Archive

78491

BASIC NAVAL ARCHITECTURE

INSTRUCTOR'S GUIDE

AND PROBLEM SET

Prepared by

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for

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Volume II Units 12-26

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16. Abstract

A video lecture course presenting the fundamentals of naval architecture was developed as part of the government-industry-supported National Shipbuilding Research Program (NSRP). This publication, along with Volumes I and III, contains the instructor syllabus, problem sets, and solutions that complement the videotapes. The notes include many of the slides used in the videotapes and are intended to be used by the instructor for overhead transparencies.

The following topics are covered in this volume: Static Stability, Ship Hazards and Vulnerability, Submarine Hydrostatics and Stability, Forces Opposed to Propulsion, Propulsion Systems.

This material was developed to convey to trade school students the foundations of naval architecture. The level of material presented makes it suitable for engineers transferring into the field of naval architecture, a college level study course for students not majoring in the field (e.g. Ocean Engineering majors) or a naval or merchant marine officer candidate program.

The course consists of 45 videotapes (average length of 35 minutes each) presented in a classroom lecture format by Dr. Paul R. Van Mater Jr., of Giannotti and Associates Inc. An additional text is required for the course: *Modern Ship Design*, Second Edition, 1977, Thomas C. Gillmer, Naval Institute Press, Annapolis, MD 21402.

Inquiries regarding the purchase of the videotapes should be forwarded to the AVMAST Library, Marine Systems Division, University of Michigan Transportation Research Institute, 2901 Baxter Road, Ann Arbor, MI 48109, (313) 763-2465.

17. Key Words	18. Distribution Statement
Naval Architecture, Stability, Marine Engineering, Ship Propulsion, Ship Hazards	

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Unit Number: 27

Title: Maneuverability and ship control

Tape Running Time: $37^M\ 0^S$

Reading Assignment: MSD, pp 151-169

Additional References: PNA, pp 463-465, 477-481, 482-486, 489-495

INA, pp 274-288

Scope:

Basic concepts of lifting surfaces as applied to rudders are reviewed. Forces on a ship in a turn are explained. Phases of a turn are described. Maneuvering control devices, including bow thrusters, z-drives, active rudders are described.

Key Points to Emphasize:

1. Emphasize lift-drag characteristics of the rudder as a hydrofoil, Figs. 8-1, 8-2, MSD, pp 152, Figs. 35, 36, PNA, pp 494-495, Figs. 14-3, 14-4, INA, pp 266-267.

2. Explain Fig. 8-4, MSD, pp 153.

3. Discuss stall and cavitation applied to rudders.

4. Go over advance, transfer, tactical diameter.

5. Phases of a turn.

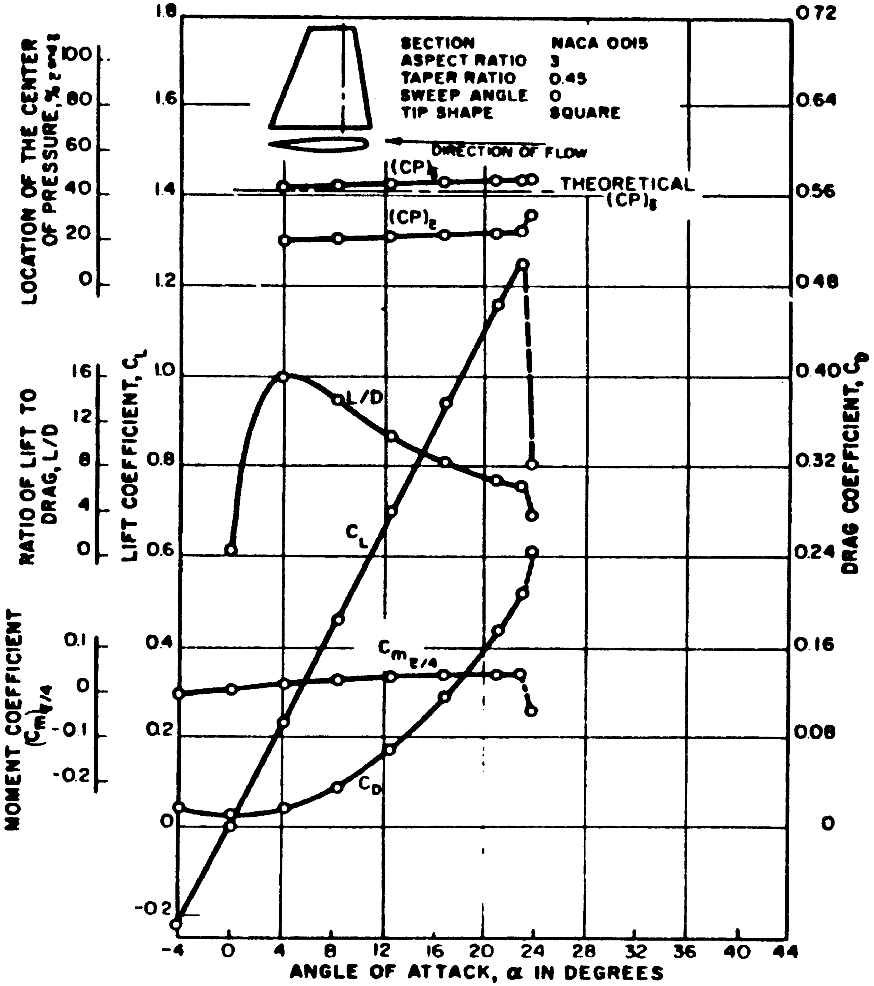
6. Explain Fig. 8-11, MSD, pp 160.

7. Discuss types of rudders and other control surfaces not covered in video tape.

Suggested Problem Assignment: Select from previously unassigned problems.

