Design and methods of construction of Welded Steel Merchant Vessels

Lecture 19

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**REPORT OF STRUCTURAL FAILURE OF INSPECTED VESSEL**
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## DESCRIPTION OF VESSEL

| NAME | OFFICIAL NO. | TYPE | M.C. DESIGN |
|---|---|---|---|
| SCHENECTADY | 242620 | Tank Vessel | T2-SE-A1 |
| **BUILDER** | | **BUILDER'S HULL NO.** | **DATE COMPLETED** |
| Kaiser Co., Inc., Portland, Ore. | | #1 | 31 Dec. 43 |
| **OWNER** | | **OPERATOR** | |
| War Shipping Administration | | Deconhill Shipping Company | |

## EXTENT OF WELDING

Hull all welded
No inner bottom

| | | | |
|---|---|---|---|
| Yes SIDE SHELL SEAMS | | | Yes DECK SEAMS |
| Yes SIDE SHELL BUTTS | Yes BOTTOM SEAMS | INNER BOTTOM SEAMS | Yes DECK BUTTS |
| Yes FRAMES TO SIDE SHELL | Yes BOTTOM BUTTS | INNER BOTTOM BUTTS | Yes BEAMS TO DECK |
| Yes BULKHEADS | Yes FLOORS TO SHELL | FLOORS TO INNER BOTTOM | Yes DECK TO SHELL |

## CIRCUMSTANCES SURROUNDING FAILURE

*(Attach all available details of ship's loading)*

| DATE OF FAILURE | TIME | SHIP'S LOCATION | |
|---|---|---|---|
| 16 Jan., 1943 | 2230 PWT | Tied up at fitting out pier, Swan Island | |
| **SHIP'S SPEED** | **COURSE** | **DRAFT FWD.** | **DRAFT AFT** |
| 0 | | 6'-4" | 17'-0" |
| **SEA CONDITION** | **WEATHER** | **DIRECTION OF WAVES WITH RESPECT TO SHIP** | |
| Still water | Clear | No waves | |
| **WIND FORCE** | **WIND DIRECTION** | **AIR TEMPERATURE** | **WATER TEMPERATURE** |
| Light | East wind | 26° F | 40° F |

## DESCRIPTION OF FAILURE

*(Include sketch of fracture showing starting point and relative location of welds and other structural features)*

APPARENT STARTING POINT: The fracture started at the juncture of the fashion plate at the aft starboard corner of the bridge superstructure and the sheer strake.

GENERAL HISTORY AND DESCRIPTION OF FAILURE, INCLUDING KNOWN CONTRIBUTORY FACTORS:

Without warning and with a report which was heard for at least a mile, the deck and sides of the vessel fractured just aft of the bridge superstructure. The fracture extended almost instanteously to the turn of the bilge port and starboard. The deck side shell, longitudinal bulkheads and bottom girders fractured. Only the bottom plating held. The vessel jack-knifed and the center portion rose so that no water entered the hull. The bow and stern settled into the silt of the river bottom. Sounding taken around the vessel eliminated the alleged possibility of the vessel having grounded amidships due to a drop in water level. A slight earth tremor was alleged to have occurred at the time of the casualty. The steel of the sheer strake was slightly below specification in yield point and ultimate strength. The deck stringer was low in yield point. Both steels were notch sensitive at low temperature, but there is no existing specification for this characteristic. The welds between the fashion plate and the sheer strake and between the sheer strake and stringer plate were found to contain defects.

CLASSIFICATION OF FAILURE: Broke in two

## DISPOSITION OF VESSEL

*Repaired, lost, etc.*

Vessel repaired and put in service.

