr | Mo | V | Ti | Al | B | Grain Size |
|---|----|----|-----|-----|----|----|----|----|----|---|----|----|---|------------|
| 596 | 12 | 95 | 006 | 020 | | 22 | | | | | | | | 7-8 |
| LIMERICK GENERATING STATION, UNIT 1 PHILADELPHIA ELECTRIC COMPANY SPEC. 8031-C-2 CBI 70-7198 | | | | | | | | | | | | | | |

PHYSICAL PROPERTIES

| MELT NO. | SLAB NO. | YIELD PSI X100 | TENSILE PSI X100 | % ELONG. IN 8" | % R.A. | BHN | Long. IMPACTS V-Notch -30°F. | Fracture Appearance % Shear | DESCRIPTION |
|--|----------|----------------------|------------------------|-------------------|--------|-----|---------------------------------|-----------------------------------|----------------------|
| 3596 | 9 | 436 | 668 | 33 | | | 58 87 49 | 60-60-60 | 1-256 x 128 x 1-1/2" |
| Lateral Expansion in inches | | | | | | | .074 .053 .056 | | |
| " | 8 | 441 | 643 | 34 | | | 97 98 67 | 70-70-70 | 1- |
| Lateral Expansion in inches | | | | | | | .073 .075 .059 | | |
| plates and tests heated 1550-1650°F., held 1/2 hr. per inch min. and air cooled. | | | | | | | | | |
| Notary Public My Commission Expires April 1, 1972 SEP 23 1971 Philip A. Romandine | | | | | | | | | |

SUPERVISOR TESTING

figures are correct as contained in the records of the company.

Feedwater
Penetration X-9A

Find head

Heat No. K-5073

Cameron

IRON WORKS, INC.

P. O. BOX 1212 HOUSTON, TEXAS 77001

CERTIFICATE OF TESTS

Date 10 September 1975

S
O
L
D
T
O

SARGENT INDUSTRIES
AIRITE DIVISION
1700 East Grand Avenue
El Segundo, Ca 90245

S
H
I
P

T
O

Customer Order No.

C.I.W. Sales Order No.

N5035

F-12979

Specification

Carbon Steel in accordance with ASME Sec. II SA-350
ASME Sec. III Class 1 Component, except
as modified by P.O.

Description
of
Material

Fluidd Head Dwg. # 9256-13 N/C

CHEMICAL ANALYSIS

C.I.W. Part Number

Heat No.

C

MN

P

S

SI

CR

NI

MO

W

V

CU

60607-1

.20 1.23 .015 .012 .23

MECHANICAL PROPERTIES

C.I.W. Part No. or Size

Quantity

Heat No.

Yield
PSI

Tensile
PSI

% Elong.
in.

% Red.
Area

Charpy
Impact

Hard-
ness

60607-1

4

K 5073

See attachment for mechanical properties.

Code requirements for U.T. and P.T. not performed.

Bechtel Corp.
M. Schupp
9-22-75

C.I.W. Heat No.

Jominy Hardenability

Grain Size

Heat treat performed in accordance with approved CIW procedure FH-414 Rev. B.
1550°F., held 6 hrs. at temp. Air cooled.

VENDOR DOC. REVIEW GRP.

P 126A E 188 1

REVIEW
QUALITY CONTROL

AP
28
DC

STAMP

Subscribed and Sworn to before me this
10th Day of September 1975

MATERIAL CODE

No. 418

H. O. WRICHT, Metallurgist

Notary Public
G. A. TOUCHTON

Notary Public in and for Harris County, Texas

My Commission Expires June 1, 1976

CAMERON 488-1 H.C.U. 3/75

33

MECHANICAL PROPERTIES:

| Forging Ser.# | Heat# | .2% Offset Y.S. psi | Ult. T.S. psi | Elong. % | R.A. % |
|------------------|-------|------------------------|------------------|-------------|-----------|
|------------------|-------|------------------------|------------------|-------------|-----------|

Impact test performed in accordance with approved CIW
Inspection procedure FI-77 N/C
Test Temp. ~~Recorded Energy~~ ~~Transition~~ ~~Fracture~~ ~~Temp~~

0001 K 5073

| Test Temp. | Recorded Energy | Transition | Fracture | Temp |
|------------|-----------------|------------|----------|------|
| +32°F. | 138.0 Ft.Lbs. | .084 | 100% | 4 |
| 32 | 92.0 | .072 | 60 | |
| 32 | 104.0 | .072 | 80 | |
| 32 | 140.0 | .090 | 99 | |
| 32 | 140.0 | .084 | 100 | |
| 32 | 136.0 | .086 | 100 | |

0002 K 5073

| Test Temp. | Recorded Energy | Transition | Fracture | Temp |
|------------|-----------------|------------|----------|------|
| +32°F. | 147.0 | .089 | 100% | 4 |
| 32 | 134.0 | .085 | 100 | |
| 32 | 101.0 | .071 | 80 | |
| 32 | 100.0 | .071 | 80 | |
| 32 | 114.0 | .075 | 80 | |
| 32 | 121.5 | .079 | 80 | |

0003 K 5073

| Test Temp. | Recorded Energy | Transition | Fracture | Temp |
|------------|-----------------|------------|----------|------|
| +32°F. | 144.0 | .090 | 100% | 4 |
| 32 | 143.0 | .094 | 100 | |
| 32 | 114.0 | .081 | 70 | |
| 32 | 97.0 | .082 | 70 | |
| 32 | 102.0 | .085 | 80 | |
| 32 | 126.0 | .093 | 99 | |

0004 K 5073

52,400

76,100

30.8

70.4

| Test Temp. | Recorded Energy | Transition | Fracture | Temp |
|------------|-----------------|------------|----------|------|
| +32°F. | 102.0 | .075 | 80 | 4 |
| 32 | 154.0 | .085 | 100 | |
| 32 | 108.0 | .076 | 80 | |
| 32 | 146.0 | .088 | 100 | |
| 32 | 109.0 | .080 | 80 | |
| 32 | 138.0 | .079 | 99 | |

126A F 188.1
VENDOR DOC. REVIEW GRP.

MRR-8031-SF-1325

MATERIAL CODE

No. 418

REVIEW
QUALITY CONTROL

AP
26
OC

STAMP

9/15/75

Bechtel Corp.

M. Z. Phillips

9-22-75

FW penetration X-9B
finned head

Heat No. K-5073

Casper

IRON WORKS, INC.

P. O. BOX 1212 HOUSTON, TEXAS 77001

CERTIFICATE OF TESTS

Date 10 September 1975

S
O
L
D
T
O

SARGENT INDUSTRIES
AIRITE DIVISION
1700 East Grand Avenue
El Segundo, Ca 90245

S
H
I
P
T
O

Customer Order No.

C.I.W. Sales Order No.

15035

F-12979

Specification
Carbon Steel in accordance with ASME Sec. II SA-312
LF 2, ASME Sec. III 1974 Class I Component, except
as modified by P.O.

Description
of
Material

Fluid Head Dwg. # 9256-13 N/C

C.I.W. Part Number

Heat No.

CHEMICAL ANALYSIS

C MN P S SI CR NI MO W V CU

60607-1

K 5073

.20 1.23 .015 .012 .23

C.I.W. Part No. or Size

Quantity

Heat No.

Yield
PSI

MECHANICAL PROPERTIES
Tensile
PSI

% Elong.
In.

% Red.
Area

Charpy
Impact

Hard-
ness

60607-1

4

K 5073

See attachment for mechanical properties.

Code requirements for U.T. and P.T. not performed.

*Bechtel Corp.
M. R. Phillips
9-12-75*

C.I.W. Heat No.

Jominy Hardenability

Grain Size

Heat treat performed in accordance with approved CIW procedure FH-414 Rev. B.
1550°F., held 6 hrs. at temp. Air cooled.

REVIEW
QUALITY CONTROL

AP
28
QC

STAMP

MATERIAL CODE

No.

418

H. O. WRIGHT

1st

Notary Public in and for Harris County, Texas
My Commission Expires June 3, 1977

P. 125 A F 175 1 33

10 Sept. 1975

MECHANICAL PROPERTIES:

| | | | | | | Impact test performed in accordance with approved CIW Inspection procedure FI-77 N/C | | | | Tensile Test |
|-------------------|--------|------------------------|------------------|-------------|-----------|---|-----------------|----------------|-------|-----------------|
| Forging Ser. # | Heat # | .2% Offset Y.S. psi | Ult. T.S. psi | Elong. % | R.A. % | Test Temp. | Absorbed Energy | Lat. Expansion | Shear | Fracture |
| 0001 | K 5073 | | | | | +32°F. | 138.0 Ft.Lbs. | .084 | | #4 |
| | | | | | | 32 | 92.0 | .072 | | 60 |
| | | | | | | 32 | 104.0 | .072 | | 80 |
| | | | | | | 32 | 140.0 | .090 | | 99 |
| | | | | | | 32 | 140.0 | .084 | | 100 |
| | | | | | | 32 | 136.0 | .086 | | 100 |
| 0002 | K 5073 | | | | | +32°F. | 147.0 | .089 | | 100% |
| | | | | | | 32 | 134.0 | .085 | | 100 |
| | | | | | | 32 | 101.0 | .071 | | 80 |
| | | | | | | 32 | 100.0 | .071 | | 80 |
| | | | | | | 32 | 114.0 | .075 | | 80 |
| | | | | | | 32 | 121.5 | .079 | | 80 |
| 0003 | K 5073 | | | | | +32°F. | 144.0 | .090 | | 100% |
| | | | | | | 32 | 143.0 | .094 | | 100 |
| | | | | | | 32 | 114.0 | .081 | | 70 |
| | | | | | | 32 | 97.0 | .082 | | 70 |
| | | | | | | 32 | 102.0 | .083 | | 80 |
| | | | | | | 32 | 126.0 | .093 | | 99 |
| 0004 | K 5073 | 52,400 | 76,100 | 30.8 | 70.4 | +32°F. | 102.0 | .075 | | 80 |
| | | | | | | 32 | 154.0 | .085 | | 100 |
| | | | | | | 32 | 108.0 | .076 | | 80 |
| | | | | | | 32 | 146.0 | .088 | | 100 |
| | | | | | | 32 | 109.0 | .080 | | 80 |
| | | | | | | 32 | 138.0 | .079 | | 99 |

0004

K 5073

52,400

76,100

30.8

70.4

+32°F.

102.0

.075

80

4

32

154.0

.085

100

32

108.0

.076

80

32

146.0

.088

100

32

109.0

.080

80

32

138.0

.079

99

MATERIAL CODE

No.

418

REVIEW
QUALITY CONTROLAP
26
OC

STAMP

9/15/75

Bechtel Corp.
M. Z. Phillips
9-22-75

Find Head (Gen): X-8

heat No 326N077

CARLTON FORGE WORKS

7743 EAST ADAMS STREET
PARAMOUNT, CALIFORNIA

METALLURGICAL ANALYSIS REPORT

DATE
6-5-75

CUSTOMER

Sargent-Airite Div.

CUSTOMER ORDER NO.

N5058 Item #

C.F.W. S.O. NO.
134463QUANTITY
6 & T.S.

SPECIFICATIONS

ASME-SA-105-73, Sect. II, 1974 *

PART NO.

9256-11 N/C

PART NAME OR DESCRIPTION

Not performed, to be performed by SI/AD

Not performed, to be performed by SI/AD

CONDITION OF FORGINGS

Normalize 1650 F., 2hrs., air cool, Quench
1500 F., 2hrs., oil cool, Temper 1200 F.,
6hrs., air cool per NP-AS-004 N/C ***HARDNESS
OF FORGINGS
BHN
137/156Forgings fluorescent penetrant inspected per
Forgings magnetic particle inspected per
Forgings ultrasonic inspected per
Forgings radiographically inspected perMechanical property acceptance of listed forgings are based on results from:
Separately forged test bar
Heat treat response test barX per lot
per heat
per forgingX Sectioned forgings or rolled ring
Integral test ring or slug

which conforms to material specifications listed above and are regulated below:

MILL Bethlehem Steel
HEAT NO. 325N077

CHEMICAL ANALYSIS

| | C | Mn | P | S | Si | Ca | Ni | Fe | Al | TI | Cb & Ta | Cu | B | Co | Mg | Zn | N | H | O |
|-----------|-----|-----|------|------|-----|----|----|-----|----|----|---------|----|----|----|----|----|---|---|---|
| | | | | | | | | | | | | W | Sn | V | Zr | Mo | | | |
| MILL DATA | .29 | .80 | .026 | .030 | .20 | | | Bal | | | | | | | | | | | |

TENSILE

STRESS RUPTURE

GRAIN SIZE

| SERIAL NO. | CODE | TEST | | YIELD KSI 2 OFF. KSI | ULTIMATE KSI | % ELONG. IN 40 | % RED OF AREA | TYPE BAR | STRESS KSI | TEMP. °F | HRS. TO BREAK | % ELONG. IN 40 | INCREASED STRESS TO |
|----------------------|------|----------------------|---------|----------------------------|-----------------|-------------------|------------------|-------------|---------------|-------------|------------------|-------------------|------------------------|
| | | LOCATION & DIRECTION | TEMP. | | | | | | | | | | |
| CFW DATA | | | | | | | | | | | | | |
| #001 thru #015 | | Heavy Thin | R RT | 46.6 45.1 | 75.2 75.7 | 32.0 33.0 | 69.5 71.3 | | | | | | |

Bechtel Corp.
M. P. Phillips
7-1-75

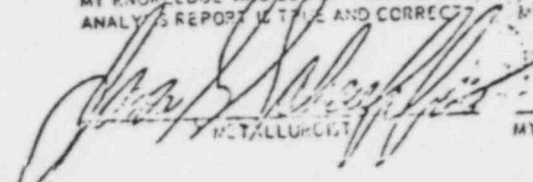
MICROSTRUCTURE:

REVIEW
QUALITY CONTROLAP
29
OC

STAMP 7/1/75

REMARKS: *** @Aircraft Heat Treat
*ASME-Section III, Class I, 1974, Edition.
Contract No. 8031-P-310

| CODE | CLEANLINESS AND PREP. | REV. | JOM. HARD. IN 1/16 OF AN INCH - R "C" - | | | | | | | | | |
|------|-----------------------------|------|---|---|---|---|---|----|----|----|----|--|
| | | | 1 | 2 | 4 | 6 | 8 | 12 | 16 | 22 | 32 | |
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I HEREBY CERTIFY THAT TO THE BEST OF MY KNOWLEDGE AND BELIEF THIS MATERIAL ANALYSIS REPORT IS TRUE AND CORRECT.
SWORN AND SUBSCRIBED TO BEFORE ME THIS 5th DAY OF JUNE 1975


MY COMMISSION EXPIRES

ASME MATERIAL CODE

COPIES OF THIS SPECIFICATION ARE AVAILABLE TO YOU ON YOUR REQUEST. THE SPECIFICATION IS TESTED, INSPECTED AND ACCEPTED IN ACCORDANCE WITH THE APPLICABLE BLUEPRINTS AND SPECIFICATIONS.