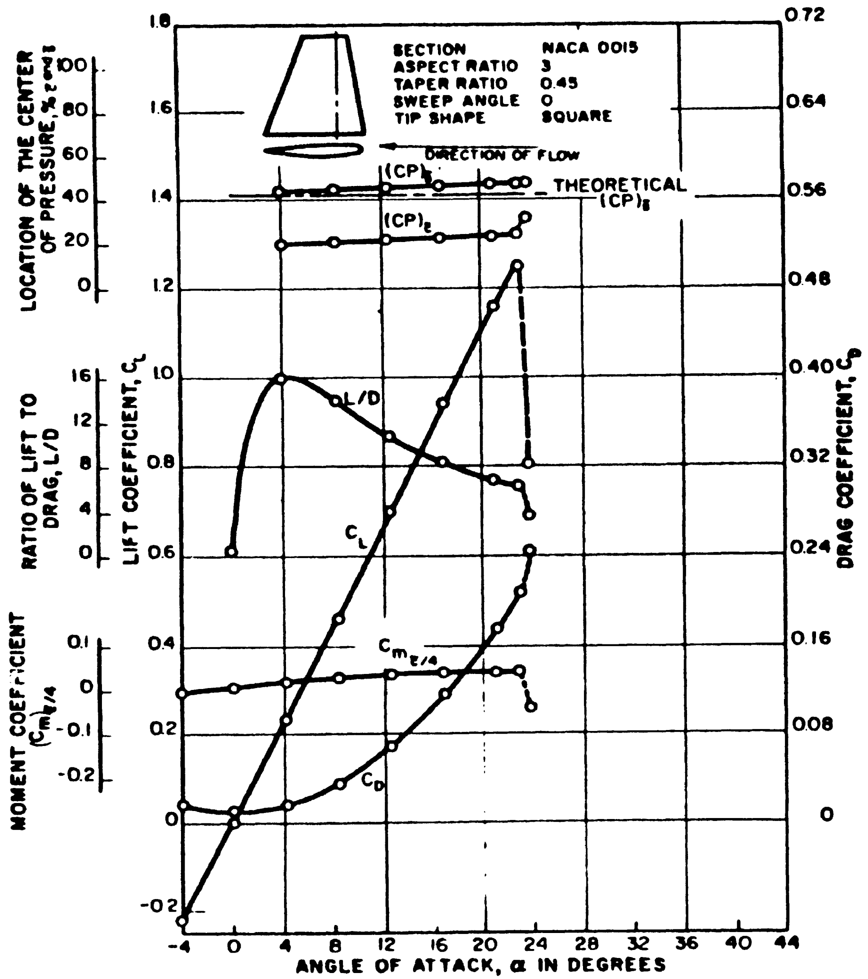
MANEUVERABILITY AND SHIP CONTROL

THE RUDDER - LIFT/DRAG DIAGRAM



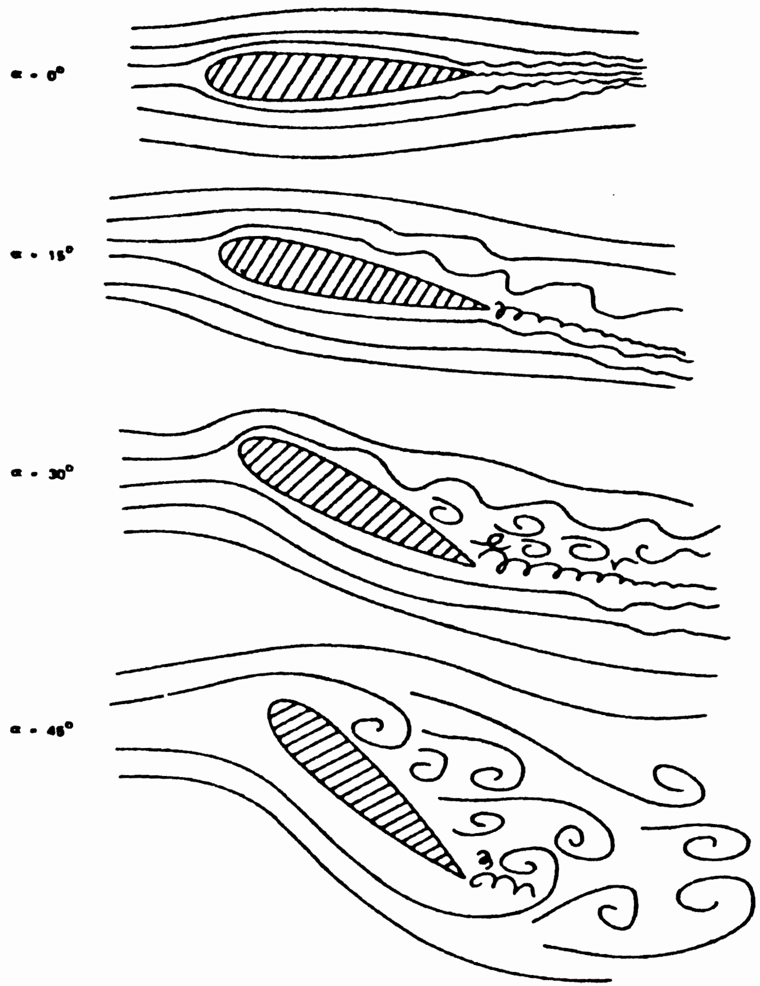
MANEUVERABILITY AND SHIP CONTROL

THE RUDDER - LIFT/DRAG DIAGRAM



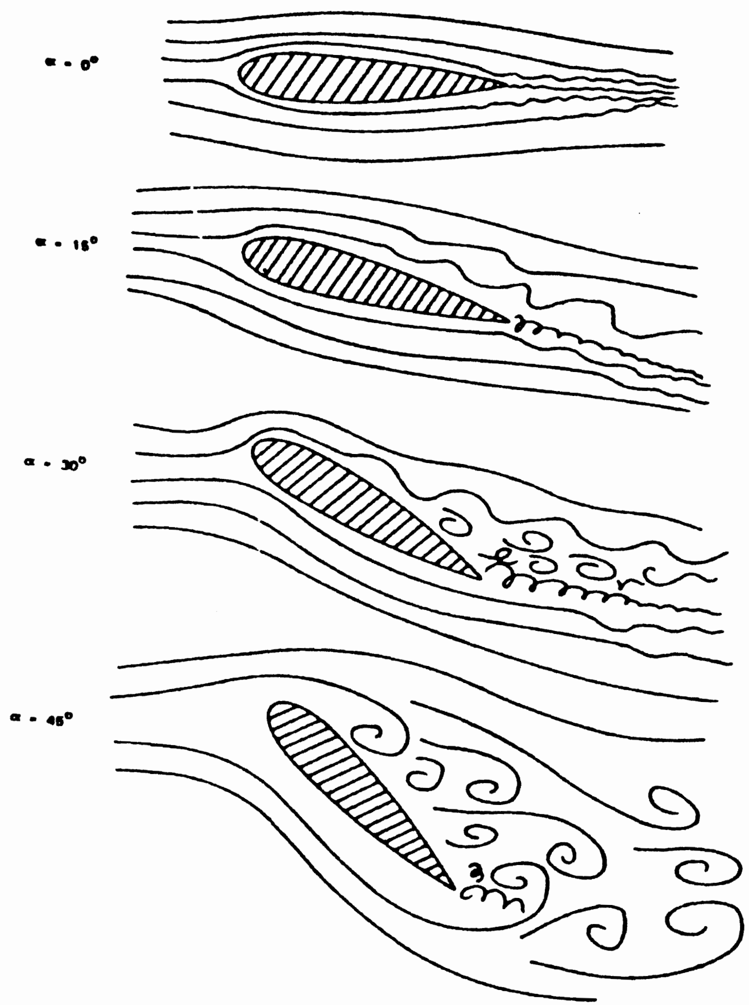
MANEUVERABILITY AND SHIP CONTROL

THE RUDDER - FLOW CONDITIONS



MANEUVERABILITY AND SHIP CONTROL