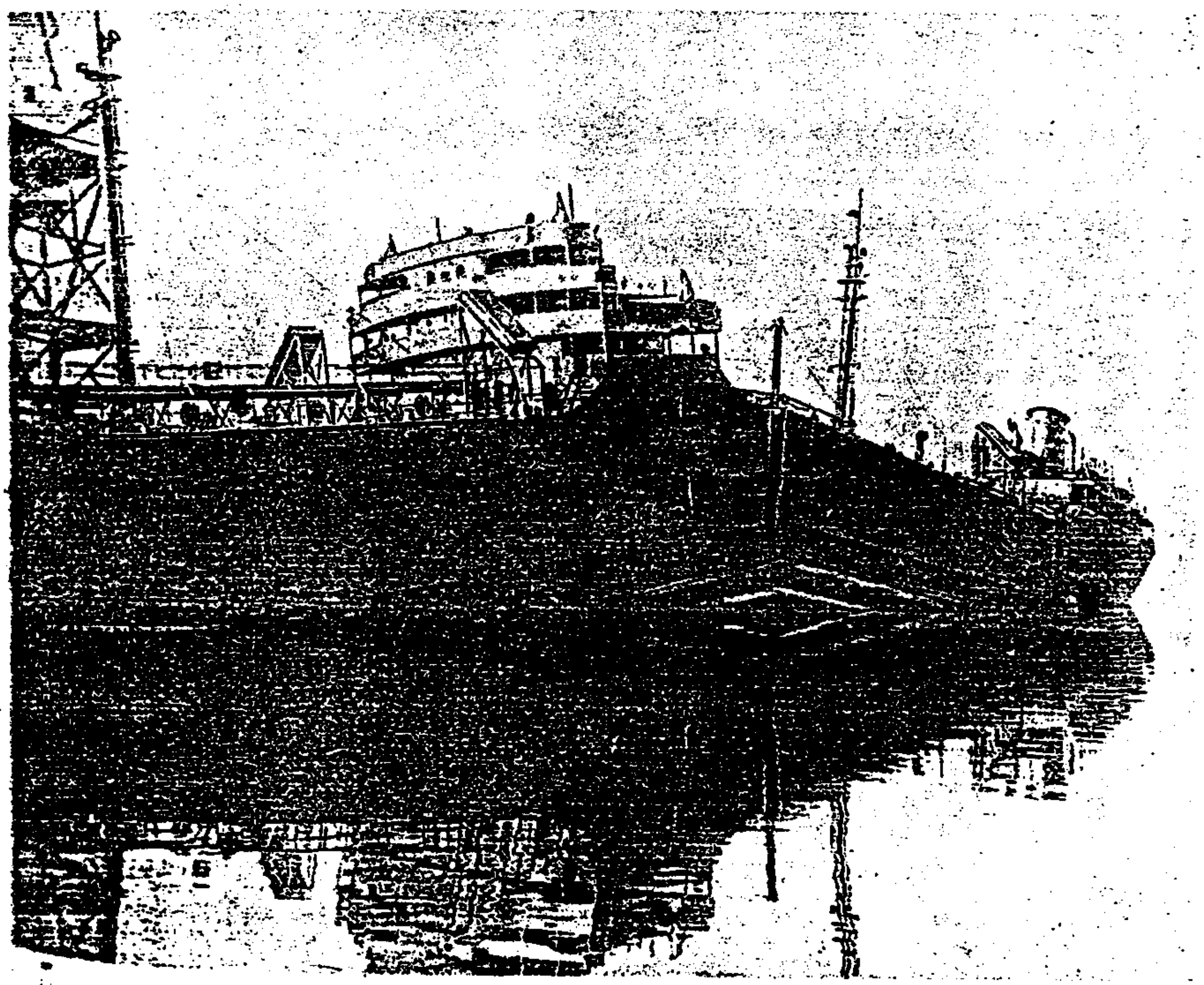
SIGNED (Name and Title)

See reverse side for loading details.

## Distribution of Weights

| | |
|---|---|
| Forepeak | 314 Long tons |
| Cargo tanks | 0 |
| F.W. Tanks | 71 |
| F.O. Bunkers Fwd. | 745 |
| F.O. Bunkers in E.R. | 486 |
| I.B. Tank 11-27 P. & S. | 73 |
| I.B. Tank 27-44 P. & S. | 166 |
| Ammunition Ford. | 20 |
| Ammunition Aft | 10 |
| Dist.Water Tank | 36 |
| F.W. Tank Aft | 29 |
| Aft Peak | 56 |
| Lightship | 5202 |
| Stores & Complement | 40 |
| Displacement | 7230 Long tons |
| Corresponding Keel Drafts | 7.0' Frd.<br>15.2' Aft |