0-126AC-F-180-1

3

Penetration X-8

Heat No. 68328

12" S/100 Gr-1

W. B. COLEMAN CO.
METALLURGISTS — CHEMISTS — ENGINEERS
 9TH AND RIDING SUN AVENUE
 PHILADELPHIA, PA. 19140

Physical Test of: Seamless Carbon Steel Pipe Date 10/7/69

Received from: Capitol Pipe & Steel Prods., Inc.

P. O. No. W 44047

Q. 1-1105-1
 G-40295-2
 70-71924
 ITEMS 12 & 13

| | | | | |
|-----------------------------------|--|---------|---------|-------------|
| Laboratory Number | 906604 | | | |
| MARKING | 12" Sch. 100 | A-333 | Gr. 1 | |
| Ht. #68328- | 1 | 2 | 3 | |
| Size of Bar 10mm | 0.394 | 0.394 | 0.394 | |
| Linear Inch 10mm x | 0.394 x | 0.394 x | 0.394 x | |
| Tensile Strength | | | | |
| Linear Inch | | | | |
| Transverse Load | | | | |
| Lbs. Corrected (In. Centers) | | | | |
| Deflection | | | | |
| Inches - Corrected | | | | |
| Impacts Charpy | | | | |
| Notch Charpy | | | | |
| Broken at Minus 50 ° F | | | | |
| Resistance to Impact | | | | Avg. impact |
| In Ft. Lbs. | | | | value |
| Brinell Hardness | 36.0 | 29.0 | 37.0 | 34.0 |
| 500 3000 Kg. Load | | | | |
| Rockwell Hardness | Minimum average impact value required | | | |
| Standard | of a set of three specimens-15.0ft.lb. | | | |
| Superficial | Minimum impact value permitted on one | | | |
| Scale | specimen only of a set-10.0ft. lb. | | | |
| Equivalent to | | | | |
| Brinell | | | | |
| Rockwell | | | | |
| Witnessed by | | | | |
| % Shear | 30.0 | 30.0 | 30.0 | |
| Lateral Expansion | | | | |
| (in inches) | 0.0345 | 0.026 | 0.033 | |

Remarks:

W. B. COLEMAN CO.

BY 

FORM 29 REV. 5-57 F. P.

LIMERICK GENERATING STATION, UNIT 1
 PHILADELPHIA ELECTRIC COMPANY
 SPEC. 8031-C-2
 CBI 70-7198

66

R27M 6-7-71

26

Penetration X-11

MTI Heat No. N31420

5C-57

MATERIAL HEAT NUMBER SHEET

Material Types:

1. Welded Assemblies
2. Non-Welded Code Matl.
3. Non Code Matl.

SHIPMENT #56 UNIT #1

| Piece-Mark | Serial No. | | Material Heat No. | Metal Type | Piece-Mark | Serial No. | - | Material Heat No. | Metal Type |
|------------|------------|-----|-----------------------------------|------------|------------|------------|-----|-------------------------------------|------------|
| (1) | | | DRYWELL INSERT | | (1) | | | PENETRATION SUB | |
| | | | ASSY 44-A | | | | | ASSY 44-E | |
| | | | (1) PENETRATION SUB | | (1) 44-9 | 1 | 348 | ✓ 29199 G53021 | 1 |
| | | | ASSY 44-B | | (1) 44-10 | - | 46 | ✓ 66B204 A36 | 3 |
| (1) 44-1 | 1 | 95 | ✓ U4716 7AD | 1 | (4) 43-3 | - | 311 | ✓ 516J0615 A36 | 3 |
| (1) 44-2 | - | 46 | ✓ 66B204 A36 | 3 | (1) 24-20 | - | - | BHR TEMP A36 | 3 |
| (4) 43-3 | - | 311 | ✓ 516J0615 A36 | 3 | (1) 24-21 | - | - | R. TEMP A36 | 3 |
| (4) 2432 | - | 153 | ✓ 526C0060 A36 | 3 | | | | (1) INS RESTRAINT PR.77 | |
| | | | (2) PENETRATION SUB | | (2) 94-1 | 1 | 87 | ✓ 68B414 A441 | 3 |
| | | | ASSY 44-C | | (2) 94-2 | 1 | 84 | ✓ 74B405 A441 | 3 |
| (2) 44-5 | - | 46 | ✓ 66B204 A36 | 3 | (2) 94-3 | 1 | 87 | ✓ 68B414 A441 | 3 |
| (2) 24-22 | - | - | P.W.C. CAP ^{TEMP} ALN=MC | 3 | (4) 94-4 | 1 | 86 | ✓ 69B390 A441 | ? |
| (2) 44-4 | -1- | 60 | ✓ 65358 G40295-1 | 1 | (4) 94-5 | 1 | 89 | ✓ 67B431 A36 | 3 |
| (2) 44-8 | - | 274 | ALNR ^{ML-1053} G-70161 | 1 | (2) 94-6 | 1 | 89 | ↓ ↓ | 3 |
| | | | (1) PENETRATION SUB | | (2) 94-7 | 1 | 86 | ✓ 69B390 A441 | 3 |
| | | | ASSY 44-D | | | | | (1) 49-A~DRYWELL | |
| (1) 24-16 | - | 155 | ✓ 55B272 A36 | 3 | | | | INSERT ASS'Y | |
| (1) 24-17 | - | 63 | ✓ 69B298 A36 | 3 | (1) 49-1 | -1- | 160 | ✓ B3596 2 | 1 |
| (4) 43-7 | - | 53 | ✓ 74B232 A36 | 3 | | | | (1)-PENETRATION | |
| (1) 44-6 | 1 | 147 | ✓ N31420 G40295-2 | 1 | | | | SUB-ASS'Y~47-R | |
| (1) 44-7 | - | 52 | ✓ 74B232 A36 | 3 | (1) 47-10 | -1- | 321 | ✓ N31420 G-42199 | 1 |
| (1) 40-72 | 1 | 179 | A8640 - IB | 1 | (4) 43-7 | - | 53 | ✓ 74B232 A36 | 3 |
| | | | | | (1) 44-7 | - | 52 | ✓ 74B232 A36 | 3 |
| | | | | | (1) 24-16 | - | 155 | ✓ 55B272 A36 | 3 |
| | | | | | (1) 24-17 | - | 63 | ✓ 69B298 A36 | 3 |
| | | | | | | | | LIMERICK GENERATING STATION, UNIT 1 | |
| | | | | | | | | PHILADELPHIA ELECTRIC COMPANY | |
| | | | | | | | | SPEC. 8031-C-2 | |
| | | | | | | | | CRI 70-7198 | |
| | | | | | | | | i. K... 24-75 | |

Data taken from applicable CBI records.

CBI Shop QA Steve H. Deane

Date 2-18-75

Revisions

8v

Chkd

Date _____

00005

Reviewed (for material covered by code):

Authorized Inspector

Date 2/19/75

Contract No.

70-71980

No. 56

Sh / of /



United States Steel Corporation

STANDARD SWORN TEST REPORT

TUBULAR PRODUCTS

20 Mr 00 Mr I

National WORKS
C-2-F-1117

8-16-71 DATE

ITEM: *Seamless pressure pipe*
TREATMENT: *Normalized at 1600°F for 105 min. & air cooled*
NAME: *Capital Pipe & Steel Products Inc.*
CITY AND STATE:

GRADE: *136*
ASTM A-533
ASME SA-333
CUSTOMER'S ORDER NO.: *57256*
U.S. STEEL DESIGN: *KC 346.75*
INVOICE NO.: *356-03600*

| CODE CBI NO. | SIZE O.D. | WALL THICKNESS | HEAT NUMBER | HYDRO. TEST PRESSURE MIN. P.S.I. | MECHANICAL PROPERTIES | | | CHEMICAL ANALYSIS (%) | | | | | | |
|--|--------------|-------------------|---|---|-----------------------------|-------------------------------|------------------|-----------------------|------|------|----|----|----|-------|
| | | | | | YIELD STRENGTH P.S.I. | TENSILE STRENGTH P.S.I. | ELONG. INCHES | C | Mn | P | S | Si | Mo | |
| 7455 | 20" | 8/12 | N31420 | 1800 | 42270 | 68670 | 51.0 | 20.82 | 0.16 | 0.21 | 18 | | | CHECK |
| | | | N31420 | 1800 | 45730 | 68640 | 49.0 | 20.82 | 0.16 | 0.21 | 18 | | | CHECK |
| | | | LIMERICK GENERATING STATION, UNIT 1 PHILADELPHIA ELECTRIC COMPANY SPEC. 8031-C-2 CBI 70-7198 | | | | | 21.25 | 0.12 | 0.24 | 17 | | | TABLE |
| Flattening test: Satisfactory | | | | | | | | | | | | | | |
| FULL SIZE LONGITUDINAL KEYHOLE CHARPY SPECIMEN @ MINUS -50°F | | | | | | | | | | | | | | |
| | | | FT LBS | | 27 | 28 | 26 | | | | | | | |
| | | | 1/2 SHEAR | | 67 | 67 | 65 | | | | | | | |
| | | | LAT. RIP | | 030 | 031 | 029 | | | | | | | |
| FULL SIZE LONGITUDINAL CHARPY V NOTCH IMPACTS @ MINUS -50°F | | | | | | | | | | | | | | |
| | | | FT LBS | | 26 | 28 | 24 | | | | | | | |
| | | | 1/2 SHEAR | | 36 | 38 | 30 | | | | | | | |
| | | | LAT. RIP | | 022 | 027 | 020 | | | | | | | |

Chicago Bridge &
Iron Company
PO# G-40293
Contract#70-7198U

Chicago Bridge &
Iron Company
PO# G-40293
Contract #70-7198U

STATE OF PENNSYLVANIA
COUNTY OF ALLEGHENY
I, *Notary Public*, DO hereby certify that the foregoing is a true and correct copy of the original as the same appears in the records of the company.
COMMISSION EXPIRES

A. F. Lefstrom BEING DULY SWORN ACCORDING TO
LAW, DEPOSES & SAYS THAT THE FIGURES SET FORTH ABOVE ARE COR-
RECT AS CONTAINED IN THE RECORDS OF THE COMPANY.
A. F. Lefstrom *C. F. Lefstrom*
UNITED STATES STEEL CORPORATION

Penetration X-15

Heat No. X5996

MATERIAL. HEAT NUMBER SHEET

Material Types:

1. Welded Assemblies
2. Non-Welded Code Matl.
3. Non Code Matl.

SHIPMENT #37 UNIT #1

C. 2-F 609.

| Piece-Mark | Serial No. | CTR REF | Material Heat No. | Matl. Type | Piece-Mark | Serial No. | CTR REF | Material Heat No. | Matl. Type |
|-------------|------------|---------|------------------------------------|------------|------------|------------|---------|----------------------|------------|
| | | | | | | | | (1) PENETRATION ASSY | |
| | | | DRYWELL INSERT | | | | | 43-C | |
| | | | ASSY 43-A | | (1) 43-6 | - | 52 | 74B232 A36 | 3 |
| | | | | | (4) 43-7 | - | 53 | 74B232 A36 | 3 |
| | | | (1) SUB ASSY SHELL | | (1) 25-1 | - | - | BAR A36 | 3 |
| | | | PL W/STIFFENERS 56-MM | | (1) 25-2 | - | - | PL A36 | 3 |
| (1) 40-67 | -1- | 221 | B3680 1B | 1 | (1) 40-67 | 1 | 52 | 68328 G40295-2 | 1 |
| (1) 56-M-1 | - | 322 | N90857 A36 | 3 | | | | | |
| (1) 56-M-2 | - | 322 | ↓ ↓ | 3 | | | | (8) INS. RESTRAINT | |
| (2) 56-M-2A | - | 322 | N90857 A36 | 3 | | | | ATT. SUB ASSY | |
| (1) 56-2M-1 | - | 301 | B75003 A36 | 3 | | | | 41-A | |
| (1) 56-2M-2 | - | 301 | ↓ ↓ | 3 | (8) 41-1 | - | 79 | 68B414 A441 | 3 |
| (7) 56-2M-3 | - | 114 | 516C2545 A36 | 3 | (16) 41-2 | - | 79 | 68E414 A441 | 3 |
| (7) 56-2M-4 | - | 114 | ↓ ↓ | 3 | (8) 41-3 | - | 79 | 68B414 A441 | 3 |
| | | | | | (16) 41-5 | - | 312 | 69D293 A21397 A36 | 3 |
| | | | (1) PENETRATION SUB | | | | | | |
| | | | ASSY 43-D | | (24) 15-15 | - | 362 | 1174503 • G110261 | 2 |
| (1) 43-9 | 1 | 103 | 102997 G42877 | 1 | | | | | |
| (1) 43-10 | - | 46 | 66B204 A36 | 3 | (2) 93-1 | 1 | 79 | 68B414 A441 | 3 |
| (4) 43-3 | - | 311 | 516C2065 A36 | 3 | (1) 93-2 | 1 | 79 | ↓ ↓ | 3 |
| (1) 24-26 | - | - | 66B204 A36 | 3 | (1) 93-3 | 1 | 46 | 66B204 A36 | 3 |
| | | | | | (1) 93-4 | 1 | 46 | 66B204 A36 | 3 |
| | | | | | (1) 93-5 | 1 | 46 | 66B204 A36 | 3 |
| | | | (1) PENETRATION SUB | | | | | | |
| | | | ASSY 43-B | | (2) 92-1 | 1 | 79 | 67S414 A441 | 3 |
| (1) 43-1 | 1 | 46 | X5996 10 | 1 | (2) 92-2X | 1 | 79 | ↓ ↓ | 3 |
| (1) 43-2 | - | 46 | 66B204 A36 | 3 | (2) 92-3 | 1 | 79 | ↓ ↓ | 3 |
| (4) 43-3 | - | 311 | 516C2065 A36 | 3 | (4) 92-4 | 1 | 46 | 66B204 A36 | 3 |
| (1) 43-4 | - | 259 | TN=1 G10161 | 1 | (4) 92-5 | 1 | 46 | 66B204 A36 | 3 |
| (1) 24-13 | - | - | BLK A36 | 3 | | | | | |
| (1) 24-19 | - | - | PL A36 | 3 | | | | | |
| | | | LIMERICK GENERATING STATION UNIT 1 | | | | | | |
| | | | PHILADELPHIA ELECTRIC COMPANY | | | | | | |
| | | | SPEC. E031-C-2 | | | | | | |
| | | | GBI 70-7198 | | | | | | |

Data taken from applicable CBJ records.

CBI Shop QA

Date 11/23/74

Reviewed (for material covered) by con...

Authorized Inspector

Date 11-2-51

Contract No. _____

No. 37

70-7199 U

Sh 1 of 1

Revisions

8

Chkd

Date _____

$$(8.20)^{\frac{11}{17}}$$

PURCHASER:

66
Chicago Bridge & Iron Co.
Pur. Dept.
Greenville, Pa. 16125

LUKENS STEEL COMPANY

COATESVILLE, PA. 19320

TEST CERTIFICATE

DATE: 6-7-71

FILE NO: 1540-03-05

CONSIGNEE:

MILL ORDER NO.

50018-2

CUSTOMER P.O.

70-7198U-23

DP 6271 LX

C-2-F-609-1

SPECIFICATIONS:

SA-516 Gr. 60 CB & I MS-603B Rev. 0 DTD 3/9/60 Sect. 111 Winter 68 Addenda CB & I GPS 516
Rev. 4 DTD 2/25/70

BEND TEST

C.R. HOMOGENEITY TEST

CHEMICAL ANALYSIS

| MELT NO. | C | Mn | P | S | Cu | Si | Ni | Cr | Mo | V | Ti | Al | B | Grain Size |
|---|----|------|-----|-----|----|----|----|----|----|---|----|----|---|------------|
| U4736 | 14 | 1.02 | 012 | 028 | | 29 | | | | | | | | |
| X5996 | 12 | 1.11 | 010 | 028 | | 23 | | | | | | | | |
| LIMERICK GENERATING STATION, UNIT 1 PHILADELPHIA ELECTRIC COMPANY SPEC. 8031-C-2 CBI 70-7198 | | | | | | | | | | | | | | |

Affirmed and subscribed before me
this day of JUN 7 1971

7 - 8
6 - 7

Phillip A. Romanick Jr.

Notary Public

My Commission Expires April 1, 1972

PHYSICAL PROPERTIES

| MELT NO. | SLAB NO. | YIELD TSI X100 | TENSILE PSI X100 | % ELONG IN 8 | % R.A. | BHN | Long. IMPACTS V-Notch -30°F. | Fracture Appearance | DESCRIPTION |
|----------|----------|----------------|------------------|--------------|--------|-----|--|---------------------|------------------------------------|
| U4736 | 1 | 482 | 714 | 27 | | | 42 39 44 | % Shear 40-40-40 | 1-256 x 115 x 1-1/2" - ITEM 60 |
| | | | | | | | Lateral Expansion in Inches .042 .041 .044 | | ITEM 60 |
| U4736 | 10 | 487 | 718 | 25 | | | 57 69 49 | 50-50-50 | 2-224 x 109-1/4 x 1-1/2" - ITEM 61 |
| | | | | | | | Lateral Expansion in Inches .053 .062 .047 | | |
| X5996 | 10 | 442 | 653 | 32 | | | 111 119 139 | 80-80-80 | 2-240 x 54 x 1-1/4" - ITEM 61A |
| | | | | | | | Lateral Expansion in Inches .094 .097 .091 | | |

RAM 6-10-71

Plates and tests heated 1625°F. ±25°F., held 1/2 hr. per inch min. and air cooled.

We hereby certify that the above material has been manufactured according to SA-516 Gr. 60 CB & I MS-603B Rev. 0 DTD 3/9/70 Sect. 111 Winter 68 Addenda CB & I GPS 516 Rev. 4 DTD 2/25/70 and that we have complied with all the requirements of these specifications.

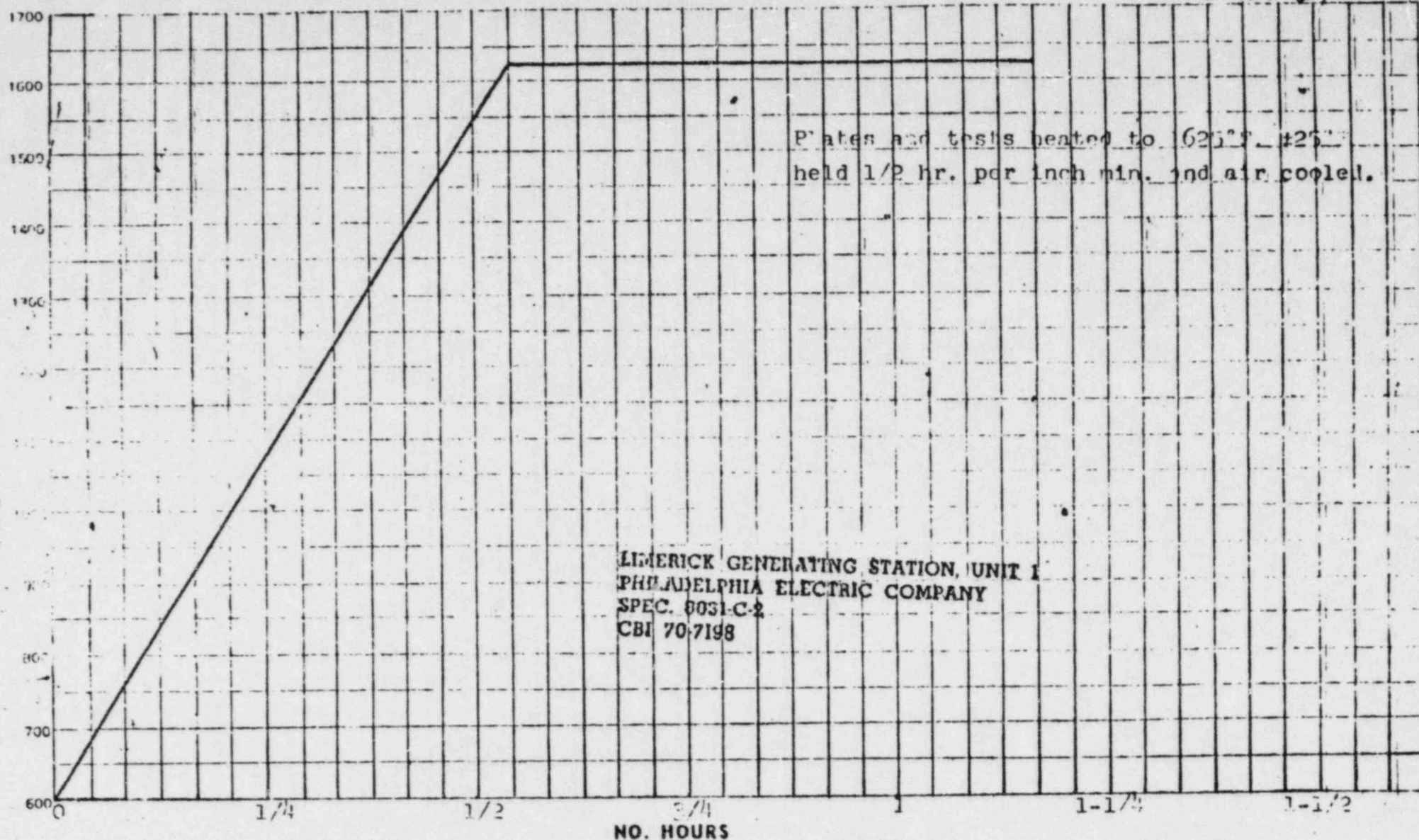
AL H. R. inc

66

LUKENS STEEL COMPANY
COATESVILLE, PA.

JUN 1 1971

C-2-F-69-1



Order # 50018-2 Contract _____ Furnace 200' Date 5-16-71

Heat No. X5996-10 Original Charts are available for customer verification

At St. Line

77

Equipment Hatch 69-3

Heat No. 66B094

Equipment Hatch 70-7

Heat No 67A756

Material Types:

1. Welded Assemblies
2. Non-Welded Code Matl.
3. Non Code Matl.

See Standard 607.37 for instructions
for using this form.

MATERIAL HEAT NUMBER SHEET

SHIPMENT # 75 UNIT # 1

| Piece-Mark | Serial No. | CTR REF No. | Material Heat No. | Matl. Type | Piece-Mark | Serial No. | Material Heat No. | Matl. Type |
|------------|------------|----------------------------|---|------------|------------|------------|-------------------|------------|
| (1) | | | 69-A~EQUIPMENT DOOR NECK & HEAD ASSEMBLY ~ 1 1~EQUIPMENT DOOR PENETRATION NECK SUB- ASSEMBLY ~ 67-B | | | | | |
| (1) 67-4 | - | 275 655H111 | A36 | 3 | | | | |
| (2) 67-5 | - | 275 655H111 | A36 | 3 | | | | |
| (1) 67-9 | - | 275 63576 | 5 | 1 | | | | |
| (1) 67-10 | - | 275 X6003 | 17A | 1 | | | | |
| (1) 67-13 | - | 275 655H111 | A36 | 3 | | | | |
| (1) 69-1 | - | 275 2272 MS-572 | G-21166 | 3 | | | | |
| (1) 69-2 | - | 275 2272 MS-572 | G-21166 | 3 | | | | |
| (1) 69-3 | -1- | 275 663094 | 46253 | 1 | | | | |
| (1) 69-3 | -2- | 275 663094 | 46253 | 1 | | | | |
| (1) 70-12 | - | 275 704541 | 210723 | 1 | | | | |
| (1) 70-14 | - | 275 704541 | 210723 | 1 | | | | |
| (2) 70-17 | - | 275 67A756 | 224703 | 1 | | | | |
| (3) 70-18 | - | 275 728392 | 139036 | 1 | | | | |
| (48) 70-3 | - | 275 70A541 | 210723 | 1 | | | | |
| (2) 70-5 | - | 275 70A541 | 210723 | 1 | | | | |
| (2) 70-9 | - | 275 70A541 | 210723 | 1 | | | | |
| (24) 70-11 | - | 275 70A541 | 210723 | 1 | | | | |
| (24) 70-1 | - | 275 06A4523 G-51 MS-800-6 | G-112262 | 1 | | | | |
| (24) 70-10 | - | 275 73M351 G-51 MS-800-6 | G-112262 | 1 | | | | |
| (50) 70-15 | - | 263 1/38 CUTTER PINS STEEL | G-21164 | 3 | | | | |
| (24) 70-14 | - | 265 73A691 MS-8018 | G-112262 | 1 | | | | |
| (24) 70-13 | - | 267 3201655 G-51 MS-8018 | G-112262 | 3 | | | | |

LIMERICK GENERATING STATION, UNIT 1
PHILADELPHIA ELECTRIC COMPANY
SPEC. 8031-C-2
CBI 70-7198

James P. Baccetti
4-25-75

a taken from applicable CBI records.

CBI Shop QA *Steve H. H. H.*

Date 4-25-75

Revisions
By
Chkd
Date

Reviewed (for material covered by code):

Authorized Inspector *John H. H.*

Date 4/25/75

Contract No.