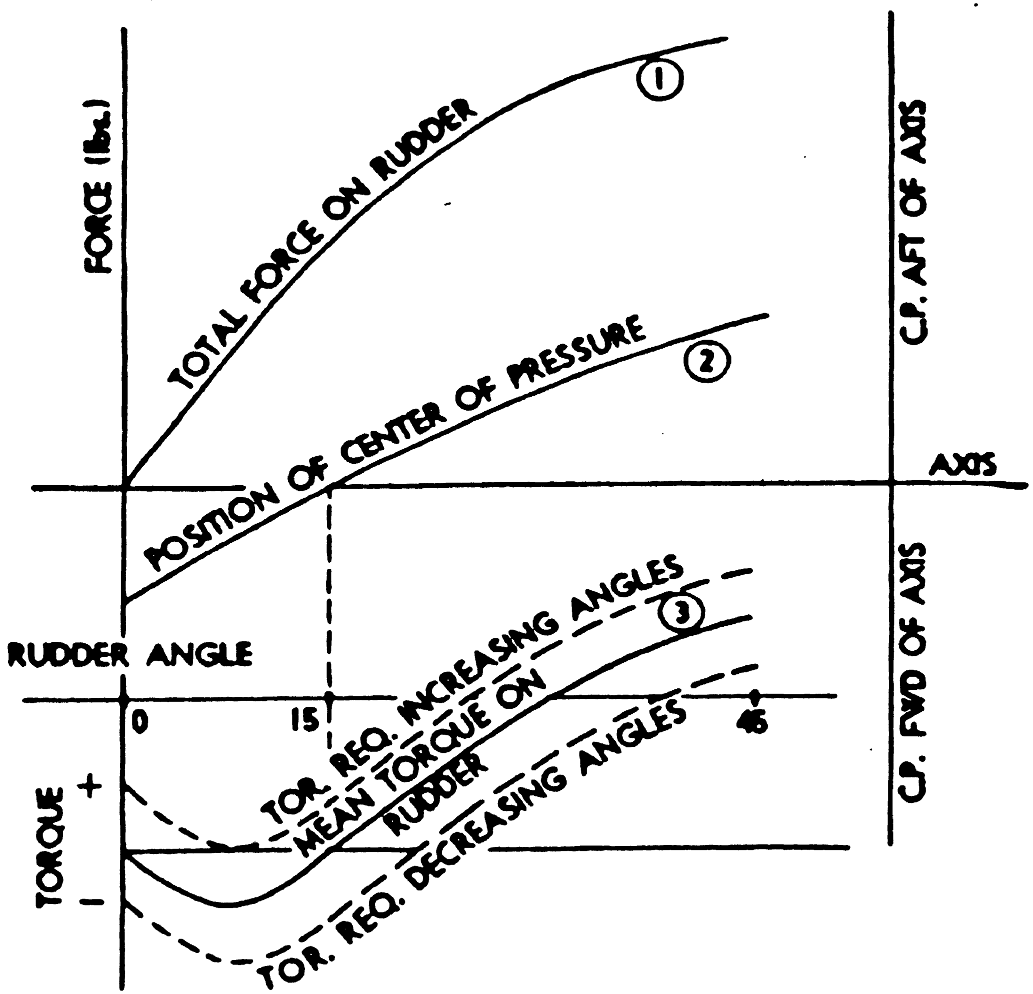
THE RUDDER - FLOW CONDITIONS



MANEUVERABILITY AND SHIP CONTROL

THE RUDDER

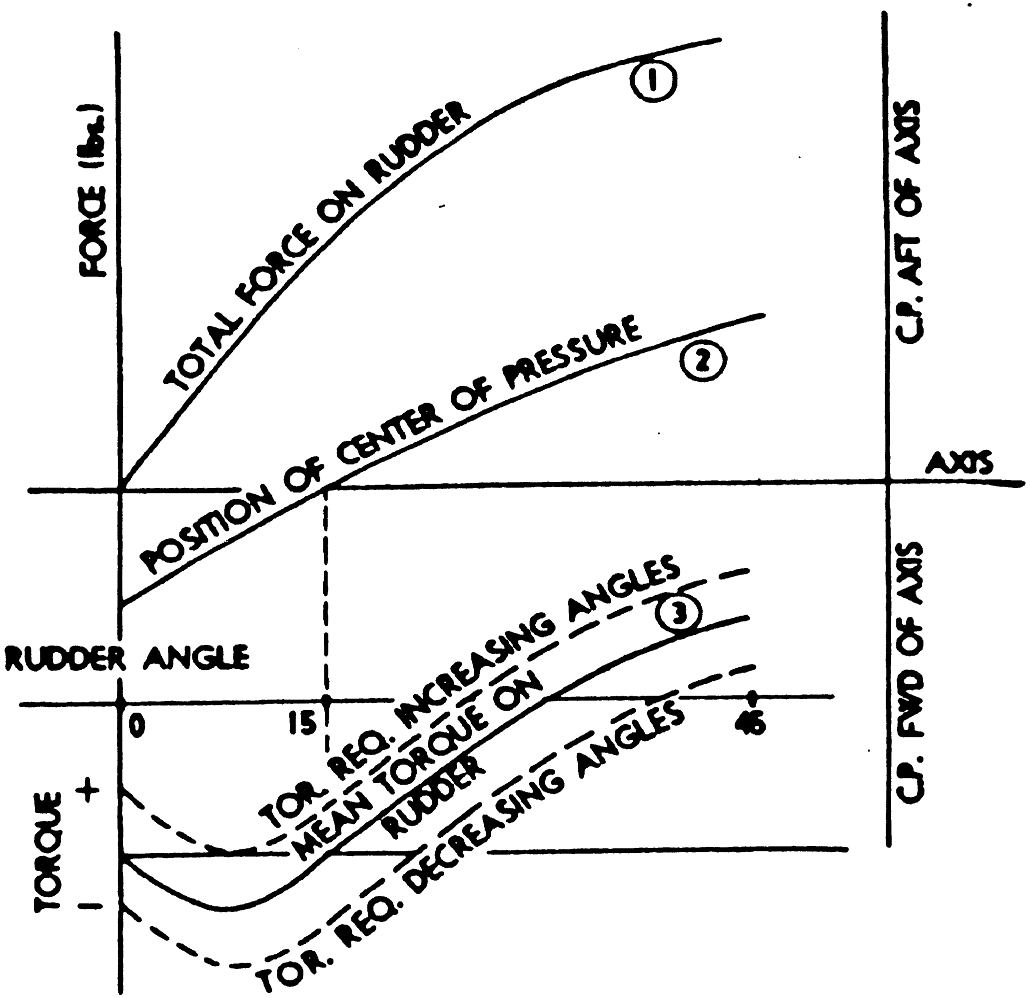
- FORCE, CENTER OF PRESSURE AND TORQUE.



MANEUVERABILITY AND SHIP CONTROL

THE RUDDER

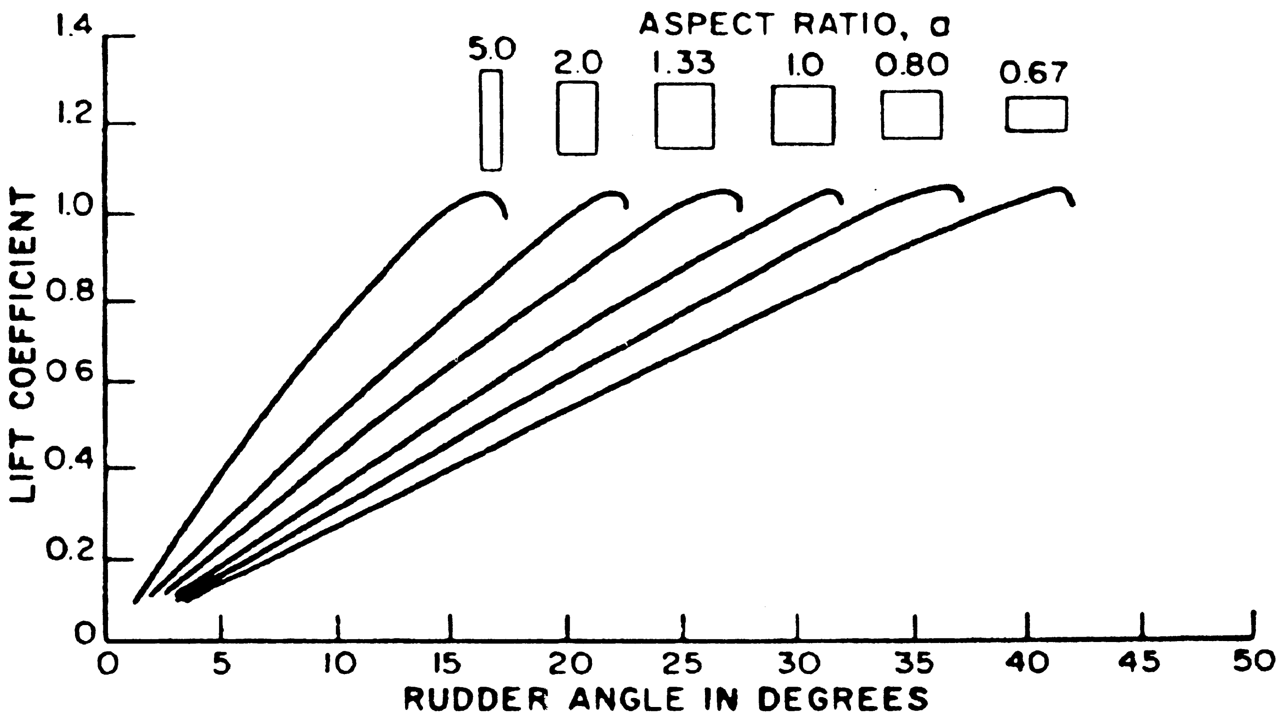
- FORCE, CENTER OF PRESSURE AND TORQUE.