On the basis of the loading indicated to the left, bending moment calculations were made. The uniform calculated stress in the crown of the deck in still water is 10,700 lbs./in.$^2$



*S. S. Schenectady*

# ARTICLE G-1000
# INTRODUCTION

This Appendix presents a procedure for obtaining the allowable loadings for ferritic pressure retaining materials in components. This procedure is based on the principles of linear elastic fracture mechanics. At each location being investigated a maximum postulated flaw is assumed. At the same location the *mode I stress intensity factor*[1] $K_I$ is produced by each of the specified loadings as calculated and the summation of the $K_I$ values is compared to a reference value $K_{IR}$ which is the highest critical value of $K_I$ that can be ensured for the material and temperature involved. Different procedures are recommended for different components and operating conditions.

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[1]The *stress intensity factor* as used in fracture mechanics has no relation to and must not be confused with the *stress intensity* used in Articles of this Section. Furthermore, stresses referred to in this Appendix are calculated normal tensile stresses not stress intensities in a defect free stress model at the surface nearest the location of the assumed defect.

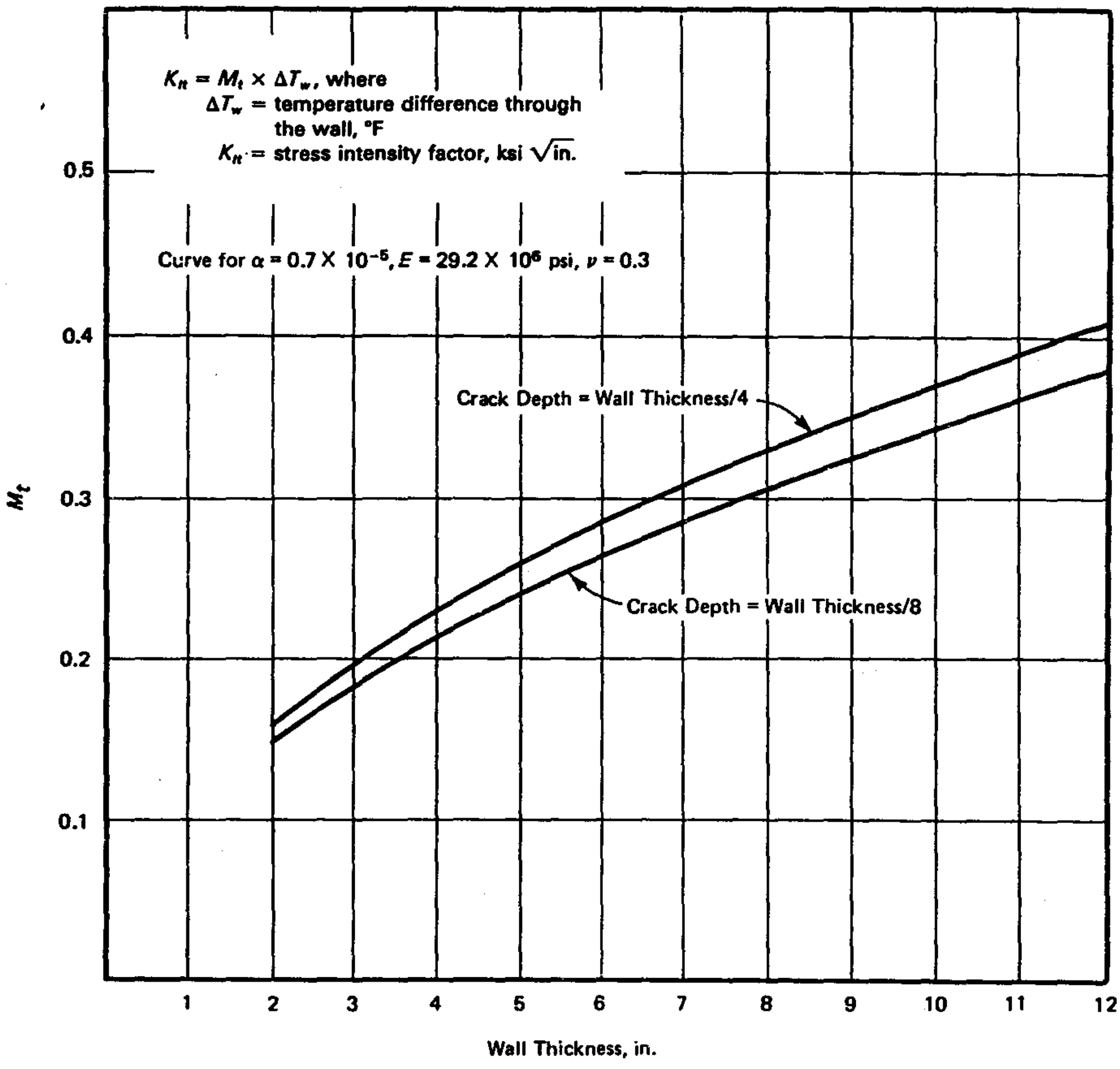
$K_{It} = M_t \times \Delta T_w$, where
$\Delta T_w$ = temperature difference through the wall, °F
$K_{It}$ = stress intensity factor, ksi $\sqrt{in.}$
Curve for $\alpha = 0.7 \times 10^{-5}$, $E = 29.2 \times 10^6$ psi, $\nu = 0.3$
Crack Depth = Wall Thickness/4
Crack Depth = Wall Thickness/8
$M_t$
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
7
8
9
10
11
12
Wall Thickness, in.