70-7198U

No. 75

Sh 1 of 1

GO 810 REV DEC

MEMBER, PENNSYLVANIA ASSOCIATION
MY COMMISSION EXPIRES APRIL 30, 1973

LET REPORT OF

PLATES

C. 2.1- 1187.1

GRS HOMESTEAD DISTRICT U.S.S. ORDER NO. LA34248 LOAD TALLY ON INVOICE NO. 163-17251

CUSTOMER ORDER NO. 73-71930 6/30/71

CAR OR TRUCK NO. GLE 012264 SHIPPER NO. & DATE 51769 10/28/71 160

CHICAGO BRIDGE & IRON CO
P.O. BOX 610
GREENVILLE PA 16125

SHIP TO

CHICAGO BRIDGE & IRON CO
GREENVILLE PA

AS-25-SAN-510-89-HANE-70-PRESSURE-VESSEL-MATERIAL-4140-8-TEMPER-LONG-
CH-25-PYR-5-NOTCH-IMPACT-PR-TEST-4-MINUS-30-DEG-F-STRESS-RELIEVE-TEST
-70CS-15-HRS-400-PR-CB&I-SPEC-MS6018-DTD-2/25/70-8-GPS-516-REV4

008975

FOR LOADS WITHIN 2 TON INSPECTION FOR HEAT TREATMENT ONLY NOT SUR
FACE OR TESTING NOTIFY MR SMITH 412-588-5500 PRIOR TO HEAT TREAT
920690KENT SLOAN T/R LADLE FULL ANAL ALSO COST SPEC GPS#16 REV

0703

SIGNATURE M. W. JAYSON, CH. VET.

DATE 10/29/79

BEING DULY SWEORN ACCORDING
TO LAW, DEPOSES AND SAYS
THAT THE CHEMICAL ANALYSIS IS
AND/OR TESTS SHOWN IN THIS
REPORT ARE CORRECT AS CON-
TAINED IN THE RECORDS OF
THE COMPANY.

| ITEM NO. | HEAT NO. | TEST OR PIECE IDENTITY NO. | MATERIAL DESCRIPTION | | | | | YIELD ST. PSI | TENSILE STR. PSI | LOCATION IN | | % RED. OF AREA |
|--|----------|----------------------------|----------------------|----------------------|------------------------|--------|--------|--|------------------|-------------|--------------|----------------|
| | | | NO. PCS. | THICKNESS OR SECTION | WIDTH, DIA. OR FT. WT. | LENGTH | WEIGHT | | | IN 8" | IN 2" | |
| 15 | 668094 | 46253 BC TC | 1 | 3.0000 | 57 | 233 | 11288 | * 52500 * 52800 F. 094.0-070.0-058 MILS. | 75800 79600 | 67.0 | 30.0 32.0 | 35 |
| FULL SIZE LONG. V NOTCH CHARPY IMPACT TEST 10' 10MM MADE AT - 30 DEG. & SHEAR RATE 055.0-064.0-043.0-000.0 AND LATERAL EXPANSION .074-.060- AVERAGE IMPACT STRENGTH = 77 | | | | | | | | | | | | |
| 25 | 668094 | 46254 BC TC | 1 | 3.0000 | 57 | 233 | 11288 | * 50400 * 51800 F. 065.0-095.0-056 MILS. | 78800 80200 | 63.0 | 29.0 32.0 | 35 |
| FULL SIZE LONG. V NOTCH CHARPY IMPACT TEST 10' 10MM MADE AT - 30 DEG. & SHEAR RATE 044.0-062.0-032.0-000.0 AND LATERAL EXPANSION .055-.076- AVERAGE IMPACT STRENGTH = 74 | | | | | | | | | | | | |
| Above Test Specimens Stress Relieved at 1150 Deg. F., Maintained 15 hrs. Furnace cooled to below 600 Deg. F. Test Specimens Charged Cold. Heating Rate 110 Deg. F. Per Hour. Cooling Rate 140 Deg. F. Per Hour. Heat treated in accordance with heat treat referenced Number C2.2 Above Plates Quenched at 1697 Deg. F., Tempered at 1185 Deg. F. | | | | | | | | | | | | |

FORMERLY TESTED ACCORDING TO COMPANY RECORDS CONFORMS TO THE REQUIREMENTS OF THE SPECIFICATION LISTED ABOVE

* B OR H INDICATE COMPLIANCE OF BEND OR HOMO TESTS, RESPECTIVELY.

| | C | Mn | P | S | Si | Cu | Ni | Cr | Mo | Sn | Al | N | V | B | Ti | Co | Co |
|-------|-----|-----|-----|-----|----|----|----|---|----|----|----|---|---|---|----|----|----|
| 65709 | 122 | 112 | 015 | 015 | 20 | | | | | | | | | | | | |
| | | | | | | | | LIMERICK GENERATING STATION, UNIT 1 PHILADELPHIA ELECTRIC COMPANY SPEC. 8031-C-2 CBI 70-7198 | | | | | | | | | |
| | | | | | | | | GRAIN SIZE # 8 ✓ AVG GR SIZE <i>comin</i> 11-15-71 235 | | | | | | | | | |



PRODUCTION DEPARTMENT - METALLURGICAL

U. S. Steel Corporation

Sheet No. 1

J. JAMES HAFY, NOTARY PUBLIC
HOMESTEAD TOWNSHIP, ALLEGHENY COUNTY
MY COMMISSION EXPIRES JULY 10, 1973
Member, Pennsylvania Association of Notaries

TEST REPORT OF

PLATES

WORKS HOMESTEAD DISTRICT U.S.S. ORDER NO. LA34246 LOAD TALLY OR INVOICE NO. 163-17249CUSTOMER ORDER NO. 70-7198U-46 8/30/71AIR OR TRUCK NO. BLE 019288 SHIPPER NO. & DATE 51789 10/28/71 160

CHICAGO BRIDGE & IRON CO
PO BOX 610
GREENVILLE PA 16125

SHIP TO

CHICAGO BRIDGE & IRON CO
GREENVILLE PA

45 E-54-516-69-GRADE-70-PRESSURE-VESSEL-JUAL-NORMALIZED-LONG-CHAMP
Y-V-NOTCH-IMPACT-TESTS-W-HINUS-30-DEG-F-MOD-PER-CR11-SPEC-MS601B-R
1-DTD-2/25/70-8-GPS-516-REV-4-DTD-2/25/70-8-GPS-516-REV-4-

008974

CHICAGO BRIDGE & IRON INSPECTION FOR HEAT TREATMENT ONLY NOT SUB
FACE OR TESTING NOTIFY NK SMITH 412-588-5500 PRIOR TO HEAT TREAT
220020 ENT SWORN T/R LADLE FULL ANAL ALSO CUST SPEC GPS 516 RE

0703

SIGNATURE M.W. MAYSON, CH. MET.DATE 10/29/71

| ITEM NO | HEAT NO | TEST OR PIECE IDENTITY NO | MATERIAL DESCRIPTION | | | | | YIELD ST. PSI | TENSILE ST. PSI | ELONGATION % | | RED OF AREA |
|---------|--|---------------------------|----------------------|----------------------|----------------------|--------|--------|---------------|-----------------|--------------|------|-------------|
| | | | NO. PCS | THICKNESS OR SECTION | WIDTH, DIA OR FT. WT | LENGTH | WEIGHT | | | IN 8 | IN 2 | |
| 04 | 67A756 | 224783 | 50 | 1 | 1.0000 | 79 | 300 | 6714 | * 47100 | 75800 | 35.0 | |
| | FULL SIZE LONG, V NOTCH CHAMPY IMPACT TEST 10X10MM MADE AT = 30 DEG. F. AND LATERAL EXPANSION .027-.020-.024 MILS. | | | | | | | | | | | |
| | 8 SHEAR RATE 029.0-027.0-027.0-000.0 | | | | | | | | | | | |
| | Avg. Impact Str. = 24 | | | | | | | | | | | |
| 04 | 75A924 | 272637 | 50 | 1 | 1.0000 | 79 | 300 | 6714 | * 45200 | 74100 | 25.0 | |
| | FULL SIZE LONG, V NOTCH CHAMPY IMPACT TEST 10X10MM MADE AT = 30 DEG. F. AND LATERAL EXPANSION .020-.021-.027 MILS. | | | | | | | | | | | |
| | 8 SHEAR RATE 066.0-088.0-038.0-000.0 | | | | | | | | | | | |
| | AVERAGE IMPACT STRENGTH = 28 | | | | | | | | | | | |
| | Above Plates Normalized at 1660 Deg. F. for 40.0 Minutes | | | | | | | | | | | |
| | Heat treated in accordance with heat treat reference Number: C2.1 | | | | | | | | | | | |

LIMERICK GENERATING STATION, UNIT 1
PHILADELPHIA ELECTRIC COMPANY
SPEC. 8031-C-2
CBI 70-7198

11-3-71

* B OR H INDICATE COMPLIANCE OF BEND OR HOMO TESTS, RESPECTIVELY

OTHER SIZE TESTED ACCORDING TO COMPANY RECORDS, CONFORMS TO THE REQUIREMENTS OF THE SPECIFICATION LISTED ABOVE

| HEAT NO | TYPE | C | Mn | P | S | Si | Cu | Ni | Cr | Mo | Sn | Al | N | V | B | Ti | Cb | Co | Grain Size #7 | Grain Size #8 |
|---------|-------|----|------|------|------|----|----|----|----|----|----|----|---|---|---|----|----|----|---------------|---------------|
| 67-756 | LADLE | 24 | 1.06 | 0.11 | 0.27 | 19 | | | | | | | | | | | | | | |
| 75-924 | LADLE | 25 | 1.10 | 0.10 | 0.22 | 21 | | | | | | | | | | | | | | |

Grain Size #7
Grain Size #8

Airlock 162-1

Heat No. C8076

C-2-F 70-7198

METAL MATERIAL VERIFICATION SUMMARY SHEET

CHICAGO BRIDGE & IRON COMPANY

Contract No. 70-7198
Sheet 1 of 4

Copy to Engineering - By _____ Date _____ No. of Ctrs For Customer _____

| NO. OF Pcs | ORDERED ITEM NO. | SUPPLIER'S HEAT, LOT OR OTHER IDENTIFICATION NUMBER | SUPPLIER'S SLAB NUMBER | MATERIAL SPEC. THICKNESS AND PLATES FOR | CAR OR TRUCK NUMBER AND SUPPLIER | CTR CHECKED DATE AND INITIAL | METAL INSPECTION REPORT CHECKED DATE AND INITIAL | DAILY FABR OR STORES RELEASE REPORT CHECKED DATE AND INITIAL | PIECE MARK | SERIAL NUMBER | NO. OF PIECES | CHECKED COMPLETE INITIAL | REMARKS |
|------------|------------------|---|------------------------|---|----------------------------------|------------------------------|--|--|------------|---------------|---------------|--------------------------|---------|
| 1 | MI-5 | 80C01200 | C31547 | SAS16-70 1/2" T=3/4 | M7198-3 Beth. | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 7 | 1 | RCC | |
| 1 | MI-7(A) | 879C02040 | C31571 | T=1 | M7198-5 Beth. | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 7 | 1 | RCC | |
| 1 | MI-22 | 6000-2 | P41319 | T=3/4 | M7198-6 Ad. H.C.O. | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 8 | 1 | RCC | |
| 1 | MI-9 | X5998 | 5A | T=2 | M7198-7 LUKENS | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 1 | 1 | RCC | |
| 1 | MI-11 | C8676 | 1B | T=1/3 | M7198-8 G.O. CARLSON | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 11-12 | 1 | RCC | |
| 1 | MI-13 | X300403 | 2C | SAS16-70 1/2" T=3/4 | M7198-9 Beth. | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 1 | 1 | RCC | |
| 2 | MI-15 | X300403 | 2C | SAS16-70 1/2" T=3/4 | M7198-10 Beth. | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 1 | 1 | RCC | |
| 1 | MI-16 | 801809500 | B32510 | T=3/8 | M7198-11 Beth. | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 1 | 1 | RCC | |
| 1 | MI-7(B) | 802C04120 | C31587 | SAS16-70 1/2" T=3/4 | M7198-12 Beth. | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 6 | 1 | RCC | |
| 1 | MI-7(C) | 801309500 | B10553 | SAS16-70 1/2" T=3/4 | M7198-13 Beth. | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 12 | 1 | RCC | |
| 1 | MI-7(D) | 801811530 | B32526 | SAS16-70 1/2" T=3/4 | M7198-14 Beth. | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 5 | 1 | RCC | |
| 1 | MI-7(E) | 801809500 | C71586-1 | SAS16-70 1/2" T=3/4 | M7198-15 Beth. | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 39 | 1 | RCC | |
| 1 | MI-7(F) | 71A527 | 170008 | SAS16-70 1/2" T=3/4 | M7198-16 Beth. | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 7 | 1 | RCC | |
| 1 | MI-7(G) | 801C03400 | 10265-1 | SAS16-70 1/2" T=3/4 | M7198-17 Beth. | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 1-5 | 1 | RCC | |
| 1 | MI-7(H) | 23D169 | T3763 | AE16-70 T=1/2 | M7198-18 Beth. | 5-13-71 Rcc | 6-1-71 Rcc | 10-11-71 Rcc | See | 5 | 1 | RCC | |

| NOTIFICATION | LT NO. SYSTEM | QUAL. NO. | ENG. PC. AIR. | Serial No. | NO. PGS. |
|-------------------|---------------|------------------|---------------|-----------------|------------|
| ML-11 | 2 | [REDACTED] | [REDACTED] | 11 | 2 |
| 76-18 ✓ | 1 | [REDACTED] | [REDACTED] | 11 | 1 |
| MS L3 | 1 | [REDACTED] | [REDACTED] | 11 | 1 |
| G'ville | 2 | [REDACTED] | [REDACTED] | 1-2 | 2 |
| 11-7B) | 2 | [REDACTED] 5-5 ✓ | [REDACTED] | 4 | 2 |
| 1 5/8" | 4 | [REDACTED] 5-5 | [REDACTED] | 4 | 4 |
| M104 LB | 1 | [REDACTED] | [REDACTED] | 4 THIS PC. RESE | get |
| 302C 04120 ✓ | 1 | [REDACTED] | [REDACTED] | 4 | 1 |
| C 31587 | 2 | 141-6 | [REDACTED] | 4 | 1 |
| | 1 | 150-12 | [REDACTED] | 4 | 1 |
| | | | | | C2F-1188-1 |
| 11B11530-832526 ✓ | 1 | [REDACTED] ✓ | [REDACTED] | 12 | 1 |
| 2" | 1 | [REDACTED] ✓ | [REDACTED] | 12 | 1 |
| | 2 | [REDACTED] ✓ | [REDACTED] | 12 | 2 |
| | 2 | [REDACTED] | [REDACTED] | 12 | 2 |
| | 1 | [REDACTED] | [REDACTED] | 12 | 1 |
| | 1 | [REDACTED] | [REDACTED] | 12 | 1 |
| | 1 | [REDACTED] | [REDACTED] | 12 | 1 |
| | 2 | [REDACTED] | [REDACTED] | 12 | 2 |
| | 2 | [REDACTED] | [REDACTED] | 12 | 2 |
| | 2 | [REDACTED] | [REDACTED] | 12 | 2 |
| | 2 | [REDACTED] | [REDACTED] | 12 | 2 |
| | 4 | [REDACTED] | [REDACTED] | 12 | 4 |
| | 1 | [REDACTED] | [REDACTED] | 12 | 1 |
| | 1 | [REDACTED] | [REDACTED] | 12 | 1 |
| | 1 | [REDACTED] | [REDACTED] | 12 | 1 |
| | 2 | [REDACTED] | [REDACTED] | 12 | 2 |
| | 1 | [REDACTED] | [REDACTED] | 12 | 1 |
| | 1 | [REDACTED] | [REDACTED] | 12 | 1 |
| | 2 | [REDACTED] | [REDACTED] | 12 | 2 |

C-2-F-1188-1

LUKENS STEEL COMPANY

COATESVILLE, PA. 19320

TEST CERTIFICATE

MILL ORDER NO.