MANEUVERABILITY AND SHIP CONTROL

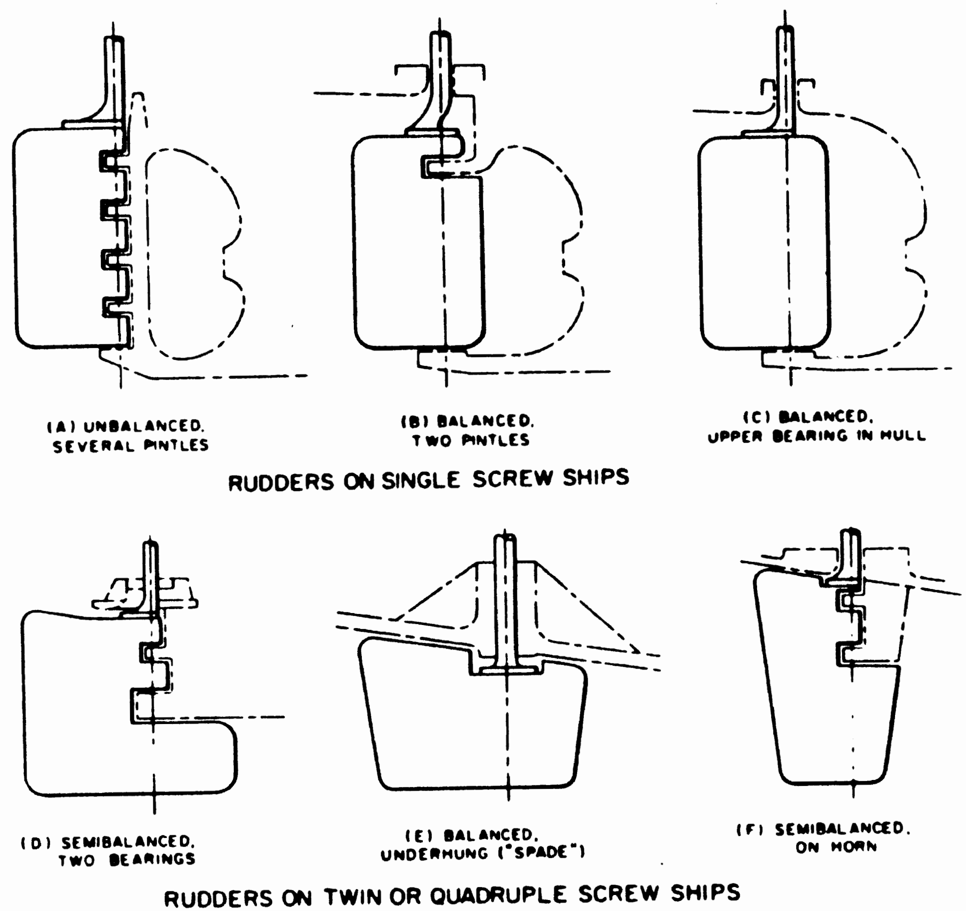
THE RUDDER - ASPECT RATIO

- ASPECT RATIO = $\frac{\text{SPAN}}{\text{CHORD}}$



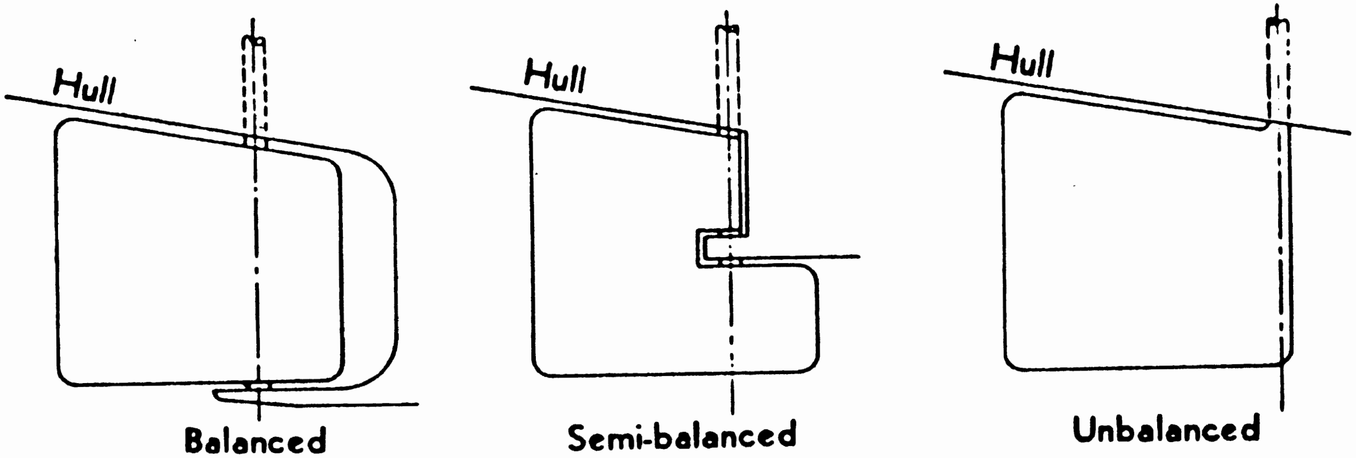
MANEUVERABILITY AND SHIP CONTROL

THE RUDDER - TYPES OF RUDDERS



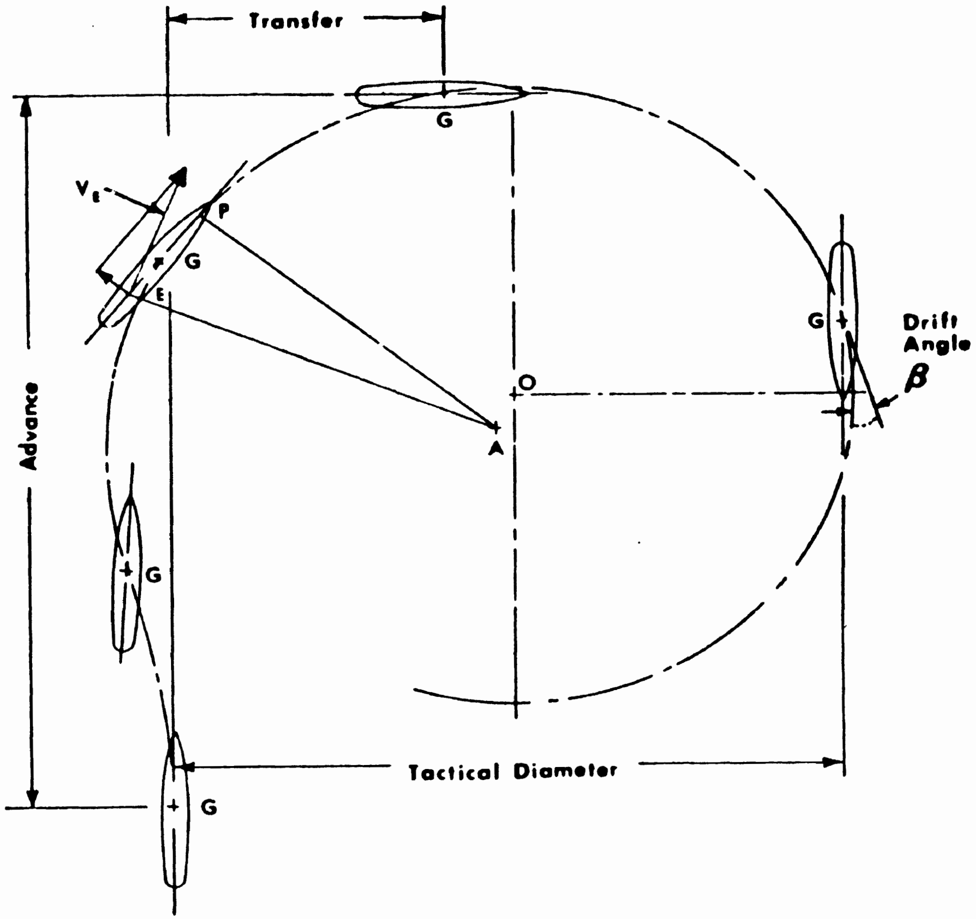
MANEUVERABILITY AND SHIP CONTROL

THE RUDDER - RUDDER BALANCE



MANEUVERABILITY AND SHIP CONTROL

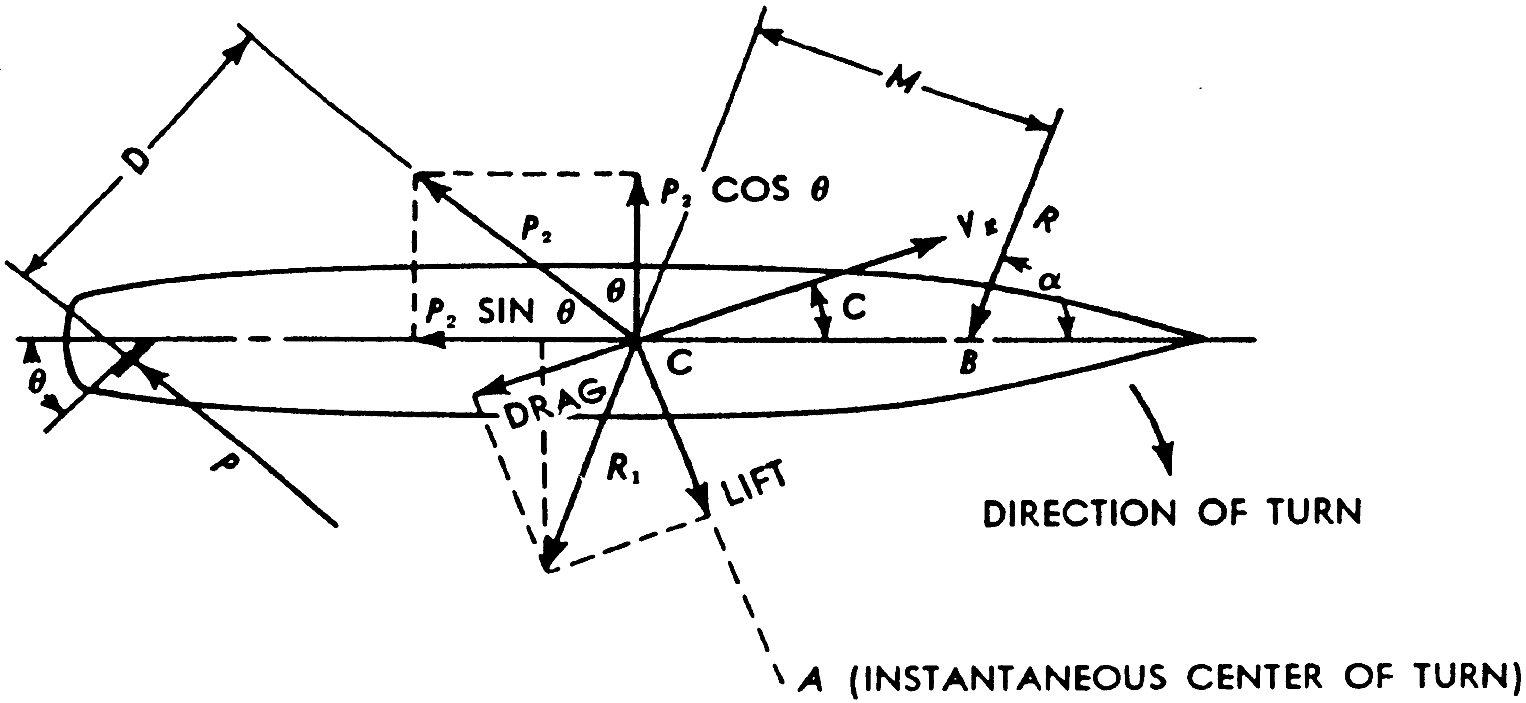
MOTION OF A SHIP IN TURNING



NOTE: POINT P IS THE PIVOT POINT.

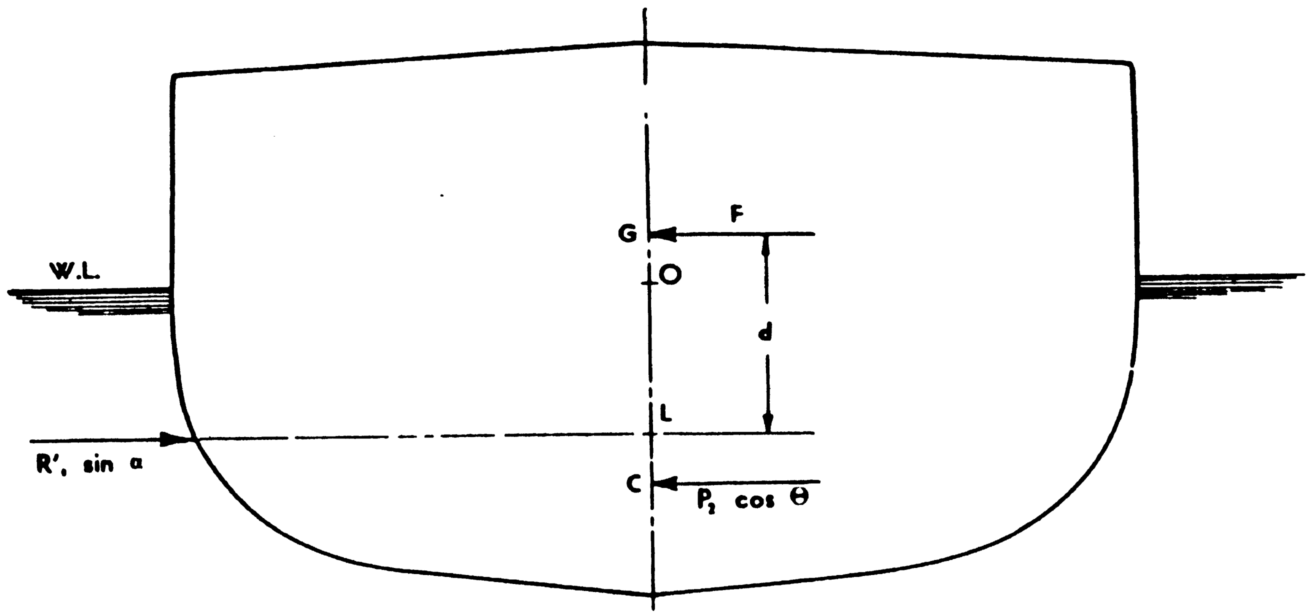
MANEUVERABILITY AND SHIP CONTROL

FORCES ON A SHIP IN A TURN



MANEUVERABILITY AND SHIP CONTROL

HEEL DURING A TURN



MANEUVERABILITY AND SHIP CONTROL

PHASES OF A TURN (CON'T)

- FIRST PHASE
  - SHIP ACCELERATES OUTWARD.
  - SHIP LOSES SPEED.
  - SHIP BEGINS TO ROTATE.
  - SHIP HEELS INWARD.

MANEUVERABILITY AND SHIP CONTROL