FIG. G-2214-2

vessel shell. Nondestructive examination methods shall be sufficiently reliable and sensitive to detect these smaller defects.

*(b)* WRCB 175 provides an approximate method in Paragraph 5C(2) for analyzing the inside corner of a nozzle and cylindrical shell for elastic stresses due to internal pressure stress.

*(c)* Fracture toughness analysis to demonstrate protection against nonductile failure is not required for portions of nozzles and appurtenances having a thickness of 2.5 in. or less, provided the lowest service temperature is not lower than $RT_{NDT}$ plus 60°F.

## G-2300 LEVEL C AND LEVEL D SERVICE LIMITS

### G-2310 RECOMMENDATIONS

The possible combinations of loadings, defect sizes, and material properties which may be encountered during Level C and Level D Service Limits are too diverse to allow the application of definitive rules, and it is recommended that each situation be studied on an individual case basis. The principles given in this Appendix may be applied, where applicable, with any postulated loadings, defect sizes, and material toughness which can be justified for the situation involved.

## G-2400 HYDROSTATIC TEST TEMPERATURE

*(a)* For system and component hydrostatic tests performed prior to loading fuel in the reactor vessel, it is recommended that hydrostatic tests be performed at a temperature not lower than $RT_{NDT}$ plus 60°F. The 60°F margin is intended to provide protection against nonductile failure at the test pressure.

*(b)* For system and component hydrostatic tests performed subsequent to loading fuel in the reactor vessel, the minimum test temperature should be determined by evaluating $K_I$. The terms given in (1) through (4) below should be summed in determining $K_I$:

*(1)* $1.5K_{Im}$ from G-2214.1 for primary membrane stress;

*(2)* $1.5K_{Ib}$ from G-2214.2 for primary bending stress;

*(3)* $K_{Im}$ from G-2214.1 for secondary membrane stress;

*(4)* $K_{Ib}$ from G-2214.2 for secondary bending stress.

$K_I$, calculated by summing the four values given in (1) through (4) above, shall not exceed the applicable $K_{IR}$ value.

*(c)* The system hydrostatic test to satisfy (a) or (b) above should be performed at a temperature not lower than the highest required temperature for any component in the system.

# ARTICLE G-4000
# BOLTING

## G-4100 GENERAL REQUIREMENTS

In the case of bolting materials for which impact tests are required, the tests and acceptance standards of this Section are considered to be adequate to prevent nonductile failure under the loadings and with the defect sizes encountered under normal, upset, and testing conditions. Level C and Level D Service Limits should be evaluated on an individual case basis (G-2300). Welding Research Council Bulletin 175 (WRCB 175) "PVRC Recommendations on Toughness Requirements for Ferritic Materials," provides procedures in Paragraph 7 for evaluating various defect sizes and associated toughness levels in bolting materials.