CUSTOMER P.O.

48174-2

M7198-6

RG 7771 DD

DATE: 7-9-71

FILE NO 1540-06199

CONSIGNEE:

Chicago Bridge & Iron Co.
Greenville, Pa.

PURCHASER:

3 Chicago Bridge & Iron Co.
Mr. Grant Wagner
P.O. Box 13308
Presidents Island
Memphis, Tenn. 38101

SPECIFICATIONS:

A-516-69 Gr. 70, A-300-68 Class 1 Mod. CB&I MS-601B Rev. 1 Sup. 5, 16 & QPS 516 Rev. 4 Sup. 18
(ASME Sect. 11 & 111 Winter 1969 Addenda)
Sheet 1 of 2

BEND TEST

O.K.

HOMOGENEITY TEST

CHEMICAL ANALYSIS

| MELT NO. | C | Mn | P | S | Cu | Si | Ni | Ca | Mo | V | Ti | Al | B | Grain Size |
|---|----|------|-----|-----|----|----|----|----|----|---|----|----|---|------------|
| CB676 | 27 | 1.01 | 010 | 019 | | | | | | | | | | 6-7 |
| CBI 70-7198 BECHTEL 8031-C-2 LGS I | | | | | | | | | | | | | | |

PHYSICAL PROPERTIES

| MELT NO. | SLAB NO. | YIELD PSI X100 | TENSILE PSI X100 | % ELONG. IN 2" | % R.A. | BHN | LONG. IMPACTS V-Notch -30°F. | Fracture Appearance | DESCRIPTION |
|---|----------|----------------------|------------------------|-------------------|--------|-----|---------------------------------|------------------------|---------------------|
| CB676 | 1B | 552 | 773 | 29 | | | 57 64 69 | 30-30-30 | 2-232 x 83-3/8 x 3" |
| Lateral Expansion in inches .060 .050 .049 | | | | | | | | | |
| P1 and tests heated 1650°F ±25°F., held 1/2 hr. per inch min. and water quenched to below 400°F., then tempered 1180°F., held 1/2 hr. per inch min. and air cooled. Tests stress relieved by heating to 1150°F., held 15 hrs. and furnace cooled to 600°F. | | | | | | | | | |
| We hereby certify that the above material has been manufactured according to A-516-69 Gr. 70 A-300-68 Class 1 Mod. CB&I MS-601B Rev. 1 Sup. 5, 16 & QPS 516 Rev. 4 Sup. 18 (ASME Sect. 11 & 111 Winter 1969 Addenda), and that we have complied with all the requirements of these specifications. | | | | | | | | | |
| RC 7-15-71 | | | | | | | | | |

We hereby certify the above figures are correct as contained in the records of the company.

SUPERVISOR TESTING

[Signature]

PURCHASER:

LUKENS STEEL COMPANY

COATESVILLE, PA. 19320

TEST CERTIFICATE

DATE: 7-9-71

FILE NO. 1540-06-99

Chicago Bridge & Iron Co.
Mr. Grant Wagner
P.O. Box 13308
Presidents Island
Memphis, Tenn. 38101

MILL ORDER NO.

CUSTOMER P.O.

48174-2

M7198-6

RG 7771 DD

CONSIGNEE:

Chicago Bridge & Iron Co.
Greenville, Pa.

SPECIFICATIONS:

SA-516-69 Gr. 70, A-300-68 Class 1 Mod. CB&I MS-601B Rev. 1 Sup. 5, 16 & GPS 516 Rev. 4 Sup. 18
(ASME Sect. 11 & 111 Winter 1969 Addenda)

Sheet 1 of 2

BEND TEST

O.K.

HOMOGENEITY TEST

CHEMICAL ANALYSIS

| MELT NO. | C | MN | P | S | Cu | Si | Ni | Cr | Mo | V | Ti | Al | B | Grain Size |
|----------|----|------|-----|-----|----|----|----|----|----|---|----|----|---|------------|
| C8676 | 27 | 1.01 | 010 | 019 | | 22 | | | | | | | | 6-7 |

CBI 70-7198
BECHTEL 8031-C-2
LGS I

RECEIVED
MEMPHIS, TENN.

JUL 14 1971

PHYSICAL PROPERTIES

| MELT NO. | SLAB NO. | YIELD PSI X100 | TENSILE PSI X100 | ELONG. IN. 2" | R.A. | BHN | Long. IMPACTS V-Notch -30°F. | Fracture Appearance & Shear | DESCRIPTION |
|----------|----------|----------------|------------------|---------------|------|-----|------------------------------|-----------------------------|---------------------|
| C8676 | 1B | 552 | 773 | 29 | | | 57 64 69 .060 .050 .049 | 30-30-30 | 2-232 x 83-3/8 x 3" |

Plates and tests heated 1650°F ±25°F., held 1/2 hr. per inch min. and water quenched to below 400°F., then tempered 1180°F., held 1/2 hr. per inch min. and air cooled.

Tests stress relieved by heating to 1150°F., held 15 hrs. and furnace cooled to 600°F.

We hereby certify that the above material has been manufactured ~~therein~~ according to A-516-69 Gr. 70 A-300-68 Class 1 Mod. CB&I MS-601B Rev. 1 Sup. 5, 16 & GPS 516 Rev. 4 Sup. 18 (ASME Sect. 11 & 111 Winter 1969 Addenda), and that we have complied with all the requirements of these specifications.

RCC
7-15-71

156-23
156-24
156-25
162-1

We hereby certify the above figures are correct as contained in the records of the company.

SUPERVISOR TESTING

F. H. Kline

Feedwater Valve

Body

1 F074A

Heat No. F6137



QUAKER ALLOY CASTING CO.
A DIVISION OF HARSICO CORP.
MYERSTOWN, PENNA. 17067

MATERIAL TEST REPORT

| | | | | | |
|--------------------|-----------------|--------------------------|--------------------|-------------------|--------------|
| CUSTOMER ORDER NO. | PART NO. | QUAKER ALLOY DESIGNATION | SPECIFICATION | SHOP ORDER NUMBER | DATE SHIPPED |
| 2122171 | 16435-20223-505 | C50-LCB | ASME SA352 GR. LCB | | 7-29-75 |

CUSTOMER

Atwood and Morrill

| TEST NO. | C | Mn | Si | P | S | Cr | Ni | Mo | YIELD PSI | TENSILE PSI | ELONG. % | RED OF AREA % | CS5. | | R.T. | PS SHIPPED |
|---------------------------------|-----|-----|-----|------|------|----|----|----|--------------|----------------|-------------|------------------|---------|-------|------|---------------|
| | | | | | | | | | | | | | SER.# | SER.# | | |
| F6137 | .20 | .75 | .45 | .017 | .013 | | | | 42,500 | 71,500 | 30.0 | 53.3 | F6137-1 | N1127 | | |
| Charpy Impact V Notch Plus 30°F | | | | | | | | | | | | | | | | |
| 43-45-22 foot pounds | | | | | | | | | | | | | | | | |
| 41-44-23 Lateral expansion | | | | | | | | | | | | | | | | |
| 43-40-20 % Ductile Fracture | | | | | | | | | | | | | | | | |

Casting produced in accordance with ASME Boiler and Pressure Vessel Code Sect. III 1971
and 1972 Winter Addenda, and with SA352. All special requirements of Art. NB2000 Sect. III
of 1972 Winter Addenda have been met.
Castings produced in accordance with Boilers spec G331-2-350 and GC100-NA, GC102-Welding,
and ASME Section III Article Inspection, and 9-71-101-Weldings.

U. S. S. S.
Atwood and Morrill Co.
9/1/75

"I CERTIFY THE ABOVE INFORMATION IS CORRECT."
QUAKER ALLOY CASTING CO.

John Paul Jones - Authorized Inspector

AT 9-23-75 visited per check-off

Followed by 8A

Feedwater Valve

Body

1F074 B

Heat No.

FG152



Kit: 12681-01-~~51~~
Body for 14-963#

CHEMICAL & PHYSICAL
REPORT CHECKED

Atwood and Morrill

BY L. L. L. L. L.
DATE 8/5/75
ATWOOD & MORRILL CO. INC.

REMARKS

Castings produced in accordance with ASME Boiler and Pressure Vessel Code Sect. II 1971 and 1972 Winter addenda and with Bechtel spec 8031-P-350 and QC100-Rad., QC102-Welding, QC103 Mag, and 90-71-101-Markings.

Castings produced in accordance with ASME SA352. All requirements of Art. MD2000
Sect. III 1971 & 1972 Winter add. have been met.

7-31-75

"I CERTIFY THE ABOVE INFORMATION IS CORRECT"

QUAKER ALLOY CASTING CO.

STATE OF MISSISSIPPI, COUNTY OF DEKALB, SS
I, _____, Clerk of the Circuit Court of the County of Dekalb, do hereby certify that the foregoing is a true and correct copy of the original as the same appears in the records of the Court.

John Paul Jones - Authorized Inspector

① A.T. 9.23.75. Verified A + m requirements

BY

RETAILED

FW Valve IF074A

Cover

Heat No. 213643

CANN & SAUL STEEL CO.

ROYERSFORD, PA. 19468

Report of Physical Tests and/or Chemical Compositions

7/25/75

Customer's Order No.

Conn & Saul Order No.

Customer

Atwood & Morrill Co., Inc. Atm-24,522

32759

285 Canal St.

Ref. 12521-01-014(4)

Address

Salem, Mass. 01970

#12681-01-009(4)

Attention

Purchasing Dept.

CHEMICAL COMPOSITIONS

| HEAT NO. | C | MN | P | S | SI | CR | NI | MO | CB |
|----------|-----|------|------|------|-----|----|----|----|----|
| 213643 | .23 | 1.10 | .011 | .018 | .21 | | | | |

Lab. No.

PHYSICAL TESTS

| CUT FROM | TEST NUMBER | GAUGE | YIELD PT. LBS. | YIELD PER Square In Lbs. | BROKE AT LBS. | ULTIMATE TENSILE LBS. | ELONG % | REDUCED AREA | Reduction % | B.H.N. |
|---------------|-------------|-------|----------------|--------------------------|---------------|-----------------------|---------|--------------|-------------|--------|
| Forging | 32759 1 | .505 | 8,500 | 42,500 | 14,000 | 70,000 | 35.0 | .070 | 65.0 | |
| Charpy Impact | | | 20.0 | 20.0 | 22.0 | Ft. Lbs. @ plus 30°F | | | | |
| Notch | | | 52 | 49 | 50 | mils Lat. Exp. | | | | |
| | | | 15 | 15 | 15 | percent shear | | | | |

APPROVED

BY

DATE

N. Sullivan

9/23/75

OTHER TESTS

ATWOOD & MORRILL CO. INC.

See C&S Proc. A388, Rev. 16 Mod. 2 (4/25/75)
 Attach. #1 (4/25/75) O.K.

We certify the material meets
 the requirements of the speci-
 fication and/or P.O.

Customer's Specifications: ASME SA-350, Gr. LF-2
 Charpy "V" impacts 40 mils Lat. exp. @ plus 30°F
 Lbs. and percent shear for info.
 30 Carbon

Y. P. 36,000
 T. 70,000
 C. 22.0
 B. 30.0
 CHEMICAL & PHYSICAL
 REPORT CHECKED

THE ABOVE TESTS COVER THE FOLLOWING MATERIAL:

Cover Forgings 23-1/4" dia. x 5-1/4" thick
 Forgings serialized #1 thru 8

7-25-75
 Inspection

7-25-75
 Inspector

(P) A.T. 7-23-75 - Confirmed as an acceptance

RECEIVED
 P 116AC E 2

CANN & SAUL STEEL CO.

BY W. Francis

DATE 7-30-75
 ATWOOD & MORRILL CO. INC.