PHASES OF A TURN (CON'T)

- SECOND PHASE

  - BECAUSE OF THE OUTWARD MOTION OF THE HULL THE PRESSURE ALONG THE OUTWARD SIDE OF THE HULL INCREASES.

  - THIS PRESSURE AT FIRST IS WELL FORWARD, THEN BEGINS TO MOVE AFT.

  - SHIP BEGINS TO ACCELERATE INWARD.

  - INWARD HEEL CONTINUES, DIMINISHES, THEN HEELS OUTWARD.

MANEUVERABILITY AND SHIP CONTROL

PHASES OF A TURN (CON'T)

- STEADY TURNING PHASE

  - GREATEST ANGLE OF HEEL OCCURS WHEN SHIP CHANGES FROM INWARD HEEL TO OUTWARD HEEL BECAUSE OF OVERSHOOT.

  - MESSAGE TO THE SHIP OPERATOR. EASING THE HELM AT THIS POINT WILL ONLY AGGRAVATE THE OUTWARD HEEL. HOLD THE HELM STEADY AND, IF ABSOLUTELY NECESSARY, REDUCE SPEED.

MANEUVERABILITY AND SHIP CONTROL

CAVEAT

THE IDENTIFICATION OF SPECIFIC VENDORS IN THIS COURSE DOES NOT CONSTITUTE AN ENDORSEMENT OF THE DESCRIBED EQUIPMENT BY THE UNIVERSITY OF MICHIGAN OR THE COURSE SPONSORS.