## Tutorial: 2 Flux Shielded Processes (Lecture 2&3)

1. List five functions of fluxes used in electric fusion welding processes.

2. Name four main types of SMAW covered electrode

3. What ultimate tensile strength do you expect in weld metal deposited with E7018 SMAW electrodes?

4. How do basic fluxes used in SAW differ from acid fluxes?

5. What welding positions can SAW be used in?

6. What are the advantages of FCAW as compared with SMAW?

# Tutorial: 3 Gas Shielded Processes (Lecture 4&5)

1. What are the three modes of droplet transfer in GMAW?

2. What is meant by "electrode stickout" in GMAW?

3. Is the welding electrode consumed in the GTAW process?

4. Name two shielding gases commonly used in GTAW.

5. What techniques can be used to compensate for the low deposition rate of GTAW?

7 What is the difference between non-transferred and transferred PAW?

8 What is meant by "keyhole penetration"?

# Tutorial: 4 Power Supplies & Heat Flow (Lecture 6,7,&8)

1. To maintain a constant heat input in spite of torch height variations, what type of power supply output characteristic is needed?

2. What are the main advantages of inverter power supplies?

3. What processes generate most of the heat input at the arc anode?

4. What is the typical range of arc thermal efficiency in GTAW?

5. Assume that in the example given on page 23 of the presentation the welding current is increased to 250 A. What would be the effect on (a) weld area? (b) the cooling rate on the weld centreline at 550 C?

## QW-254 (CONT'D)
## WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
### Submerged-Arc Welding (SAW)

| Paragraph | | Brief of Variables | Essential | Supplementary Essential | Nonessential | Special Process Essential Variables: Hardfacing Overlay (QW-216) | | Special Process Essential Variables: Corrosion-Resistant Overlay (QW-214) | |
|---|---|---|---|---|---|---|---|---|---|
| QW-410 Technique | .1 | ϕ String/weave | | | X | .10 | ϕ No. of elec. | .10 | ϕ No. of elec. |
| | .5 | ϕ Method cleaning | | | X | .38 | ϕ Multi- to single-layer | .38 | ϕ Multi- to single-layer |
| | .6 | ϕ Method back gouge | | | X | | | .40 | − Sup. device |
| | .7 | ϕ Oscillation | | X | X | .42 | ± Oscillation | .42 | ± Oscillation |
| | .8 | ϕ Tube-work distance | | | X | | | | |
| | .9 | ϕ Multi to single pass/side | | X | X | | | | |
| | .10 | ϕ Single to multi electrodes | | X | X | | | | |
| | .15 | ϕ Electrode spacing | | | X | | | | |
| | .25 | ϕ Manual or automatic | | | X | | | | |
| | .26 | ± Peening | | | X | | | | |

Legend:
+ Addition
− Deletion
> Increase/greater than
< Decrease/less than
↑ Uphill
↓ Downhill
← Forehand
→ Backhand
ϕ Change