John Paul Jones
 Authorized Inspector

127

FW Valve IF074B

Cover

Heat No. 213643

CANN & SAUL STEEL CO.

SN 3-5212

ROVERSFORD, PA. 19080

Report of Physical Tests and/or Chemical Compositions

7/25/75

Customer's Order No.

Cann & Saul Order No.

Customer Atwood & Morrill Co., Inc. AM-21502
 285 Canal St. Ref. 12521-01-014(4)
 Address Salem, Mass. 01970 #12521-01-009(4)

Attention Purchasing Dept.

CHEMICAL COMPOSITIONS

| HEAT NO. | C | MN | P | S | SI | CR | NI | MO | CB |
|----------|-----|------|------|------|-----|----|----|----|----|
| 213643 | .23 | 1.10 | .011 | .018 | .21 | | | | |

Lab. No.

PHYSICAL TESTS

| CUT FROM | TEST NUMBER | GAUGE | YIELD PT. LBS. | YIELD PER Square In Lbs. | BROKE AT LBS. | ULTIMATE TENSILE LBS. | ELONG % | REDUCED AREA | Reduction % | B.H.N. |
|---------------|-------------|-------|----------------|--------------------------|----------------------|-----------------------|---------|--------------|-------------|--------|
| Forging | 32759 1 | .505 | 8,500 | 42,500 | 14,000 | 70,000 | 35.0 | .070 | 65.0 | |
| Charpy Impact | | 20.0 | 20.0 | 22.0 | Ft. Lbs. 9 plus 30°F | | | | | |
| Notch | | 52 | 49 | 50 | Mils Lat. Exp. | | | | | |
| | | 15 | 15 | 15 | percent shear | | | | | |

APPROVED

BY

DATE

9/23/75

OTHER TESTS

ATWOOD & MORRILL CO. INC.

ionic C&S Proc. A388, Rev. 16 Mod. 2 (4/25/75)
 Attach. #1 (4/25/75) O.K.

We certify the material meets
 the requirements of the speci-
 fication and/or P.O.

Customer's Specifications: ASME SA-350, Gr. LF-2
 Charpy "V" Impacts 40 Mils Lat. Exp. 9 plus 30°F
 Lbs. and percent shear for Info.
 1/30 Carbon B.H.N.

Y. P. 36,000
 T. 70,000
 E. 22%
 R. 30%
 CHEMICAL & PHYSICAL
 REPORT CHECKED

THE ABOVE TESTS COVER THE FOLLOWING MATERIAL:

- Cover Forgings 23-1/4" dia. x 5-1/4" thick
 Forgings serialized #1 thru 8

BY W. Francis

DATE 7-30-75

ATWOOD & MORRILL CO. INC.

CANN & SAUL STEEL CO.

John Paul Jones
 Authorized Inspector

123

FW Valve IF074A

Disc

Heat No. F6589



QUAKER ALLOY CASTING CO.
A DIVISION OF HARSICO CORP.
MYERSTOWN, PENNA. 17067

MATERIAL TEST REPORT

| CUSTOMER ORDER NO. | PATTERN NO. | QUAKER ALLOY DESIGNATION | SPECIFICATION | SHOP ORDER NUMBER | DATE SHIPPED |
|--------------------|-----------------|--------------------------|-------------------|-------------------|--------------|
| 100-173 | 16619-20545-501 | CSG-LCB | ASME SA352 GR.LCB | | 8-14-75 |

CUSTOMER

Atwood and Merrill

| | | | | | | | | | | CSTG. | | R.T. | | | | |
|--------------------------------|-----|-----|-----|------|------|----|----|----|--|--------------|--------------------|-------------|-------------------|---------|---------|----------------|
| Q. NO. | C | Mn | Si | P | S | Cr | Ni | Mo | | YIELD PSI | TENSILE PSI | ELONG. % | RED. OF AREA % | SER.# | S. ER.# | PCS SHIPPED |
| 6589 | .22 | .25 | .42 | .020 | .011 | | | | | 43,000 | 79,000 | 31.0 | 65.7 | F6539-5 | H1475 | 1 |
| Charpy Impact V Notch Plus 30° | | | | | | | | | | 69-65-69 | foot pounds | | | | | |
| | | | | | | | | | | 65-54-53 | lateral expansion | | | | | |
| | | | | | | | | | | 69-30-50 | % Ductile Fracture | | | | | |

REMARKS:

Atwood + Merrill Co.
9/11/75

Castings produced in accordance with ASME Boiler and Pressure Vessel Code Sect. III 1971 and Winter Addenda 72 and with Bechtel spec 8031-P-350 and QC100 - Rad, QC102 - Welding, QC103 - Mag, and 90-71-101 - Markings; and with SA352. All special requirements of Art. NB2000 Sect. III 1971 and 1972 Winter Addenda have been met.

P 116ACE 2



9-13-75

OF PENNA. COUNTY OF LEBANON, SS
I DO HEREBY CERTIFY ABOVE ME

DAY OF

19

9-22-75

"I CERTIFY THE ABOVE INFORMATION IS CORRECT"
QUAKER ALLOY CASTING CO.

BY

INITIALS/DATE

Fw Valve 1F074B

Disc

Heat No

F6589



QUAKER ALLOY CASTING CO.
A DIVISION OF HARSCO CORP.
MYERSTOWN, PENNA. 17067

MATERIAL TEST REPORT

476-12521-0102
Disc 4/13/75

| CUSTOMER ORDER NO. | PATTERN NO. | QUAKER ALLOY DESIGNATION | SPECIFICATION | SHOP ORDER NUMBER | DATE SHIPPED |
|--------------------|-----------------|--------------------------|-------------------|-------------------|--------------|
| NB24171 | 16553-30545-601 | Q50-LCB | ASME SA352 GR.LCB | | 814.75 |

RECEIVED

CUSTOMER'S NAME

Atwood and Morrill

| | | | | | | | | | | YIELD P.S.I. | TENSILE P.S.I. | ELONG. % | RED. of AREA % | CSTG. SER.# | R.T. SER.# | PCS SHIPPED |
|----------------------------------|-----|-----|-----|------|------|----|----|----|--|-----------------|--------------------|-------------|-------------------|----------------|---------------|----------------|
| SAT NO. | C | Mn | Si | P | S | Cr | Ni | Mo | | | | | | | | |
| F6589 | .22 | .93 | .49 | .022 | .011 | | | | | 43,000 | 73,000 | 31.0 | 65.7 | F6589-8 | N1477 | 1 |
| Charpy Impact V Notch Plus 30° F | | | | | | | | | | 39-65-69 | foot pounds | | | | | |
| | | | | | | | | | | 65-54-59 | Lateral expansion | | | | | |
| | | | | | | | | | | 99-00-00 | % Ductile Fracture | | | | | |

Charpy Impact V Notch Plus 30°F

REMARKS:

Castings produced in accordance with ASME Boiler and Pressure Vessel Code Sect. III 1971 and Winter addenda 72 and with Bechtel spec 9031-P-350 and QC100-Rad, QC102-Welding, QC103-Mag, QC104-71-101-Markings and with SA352.... All special requirements of Art. NB2000 Sect. III 1971 and 1972 Winter Addenda have been met.

CHEMICAL & PHYSICAL
REPORT CHECKED

4/3/75
QC.8
-12.75

BY *[Signature]*

"I CERTIFY THE ABOVE INFORMATION IS CORRECT"
QUAKER ALLOY CASTING CO.

NOTED BY COUNTY OF BERKLEY 33
NOTED BY COUNTY OF BERKLEY 33

[Signature]
Atwood and Morrill

John Paul Jones
Authorized Inspector

BY *[Signature]*

MSIV (IF028 A , TYP.)

• BODY

HEAT NO: 8816

Limerich MSIV

4

S.O.# 11683

Body 26'-655#

AE 11711683-91

GE 2:5 AB 319

Report of Chemical Analysis and Physical Properties

CUSTOMER

Altwood & Merrill Co.

ORDER No.

FM-3750

FILE No.

ADDRESS

PATTERN No.

16614-30147-001

DESIGNATION 070

ATTENTION OF

SPECIFICATION

ASTM A216 WCB

DATE 2-16-72

[illegible]

REMARKS: 2-16-72 JH

CHEMICAL & PHYSICAL
REPORT CHECKED

By Ch. Gerson

4) Certify the above information is correct. DATE 3-29-72

QUAKER ALLOY CASTING CO

Mark M. Lind

44-1987-Sub E-101-72 Authorized Inspector

MSIV (1F028A, TYP.)

• COVER

HEAT No: 219222

CANN & SAUL STEEL CO.

ROVERSFORD, PA.

Report of Physical Tests and/or Chemical Compositions

Date 9-21-71

Customer Atwood & Morrill Co., Inc. Customer's Order No. AM-4075
 285 Canal St.
 Address Salem, Mass. 01970

Cann & Saul Order No. 7375

Attention Purch. Dept.

CHEMICAL COMPOSITIONS

| HEAT NO. | C | MN | P | S | SI | CR | NI | MO | CB | | |
|----------|-----|-----|------|------|-----|----|----|----|----|--|--|
| 219222 | .30 | .68 | .009 | .014 | .19 | | | | | | |

Lab. No.

PHYSICAL TESTS

| CUT FROM | TEST NUMBER | GAUGE | YIELD PT. LBS. | YIELD PER Square In. Lbs. | BROKE AT LBS. | ULTIMATE TENSILE LBS. | ELONG % | REDUCED AREA | Reduction % | B.H.N. |
|----------|-------------|-------|-------------------|------------------------------|------------------|--------------------------|------------|-----------------|----------------|--------|
| Forging | 7375 2 | .505 | 9,400 | 47,000 | 15,100 | 75,500 | 30.0 | .098 | 51.0 | |

OTHER TESTS

Ultrasonic to C&S Proc. A388, Rev. 4: O.K. 9-22-71

Mag. Part. C&S P&V #1.

Heat Treat Procedure C&S #1.

Customer's Specifications: ASTM A-105, Gr. 2

Y. P. 36,000
 Y. 70,000
 E. 22%
 E. 30%

B.H.N.

THE ABOVE TESTS COVER THE FOLLOWING MATERIAL:

7 - Machined Cover Forgings, Dwg. 20884-D, Code 32113-012-2972.
 Forgings serial numbered #9, 10, 11, 12, 13, 14 & 15

A&M & G.E.

CANN & SAUL STEEL CO.

Inspector

Eng. of Tests

MSIV (1F028 A, TYP.)

• POPPET

HEAT No: 219727

CANN & SAUL STEEL CO.

POYERSFORD, PA.

Report of Physical Tests and/or Chemical Compositions

C+S # 15

11683-01-002

POPPET

1-12-72

Date 6-27-72

Customer's Order No.

AM-4075 Add'l.

Cann & Saul Order No.

8018

Customer Atwood & Morrill Co., Inc.
285 Canal St.

Address Salem, Mass. 01970

AM S.O. 11683-01 GE 205-AB319

Attention Purch. Dept.

S/1
5 THRU
8-683

CHEMICAL COMPOSITIONS

| HEAT NO. | C | MN | P | S | SI | CR | NI | MO | CB |
|----------|-----|-----|------|------|-----|----|----|----|----|
| 219727 | .33 | .72 | .009 | .016 | .24 | | | | |

Lab. No.

PHYSICAL TESTS

| CUT FROM | TEST NUMBER | GAUGE | YIELD PT. LBS. | YIELD PER Square In Lbs. | BROKE AT LBS. | ULTIMATE TENSILE LBS. | ELONG % | REDUCED AREA | Reduction % | B.H.N. |
|----------|-------------|-------|-------------------|-----------------------------|------------------|--------------------------|------------|-----------------|----------------|--------|
| Forging | 8018 3 | .505 | 9,500 | 47,500 | 15,000 | 75,000 | 30.0 | .089 | 55.5 | |

OTHER TESTS

Ultrasonic to C&S Proc. A388, Rev. 4 dated 5-10-71 & Mod. 8-11-71:- O.K. Ref. D.D.R.
Mag. Part to C&S Proc. P & V #1, Rev. 1 (7-14-71): O.K. #4377
Heat Treat Procedure C&S #1.

Q477 P 7-683

C+S # 15

Customer's Specifications: ASTM A-105, Gr. 2

Y. P. 36,000
T. 70,000
E. 22%
R. 30%

B.H.N.

THE ABOVE TESTS COVER THE FOLLOWING MATERIAL:

4 - Machined Poppet Forgings, Dwg. 30521-801D, Alt. 5, dated 1-17-72.

Forgings serial numbered #13 thru 16 inclusive

AM & GE
AM IN. 5 THRU 8-683

AM & GE

Inspection

CHEMICAL & PHYSICAL
REPORT CHECKED

CANN & SAUL STEEL CO.