MANEUVERABILITY AND SHIP CONTROL

MANEUVERING CONTROL DEVICES

- BOW THRUSTERS
  - TUNNEL TYPE
  - DIRECTIONAL THRUSTERS
- Z-DRIVE SYSTEMS
- ACTIVE RUDDER
- VERTICAL AXIS PROPELLERS (DISCUSSED IN UNIT 24)

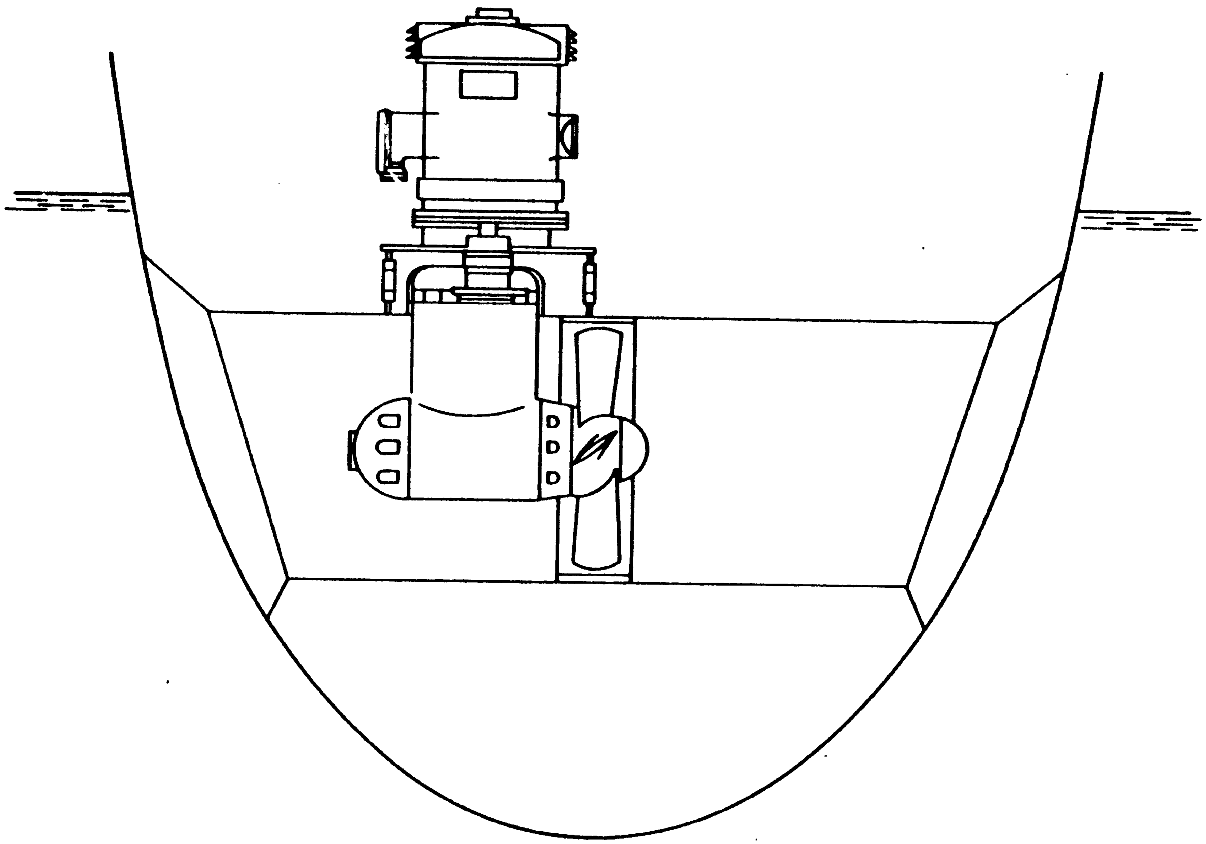
MANEUVERABILITY AND SHIP CONTROL

TUNNEL THRUSTERS

- CONTROLLABLE-PITCH OR FIXED-PITCH REVERSING.
- TRANSVERSE THRUST ONLY.
- GOOD THRUST/HP AT LOW SHIP SPEEDS, BUT AT SPEEDS ABOVE 3-4 KNOTS PERFORMANCE FALLS OFF RAPIDLY.
- TUNNEL MUST BE BELOW WATERLINE EVEN AT BALLAST DRAFT.

MANEUVERABILITY AND SHIP CONTROL

TUNNEL THRUSTERS



(MICHIGAN WHEEL CORP)

MANEUVERABILITY AND SHIP CONTROL

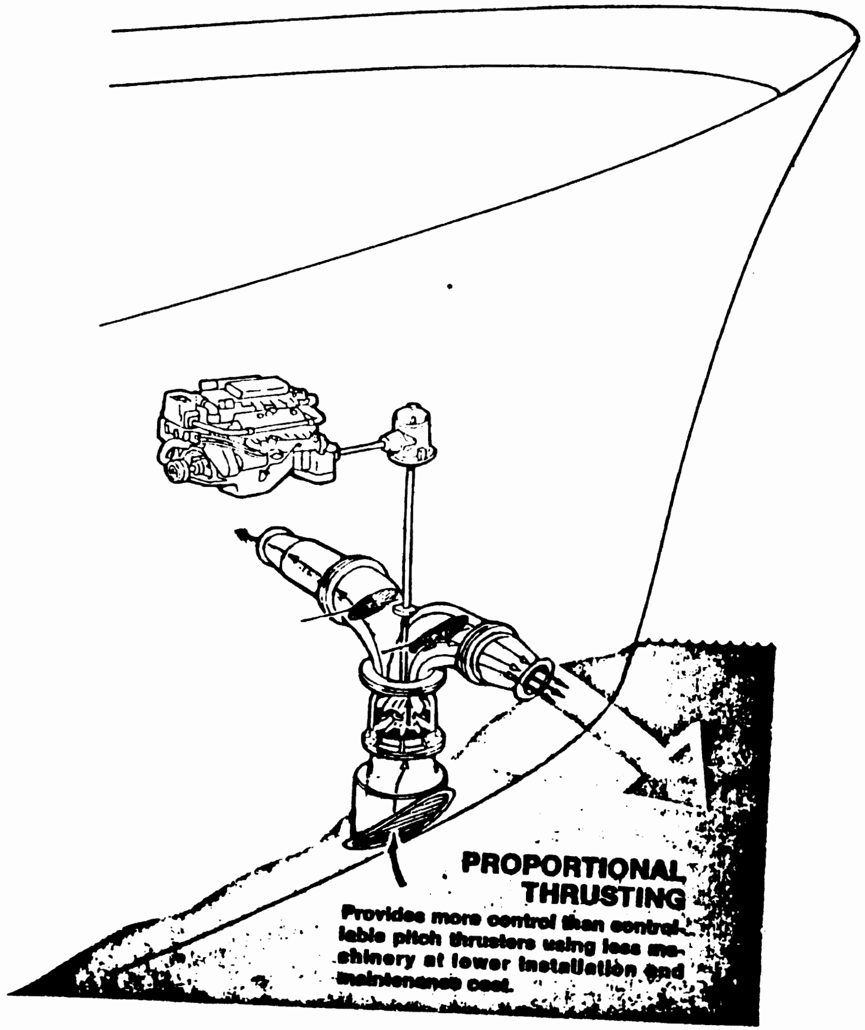
DIRECTIONAL THRUSTERS

- DIRECTION OF THRUST CAN BE CONTROLLED BY DIRECTING VANES IN THE OUTLET DUCT.

- SEVERAL DIFFERENT TYPES, BUT GENERALLY MORE EFFECTIVE AT HIGHER SHIP SPEEDS, SAY 10-12 KNOTS.