## QW-254
## WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
### Submerged-Arc Welding (SAW)

| Paragraph | | Brief of Variables | Essential | Supplementary Essential | Nonessential | Special Process Essential Variables: Hardfacing Overlay (QW-216) | | Special Process Essential Variables: Corrosion-Resistant Overlay (QW-214) | |
|---|---|---|---|---|---|---|---|---|---|
| QW-402 Joints | .1 | $\phi$ Groove design | | | X | .16 | < finished $t$ | .16 | < finished $t$ |
| | .4 | − Backing | | | X | | | | |
| | .10 | $\phi$ Root spacing | | | X | | | | |
| | .11 | ± Retainers | | | X | | | | |
| QW-403 Base Metals | .5 | $\phi$ Group Number | | X | | .20 | $\phi$ P-Number | .20 | $\phi$ P-Number |
| | .6 | $T$ Limits | | X | | | | | |
| | .7 | $T/t$ Limits > 8 in. | X | | | | | | |
| | .8 | $\phi$ $T$ Qualified | X | | | | | | |
| | .9 | $t$ Pass > ½ in. | X | | | | | | |
| | .11 | $\phi$ P-No. qualified | X | | | | | | |
| | .13 | $\phi$ P-No. 9/10 | X | | | | | | |
| QW-404 Filler Metals | .4 | $\phi$ F-Number | X | | | .12 | $\phi$ AWS class. | .5 | $\phi$ A-Number |
| | .5 | $\phi$ A-Number | X | | | .17 | $\phi$ Nom. flux comp. | .17 | $\phi$ Nom. flux comp. |
| | .6 | $\phi$ Diameter | | | X | .24 | ± Sup. filler metal | .24 | ± Sup. filler metal |
| | .9 | $\phi$ Flux/wire class. | X | | | .25 | ± Sup. powder | | |
| | .10 | $\phi$ Alloy flux | X | | | .26 | > Sup. powder | | |
| | .24 | ± Supplemental | X | | | .27 | $\phi$ Alloy elements | | |
| | .25 | ± Sup. powder | X | | | .40 | $\phi$ >10% elec. dia. sup. filler | .40 | $\phi$ > 10% elec. dia. sup. filler |
| | .26 | > Sup. powder | X | | | | | | |
| | .27 | $\phi$ Alloy elements | X | | | | | | |
| | .29 | $\phi$ Flux designation | | | X | | | | |
| | .30 | $\phi$ $t$ | X | | | | | | |
| | .33 | $\phi$ AWS class. | | | X | | | | |
| | .34 | $\phi$ Flux type | X | | | | | | |
| | .35 | $\phi$ Flux/wire class. | | X | X | | | | |
| | .36 | Recrushed slag | X | | | | | | |
| QW-405 Positions | .1 | + Position | | | X | .4 | + Position | .4 | + Position |
| QW-406 Preheat | .1 | Decrease > 100°F | X | | | .4 | Dec. > 100°F preheat > Interpass | .4 | Dec. > 100°F preheat > Interpass |
| | .2 | $\phi$ Preheat maint. | | | X | | | | |
| | .3 | Increase > 100°F (IP) | | X | | | | | |
| QW-407 PWHT | .1 | $\phi$ PWHT | X | | | .5 | $\phi$ PWHT | .5 | $\phi$ PWHT |
| | .2 | $\phi$ PWHT (T & T range) | | X | | | | | |
| | .4 | $T$ Limits | X | | | | | | |
| QW-409 Electrical Characteristics | .1 | $\phi$ I or > heat input | | X | | .1 | $\phi$ I or > heat input | .1 | $\phi$ I or > heat input |
| | .8 | $\phi$ Type I or $\phi$ I & E range | | | X | .4 | $\phi$ Current or polarity | .4 | $\phi$ Current or polarity |