Inspector

BY [Signature]

Eng. of Tests

DATE 7-31-72



C&S - Authorized Inspector

Stress Intensity Factor K_I Calculations for Assumed Flaws in 24-inch Feedwater Check Valve Body Castings

1. Bechtel prepared a report, Acceptability of 24-inch Feedwater Check Valves, Technical Report No. 1183-05EV, Revision 2, May 1984. It provided several justifications including a fracture mechanics evaluation to support the acceptability of the feedwater check valves. The fracture mechanics methodology used and actual step-by-step calculations are presented below in support of the use-as-is recommendation.
 2. The Class II shrinkage criteria for X-ray examination of valve body castings were conservatively equated to a 3.50-inch long crack for the purpose of calculating K_I . This flaw was assumed to lie normal to the principal stress (membrane and bending stresses). For a mid-thickness flaw, the width (2a) was assumed to be 1.00-inch. For a surface flaw, the depth (a) was assumed to be 1.00-inch.
- (a) The methodology of ASME Section XI, Appendix A, Analysis of Flaw Indications, was used to calculate K_I .

$$K_I = \sigma_m M_m \sqrt{\pi a/Q} + \sigma_b M_b \sqrt{\pi a/Q} \quad (1)$$

where

σ_m, σ_b = membrane and bending stresses, psi, in accordance with A-3200

a = minor half-diameter, in., of embedded flaw; flaw depth for surface flaw

Q = flaw shape parameter as determined from Fig. A-3300-1 using $(\sigma_m + \sigma_b)/\sigma_y$ and the flaw geometry

M_m = correction factor for membrane stress (see Fig. A-3300-2 for subsurface flaws; Fig. A-3300-3 for surface flaws)

M_b = correction factor for bending stress (see Fig. A-3300-4 for subsurface flaws; Fig. A-3300-5 for surface flaws)

- (b) The results of calculations in the attached sheets are summarized as follows.

| | Stress Intensity Factor K_I ksi $\sqrt{\text{in}}$ (For flaws in flat plate) | |
|---|---|---------|
| | Midthickness | Surface |
| For design stresses Membrane stress = 18.5 ksi Bending stress = 10.2 ksi | 26 | 32 |
| For conservatively assumed stresses Membrane stress = 20 ksi Bending stress = 20 ksi | 30 | 36 |

- (c) The membrane stress correction factor M_m was compared with a correction factor F for surface flaws in an internally pressurized cylindrical body. See Sheet No. 6. Using an adjustment factor ($F/M_m = 1.27$), the following values were obtained to represent K_I for the assumed flaws in the valve body castings.

| | Stress Intensity Factor K_I ksi/ $\sqrt{\text{in}}$ (For flaws in cylindrical bodies) | |
|---|--|---------|
| | Midthickness | Surface |
| For design stresses Membrane stress = 18.5 ksi Bending stress = 10.2 ksi | 26 | 40 |
| For conservatively assumed stresses Membrane stress = 20 ksi Bending stress = 20 ksi | 30 | 46 |

3. The maximum internal pressure during the 40°F lowest temperature operation is 1180 psi as compared to the 2100 psi standard calculation pressure for the above design stresses. The membrane stress corresponding to the 1180 psi internal pressure is 10.4 ksi. Using this value and the conservatively estimated 20 ksi bending stress, K_I calculations resulted in the following values.

| | Stress Intensity Factor K_I ksi/ $\sqrt{\text{in}}$ (For flaws in cylindrical bodies) | |
|---|--|---------|
| | Midthickness | Surface |
| Membrane stress = 10.4 ksi (corresponding to 40°F initial temperature) Bending stress = 20 ksi assumed | 17 | 25 |

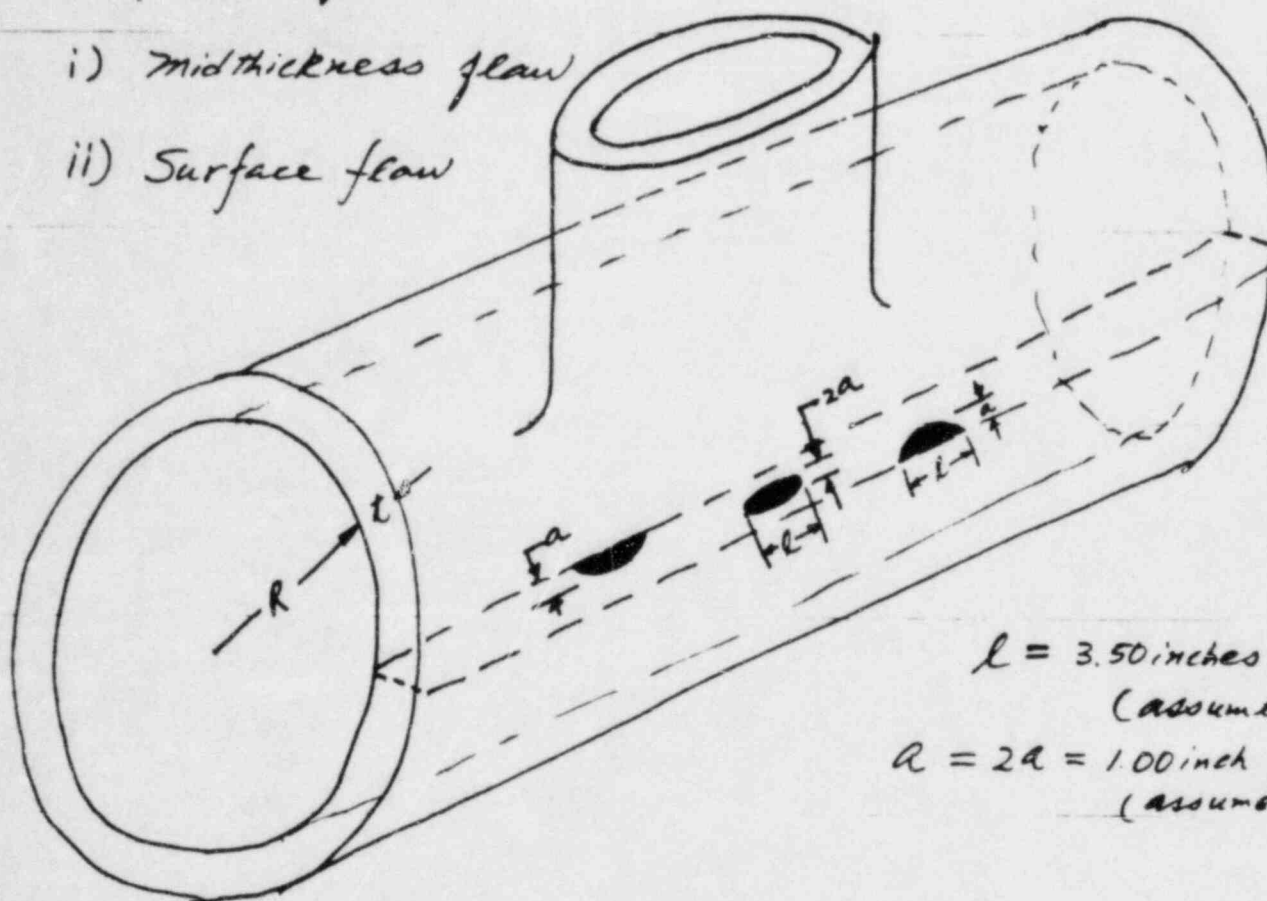
4. Estimated values for K_{Ic} from CVN energy absorption in certified material test reports are 110 to 190 ksi/ $\sqrt{\text{in}}$ (corresponding to 34 to 74 ft-lbs). These values give an ample margin against the above K_I values.
5. A surface flaw, 3.50-inch long x 1.00-inch deep, is a grossly exaggerated assumption for a valve body casting which was RT and MTed. This was done only to demonstrate the unlikelihood of brittle fracture.
6. Because of the solidification pattern of a casting, shrinkage will occur around the midthickness. Equating that to a flat crack-like flaw is still another conservative assumption.
7. The number of thermal transients and loading conditions are such that fatigue cracking will not develop from the above flaws. This is due to the low number of thermal cycles and low stress intensity factor ranges (ΔK).
8. A K_I value of 90 ksi/ $\sqrt{\text{in}}$ on page 9 of the Bechtel report (No. 1183-05EV) is a typographical error of 50 ksi/ $\sqrt{\text{in}}$, which was a value by rounding off 46 ksi/ $\sqrt{\text{in}}$ for the worst case.

DATE 8/22/84DESIGN BY YUN CHUNG DATE _____ CHECKED BY RAW 8/30/84 SHEET NO 1PROJECT Limerick JOB NO 8031-000SUBJECT Fracture Mechanics Evaluation CALCULATION NO _____ FILE NO _____of 24-inch Feedwater Check Valves

1. Flaw assumptions

i) Midthickness flaw

ii) Surface flaw


 $l = 3.50 \text{ inches}$
 (assumed)

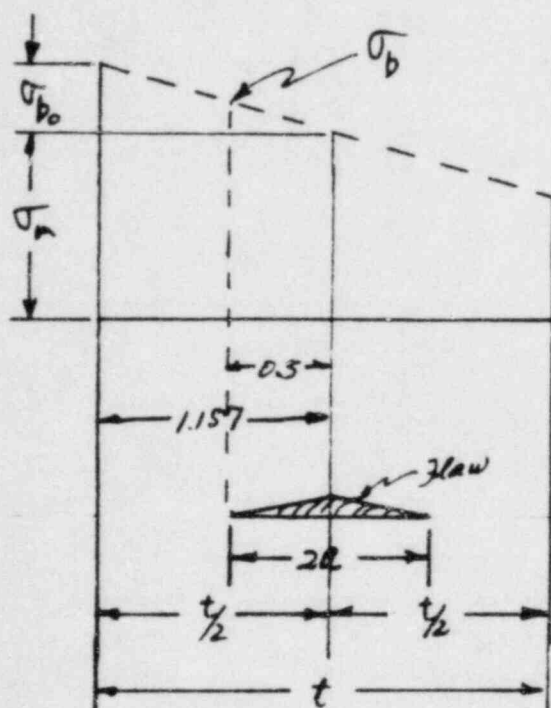
 $a = 2a = 1.00 \text{ inch}$
 (assumed)
2. Data from Design Report for 24" Feedwater Check Valve
(Atwood & Merrill order No. 12521, Sept 28, 1972) $R = 11.50 \text{ inches}$ $t = 2.313 \text{ inches}$ $P_m = 18.5 \text{ ksi}$ membrane stress $P_{eb} = 10.2 \text{ ksi}$ Bending stress

DESIGN BY _____ DATE _____ CHECKED BY _____ SHEET NO. 2

PROJECT _____ JOB NO. _____

SUBJECT _____ CALCULATION NO. _____ FILE NO. _____

3. K_I Calculation for a midthickness Flaw



(Fig. A-3200-1 (b))

$$t = 2.313 \text{ inches}$$

$$2a = 1.00 \text{ (assumed)}$$

$$\sigma_m = P_m = 18.5 \text{ ksi}$$

$$\sigma_b = P_b = 10.2 \text{ ksi}$$

$$\sigma_b = \sigma_b \cdot \frac{0.5}{1.157}$$

$$= (10.2) \left(\frac{0.5}{1.157} \right) = 4.41 \text{ ksi}$$

$$\sigma_{ys} = 40 \text{ ksi}$$

$$\frac{\sigma_m + \sigma_b}{\sigma_{ys}} = \frac{18.5 + 4.4}{40} = 0.57$$

$$\frac{a}{l} = \frac{0.5}{3.5} = 0.143$$

$$Q = 1.13 \text{ (from Fig. A-3300-1)}$$

$$\frac{2e}{t} = 0 \quad \frac{2a}{t} = \frac{1}{2.313} = 0.43$$

$$M_m = 1.14 \text{ (Fig. A-3300-2)}$$

$$M_b = 0.24 \text{ (Fig. A-3300-4)}$$

$$K_I = \sigma_m M_m \sqrt{\pi} \sqrt{a/Q} + \sigma_b M_b \sqrt{\pi} \sqrt{a/Q}$$

$$= \sqrt{3.14} \cdot \sqrt{\frac{0.5}{1.09}} \{ (18.5)(1.14) + (4.4)(0.24) \}$$

$$= (1.77)(0.67)(21.1 + 1.1)$$

$$K_I = 26 \text{ ksi} \sqrt{\text{in}}$$

DATE _____

DESIGN BY _____ DATE _____ CHECKED BY _____ SHEET NO. 3

PROJECT _____ JOB NO. _____

SUBJECT _____ CALCULATION NO. _____ FILE NO. _____

$$\text{If } \sigma_m = p_m = 20 \text{ ksi}$$

$$\sigma_{b0} = 20 \text{ ksi}$$

$$\text{Then, } \sigma_b = \sigma_{b0} \cdot \frac{0.5}{1.157} = 8.64$$

$$\frac{\sigma_m + \sigma_b}{\sigma_{ys}} = \frac{20 + 8.64}{40} = 0.72$$

$$Q = 1.08$$

$$M_m = 1.14$$

$$M_b = 0.24$$

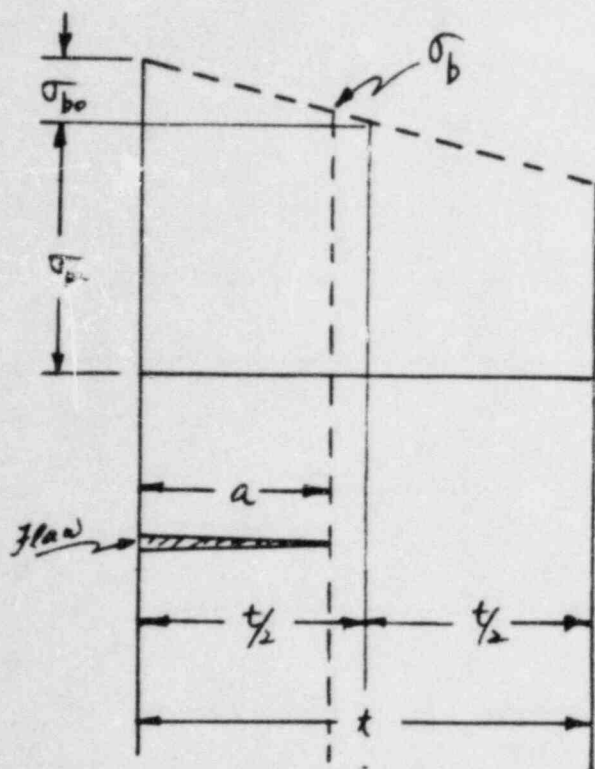
$$\begin{aligned} K_I &= \sqrt{3.14} \sqrt{\frac{0.5}{1.08}} \left\{ (20)(1.14) + (8.64)(0.24) \right\} \\ &= (1.77)(0.68)(22.8 + 2.1) \\ &= 30 \text{ ksi } \sqrt{\text{in}} \end{aligned}$$