MANEUVERABILITY AND SHIP CONTROL

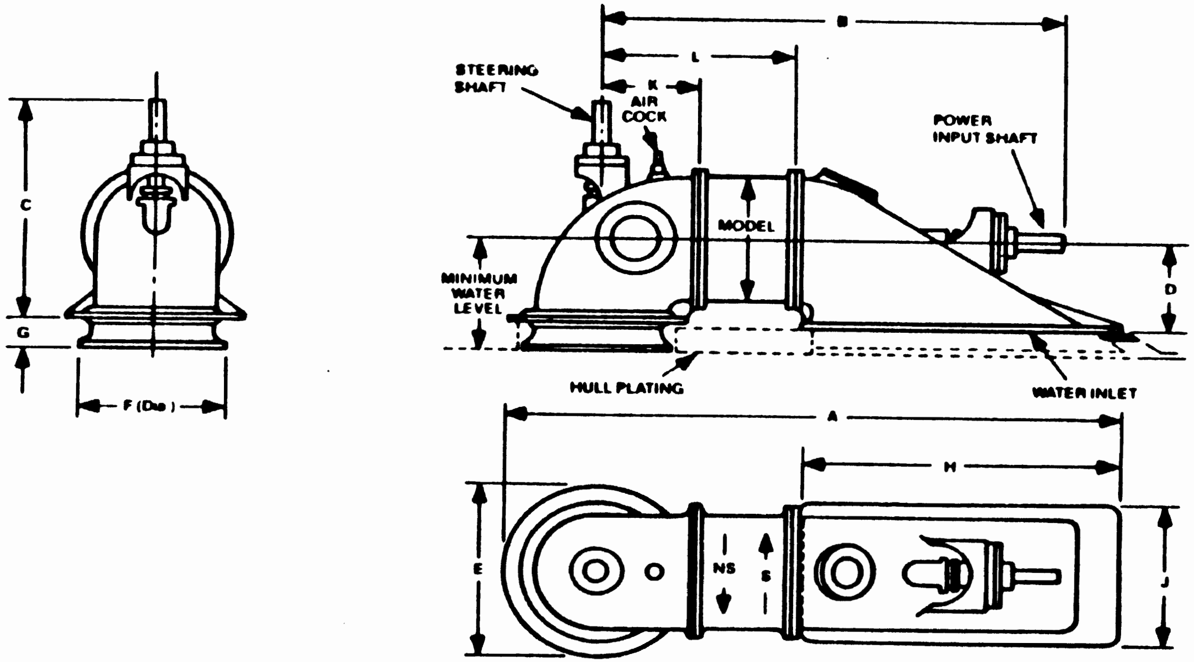
DIRECTIONAL THRUSTERS



(OMNITHRUSTER)

MANEUVERABILITY AND SHIP CONTROL

DIRECTIONAL THRUSTERS



(ELLIOT WHITE GILL™)

MANEUVERABILITY AND SHIP CONTROL

Z-DRIVES

- ALL MODELS ARE TRAINABLE, THAT IS, THEY MAY BE ROTATED AND PROVIDE THRUST THROUGH 360 DEGREES.

- RETRACTABLE AND NON-RETRACTABLE TYPES.

- NON-RETRACTABLE TYPES WILL INCREASE NAVIGATIONAL DRAFT IF LOCATED BELOW HULL.

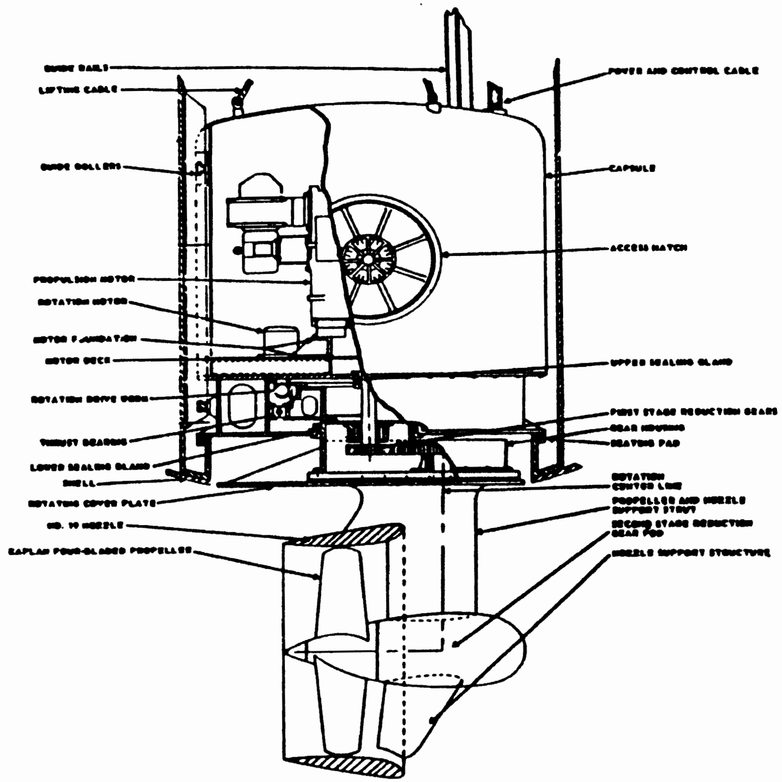
- CAN BE FITTED WITH NOZZLES.

MANEUVERABILITY AND SHIP CONTROL

Z-DRIVES

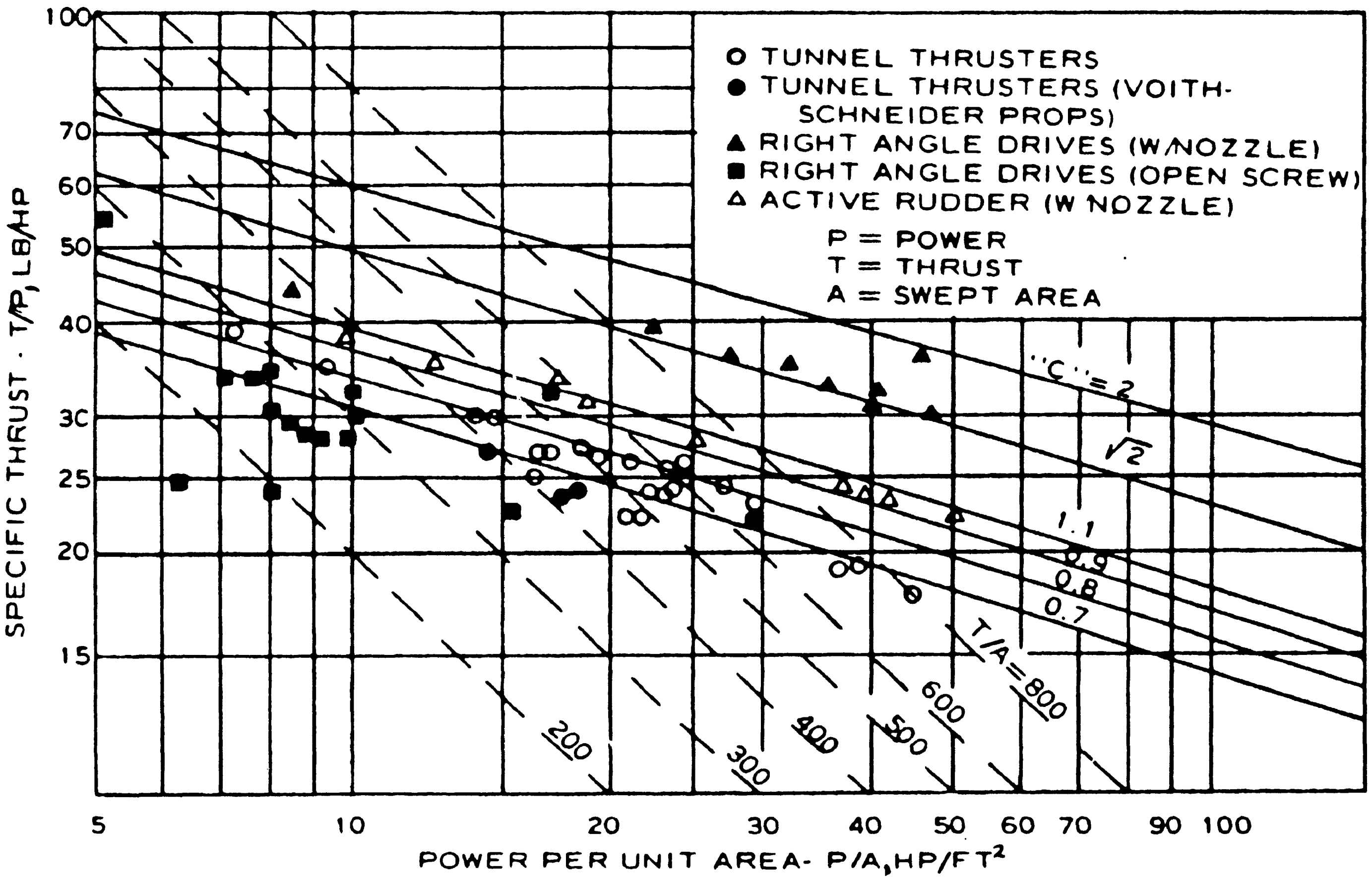
- **RETRACTABLE TYPE (ACTUALLY L-DRIVE).**