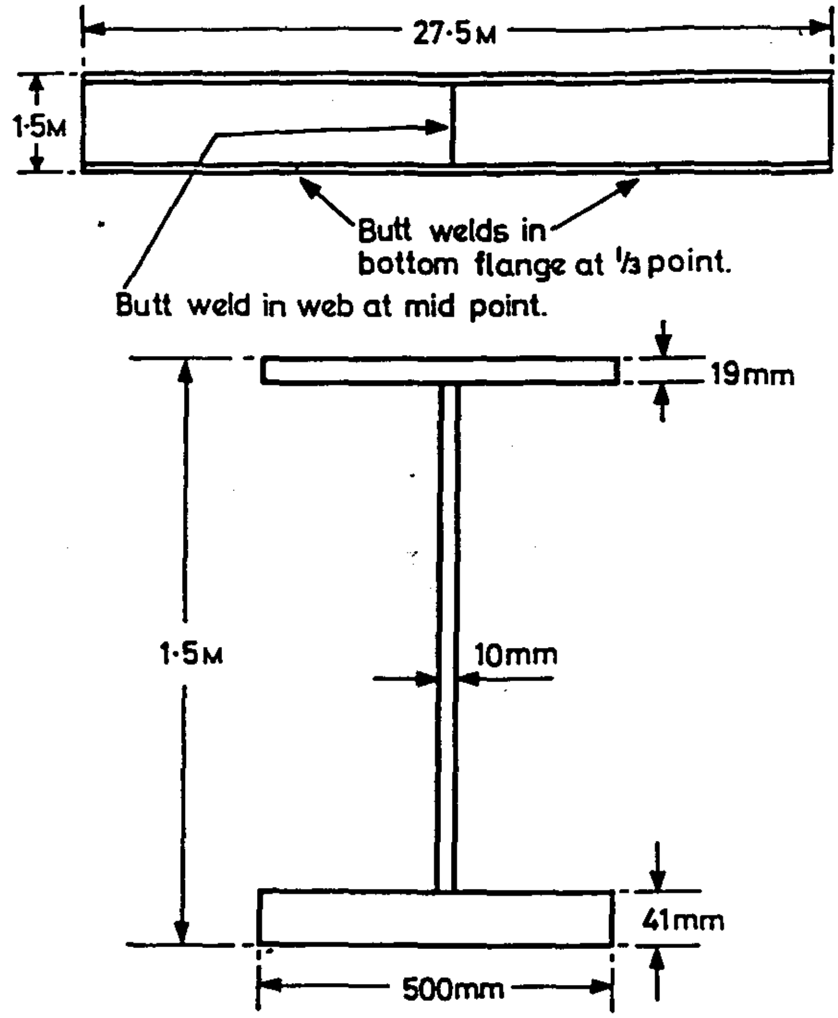


FIG. 1. DIMENSIONS OF GIRDER. (Not to scale)

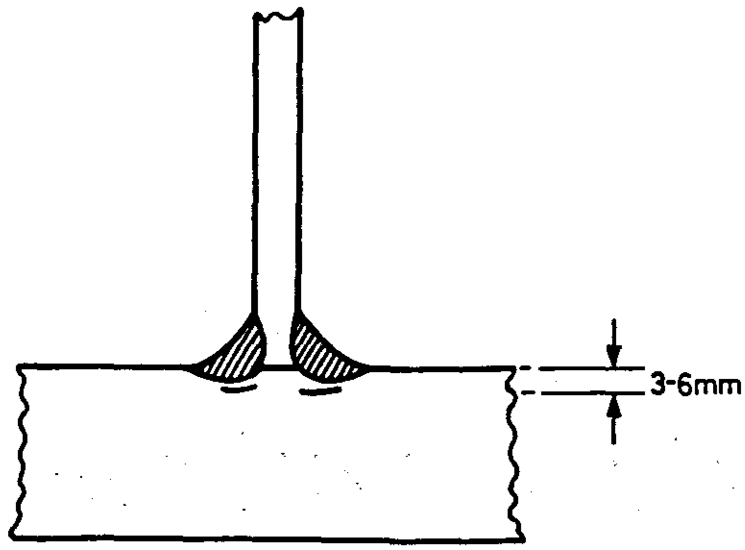


FIG. 2. POSITION OF CRACKS IN 41mm FLANGE. (Approx. to scale)

# Tutorial: 6 Weld Quality (Lecture 12,13&14)

1. Steel girders as shown in Figure 1 are being fabricated for a bridge project from a medium-carbon hot-rolled steel to ASTM A 36.The welding procedure for the web to flange fillet welds uses E7012 SMAW electrodes with a minimum preheat of 20 C. However, after production had begun, ultrasonic testing found defect indications in a girder near the fillets as shown in Figure 2. What types of discontinuity could have caused the UT indications? Give your reasoning.

2. Since the ultrasonic testing is rather slow, the inspector has suggested radiography to check the girders that had already been welded in the previous example. What would you say about the ability of radiography to detect such defects?

3. You are the welding engineer in a fabrication shop that is manufacturing several pressure vessels to ASME Code rules. Notch toughness requirements are specified for the vessels, and the submerged arc process used for the main seams has been qualified in accordance with ASME Section IX. One day, the production manager suggests to you that the welds could be made quicker if the welding current and voltage were increased. What would you tell him?