DESIGN BY _____ DATE _____ CHECKED BY _____ SHEET NO. 4

PROJECT _____ JOB NO. _____

SUBJECT _____ CALCULATION NO. _____ FILE NO. _____

4. K_I Calculation for a Surface Flaw



$t = 2.313$ inches

$a = 1.00$ inch (assumed)

$$\sigma_m = P_m = 18.5 \text{ ksi}$$

$$\sigma_{bo} = p_{eb} = 10.2 \text{ ksi}$$

$$\sigma_b = (10.2) \left(\frac{t/2 - a}{t/2} \right) = (10.2) \left(\frac{1.157 - 1.00}{1.157} \right) = 1.4 \text{ ksi}$$

$$\frac{\sigma_m + \sigma_b}{\sigma_{ys}} = \frac{18.5 + 1.4}{40} = 0.5$$

$$\frac{a}{l} = \frac{1.00}{3.50} = 0.286$$

$Q = 1.56$ (From Fig. A-3300-1)

$$a/t = 1/2 \cdot 313 = 0.43$$

$$a/l = 1/3.50 = 0.29$$

$$M_m = 1.18 \text{ (from Fig. A-3300-3)}$$

$M_b = 0.50$ (from Fig. A-3300-5)

$$\begin{aligned} K_I &= \sigma_m M_m \sqrt{\pi} \sqrt{a/Q} + \sigma_b M_b \sqrt{\pi} \sqrt{a/Q} \\ &= \sqrt{3.14} \sqrt{\frac{1}{1.56}} \{ (18.5)(1.18) + (1.4)(0.5) \} \\ &= (1.77)(0.801)(21.8 + 0.7) \end{aligned}$$

$$K_I = 32 \text{ ksi} \sqrt{\text{in}}$$

DATE _____

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PROJECT _____ JOB NO. _____

SUBJECT _____ CALCULATION NO. _____ FILE NO. _____

$$\text{If } \sigma_a = 20 \text{ ksi}, \sigma_{b0} = 20 \text{ ksi}$$

$$\text{Then, } \sigma_b = (20) \left(\frac{1.157 - 1.00}{1.157} \right) = 2.7 \text{ ksi}$$

$$\frac{\sigma_a + \sigma_b}{\sigma_{ys}} = \frac{20 + 2.7}{40} = 0.57$$

$$Q = 1.54$$

$$M_a = 1.18$$

$$M_b = 0.50$$

$$\begin{aligned} K_I &= \sigma_a M_a \sqrt{\pi} \sqrt{\frac{a}{Q}} + \sigma_b M_b \sqrt{\pi} \sqrt{\frac{a}{Q}} \\ &= \sqrt{3.14} \sqrt{\frac{1.00}{1.54}} \{ (20)(1.18) + (2.7)(0.5) \} \\ &= (1.77)(0.81)(23.6 + 1.4) \\ &= 36 \text{ ksi} \sqrt{\text{in}} \end{aligned}$$

DESIGN BY _____ DATE _____ CHECKED BY _____ SHEET NO 6
 PROJECT _____ JOB NO _____
 SUBJECT _____ CALCULATION NO _____ FILE NO _____

5. Boundary-Correction Factor F for surface flaws

Raju and Newman, J^* gave the following equations for F for surface cracks in an internally pressurized cylinder.

* J. of Pressure Vessel Technology, V.104 (Nov. 1982) PP 293-298

For internal surface cracks

$$F_i = \frac{t}{R} \left(\frac{R_0^2}{R_0^2 - R^2} \right) \left[2G_0 - 2 \left(\frac{a}{R} \right) G_1 + 3 \left(\frac{a}{R} \right)^2 G_2 - 4 \left(\frac{a}{R} \right)^3 G_3 \right]$$

$$R_0 = R + t = 11.50 + 2.313 = 13.8 \quad q/R = 1/11.5 = 0.087$$

G_0, \dots, G_3 are given in Table 2* ($t/R = 0.25$, $q/c = 0.4$, $\frac{a}{t} = 0.5$, $\frac{2\phi}{\pi} = 1.0$)

$$= \frac{2.313}{11.5} \left(\frac{13.8^2}{13.8^2 - 11.5^2} \right) \left[(2)(1.193) - 2(0.087)(0.715) + 3(0.087)^2(0.545) - 4(0.087)^3(0.454) \right]$$

$$= (0.201)(3.27) (2.386 - 0.124 + 0.012 - 0.001)$$

$$= 1.5$$

For external surface cracks

$$F_e = \frac{t}{R} \left(\frac{R^2}{R_0^2 - R^2} \right) \left[2G_0 + 2 \left(\frac{a}{R_0} \right) G_1 + 3 \left(\frac{a}{R_0} \right)^2 G_2 + 4 \left(\frac{a}{R_0} \right)^3 G_3 \right]$$

$$a/R_0 = 1/13.8 = 0.072$$

For G_0, \dots, G_3 , see Table 4 of the reference (see the next page)

$$= \frac{2.313}{11.5} \left(\frac{11.5^2}{13.8^2 - 11.5^2} \right) \left[(2)(1.360) + 2(0.072)(0.773) + 3(0.072)^2(0.575) + 4(0.072)^3(0.472) \right]$$

$$= (0.201)(2.27) (2.72 + 0.111 + 0.009 + 0.001)$$

$$= 1.3$$

6. Ratio of F_i vs M_m

$$F_i/M_m = 1.5/1.18 = 1.27$$

7. Correction for K_I surface flaw = $32 \text{ ksi}\sqrt{\text{in}} \times 1.27 = 40 \text{ ksi}\sqrt{\text{in}}$,
 of $P_m = 18.5 \text{ ksi}$, $P_{ex} = 10.2 \text{ ksi}$.

$$\text{or } = 36 \times 1.27 = 46 \text{ ksi}\sqrt{\text{in}},$$

$$\text{of } P_m = 20 \text{ ksi}, P_{ex} = 20 \text{ ksi}.$$

Table 4 Influence coefficients, G_j , for semi-elliptical surface crack on outside of a cylinder ($t/R = 0.25$)

| Type of loading | $\frac{2\phi}{\pi}$ | a/c | | | a/t | | | a/R | | |
|---------------------|---------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | | 0.2 | 0.5 | 0.8 | 0.2 | 0.5 | 0.8 | 0.2 | 0.5 | 0.8 |
| Uniform (G_0) | 0 | 0.612 | 0.786 | 1.160 | 0.793 | 0.994 | 1.400 | 1.163 | 1.286 | 1.498 |
| | 0.25 | 0.752 | 0.952 | 1.346 | 0.828 | 1.016 | 1.365 | 1.088 | 1.184 | 1.320 |
| | 0.5 | 0.972 | 1.278 | 1.860 | 0.967 | 1.175 | 1.513 | 1.049 | 1.123 | 1.183 |
| | 0.75 | 1.114 | 1.541 | 2.344 | 1.072 | 1.311 | 1.682 | 1.034 | 1.100 | 1.163 |
| Linear (G_1) | 0 | 0.080 | 0.134 | 0.242 | 0.130 | 0.195 | 0.318 | 0.204 | 0.243 | 0.302 |
| | 0.25 | 0.209 | 0.272 | 0.389 | 0.252 | 0.315 | 0.421 | 0.365 | 0.396 | 0.435 |
| | 0.5 | 0.430 | 0.532 | 0.713 | 0.451 | 0.521 | 0.626 | 0.546 | 0.570 | 0.583 |
| | 0.75 | 0.618 | 0.767 | 1.044 | 0.620 | 0.702 | 0.833 | 0.674 | 0.698 | 0.724 |
| Quadratic (G_2) | 0 | 0.023 | 0.049 | 0.097 | 0.045 | 0.078 | 0.134 | 0.077 | 0.096 | 0.122 |
| | 0.25 | 0.076 | 0.106 | 0.159 | 0.100 | 0.130 | 0.180 | 0.156 | 0.171 | 0.188 |
| | 0.5 | 0.241 | 0.291 | 0.376 | 0.261 | 0.295 | 0.345 | 0.336 | 0.347 | 0.350 |
| | 0.75 | 0.437 | 0.513 | 0.654 | 0.447 | 0.489 | 0.556 | 0.516 | 0.527 | 0.542 |
| Cubic (G_3) | 0 | 0.010 | 0.025 | 0.051 | 0.022 | 0.041 | 0.073 | 0.040 | 0.051 | 0.064 |
| | 0.25 | 0.032 | 0.050 | 0.079 | 0.046 | 0.064 | 0.093 | 0.077 | 0.086 | 0.095 |
| | 0.5 | 0.148 | 0.177 | 0.225 | 0.164 | 0.184 | 0.212 | 0.220 | 0.226 | 0.226 |
| | 0.75 | 0.337 | 0.383 | 0.468 | 0.350 | 0.375 | 0.416 | 0.418 | 0.424 | 0.435 |
| | 1.0 | 0.434 | 0.488 | 0.596 | 0.445 | 0.472 | 0.523 | 0.513 | 0.520 | 0.536 |

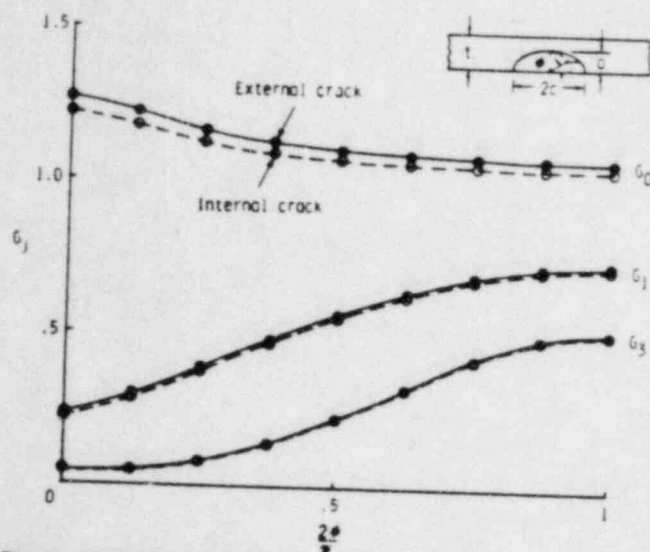


Fig. 3 Distribution of influence coefficients along crack front for semi-circular internal or external surface crack in cylindrical vessel ($t/R = 0.1$; $a/c = 1.0$; $a/t = 0.5$)

cylinder under the desired loading. The hoop stress distribution is then expanded or fitted into the form

$$\sigma_{\theta} = \sum_{j=0}^3 A_j z^j \quad (3)$$

where z is measured from the proposed crack mouth toward the crack front (see Fig. 2(c)). Rewriting equation (3) to agree with the form of equation (1) gives

$$\sigma_{\theta} = \sum_{j=0}^3 A_j \alpha' \left(\frac{z}{a} \right)^j \quad (4)$$

where the term $A_j \alpha'$ is the scale factor to be applied to equation (2) to obtain the corresponding stress-intensity factor. The stress-intensity factor for the σ_{θ} distribution is then given by

$$K_I = \sqrt{\pi a} \sum_{j=0}^3 G_j A_j \alpha' \quad (5)$$

The G_j values for all crack configurations analyzed in this study are tabulated in Tables 1 through 4.

Application to Internal Pressure

The influence-coefficient procedure was applied to obtain the stress-intensity factors for internally pressurized cylinders with internal and external surface cracks.

Internal Surface Cracks. The stress-intensity factors for an internal surface crack in an internally pressurized cylinder were obtained from equations (3) through (5) using Lamé's solution [11] for the hoop stress (σ_{θ}) in an uncracked internally pressurized cylinder. For convenience, the stress-intensity factor was written as

$$K_I = \frac{pR}{t} \sqrt{\pi a} F_i \left(\frac{a}{c}, \frac{a}{t}, \frac{t}{R}, \phi \right) \quad (6)$$

where pR/t is the "average" hoop stress and F_i is the boundary-correction factor for a surface crack on the inside of an internally pressurized cylinder. The expression for F_i , in terms of G_j , was obtained from the first four terms of a power-series expansion of Lamé's solution with the coordinate origin at the inside of the cylinder, plus the internal pressure applied to the crack surfaces. The result is

$$F_i = \frac{t}{R} \left(\frac{R_0^2}{R_0^2 - R^2} \right) \left[2G_0 - 2 \left(\frac{a}{R} \right) G_1 + 3 \left(\frac{a}{R} \right)^2 G_2 - 4 \left(\frac{a}{R} \right)^3 G_3 \right] \quad (7)$$

where each G_j was obtained from the appropriate finite-element solution (Tables 1 and 2) for the particular values of t/R , a/c , a/t , and ϕ .

External Surface Crack. The stress-intensity factors for an external surface crack in an internally pressurized cylinder were also obtained from equations (3) through (5), again using Lamé's solution. The stress-intensity factor was written as

$$K_I = \frac{pR}{t} \sqrt{\pi a} F_e \left(\frac{a}{c}, \frac{a}{t}, \frac{t}{R}, \phi \right) \quad (8)$$

where F_e is the boundary-correction factor for a surface crack located on the outside of an internally pressurized cylinder. The expression for F_e , in terms of G_j , was obtained from the first four terms of a power-series expansion of Lamé's solution with the coordinate origin at the outside of the cylinder. The result is