ELEVATION OF RETRACTABLE STEERING PROPELLER ASSEMBLY



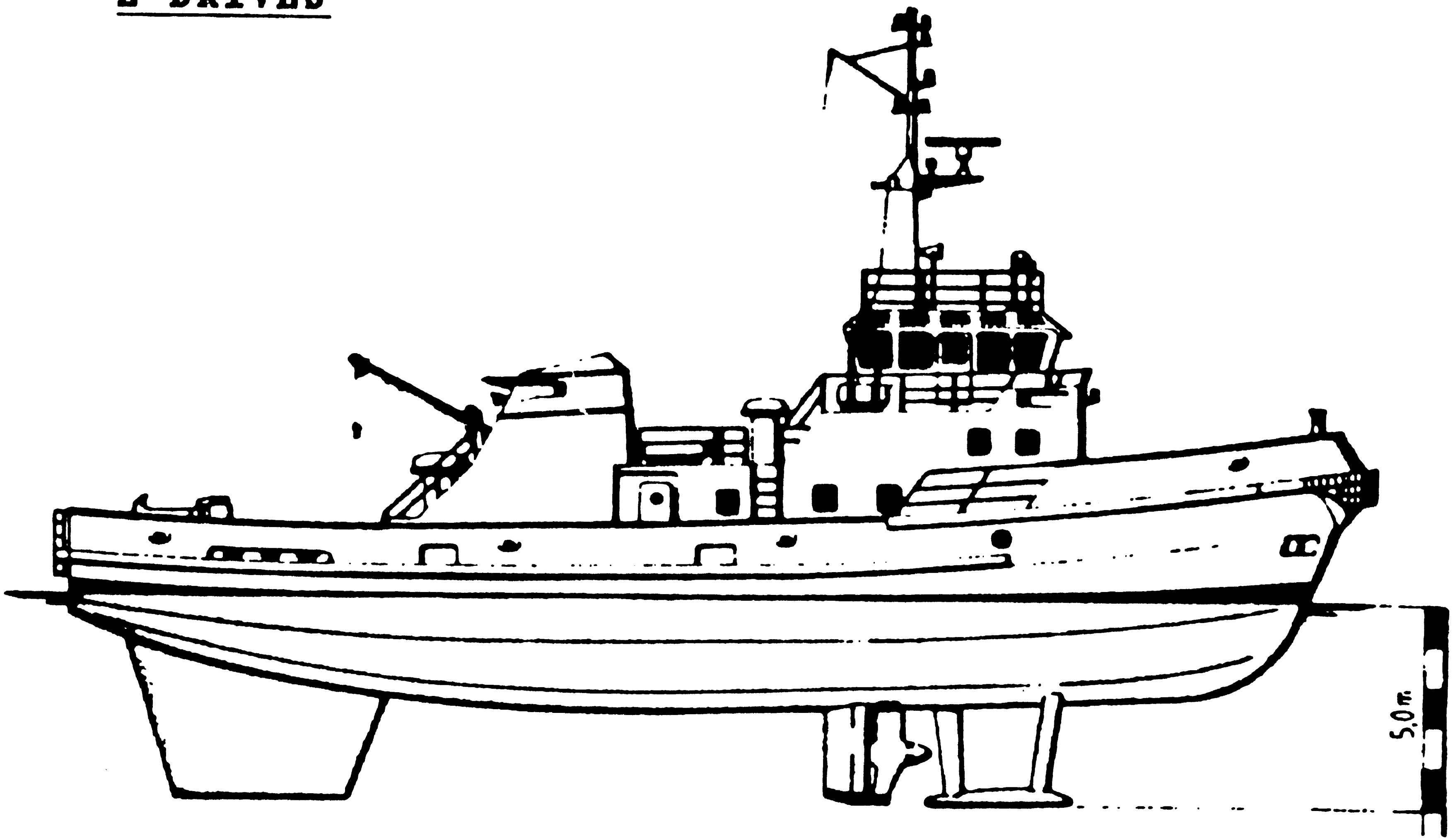
MANEUVERABILITY AND SHIP CONTROL

COMPARISON OF THRUSTER TYPES



MANEUVERABILITY AND SHIP CONTROL

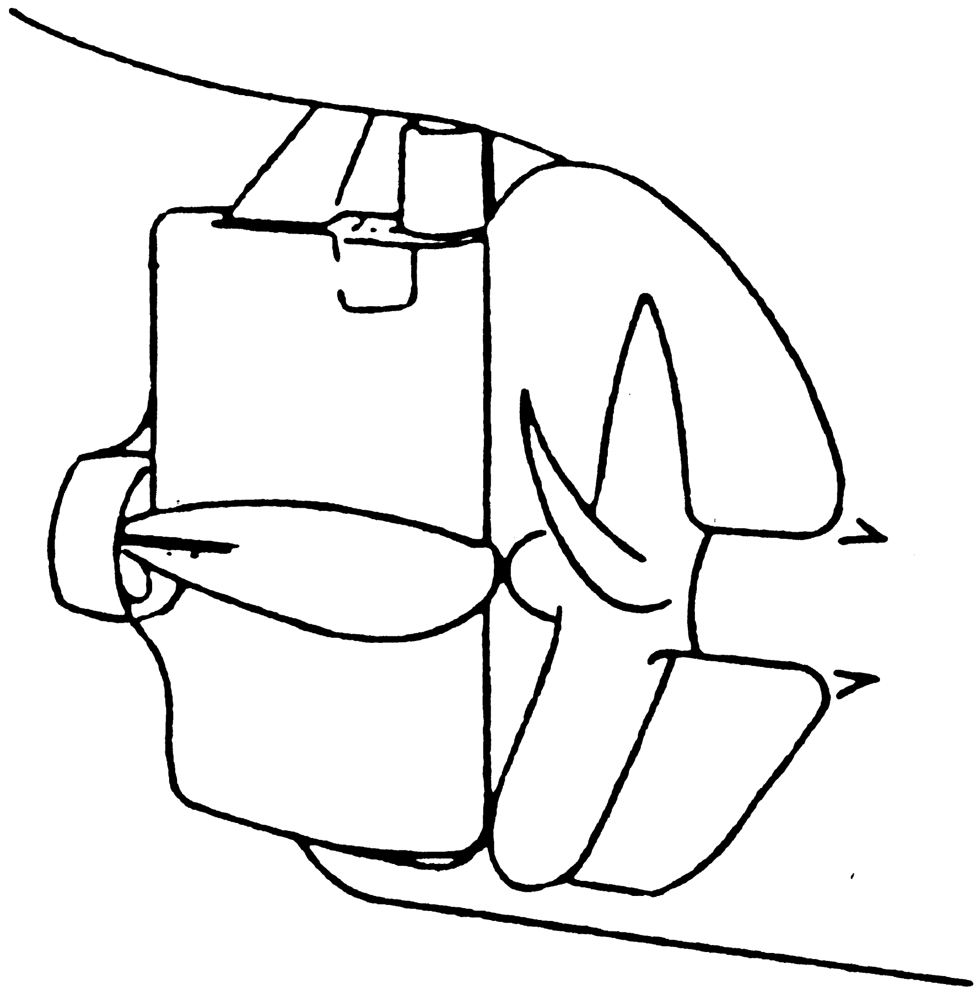
Z-DRIVES



(SCHOTTEL-WERFT)

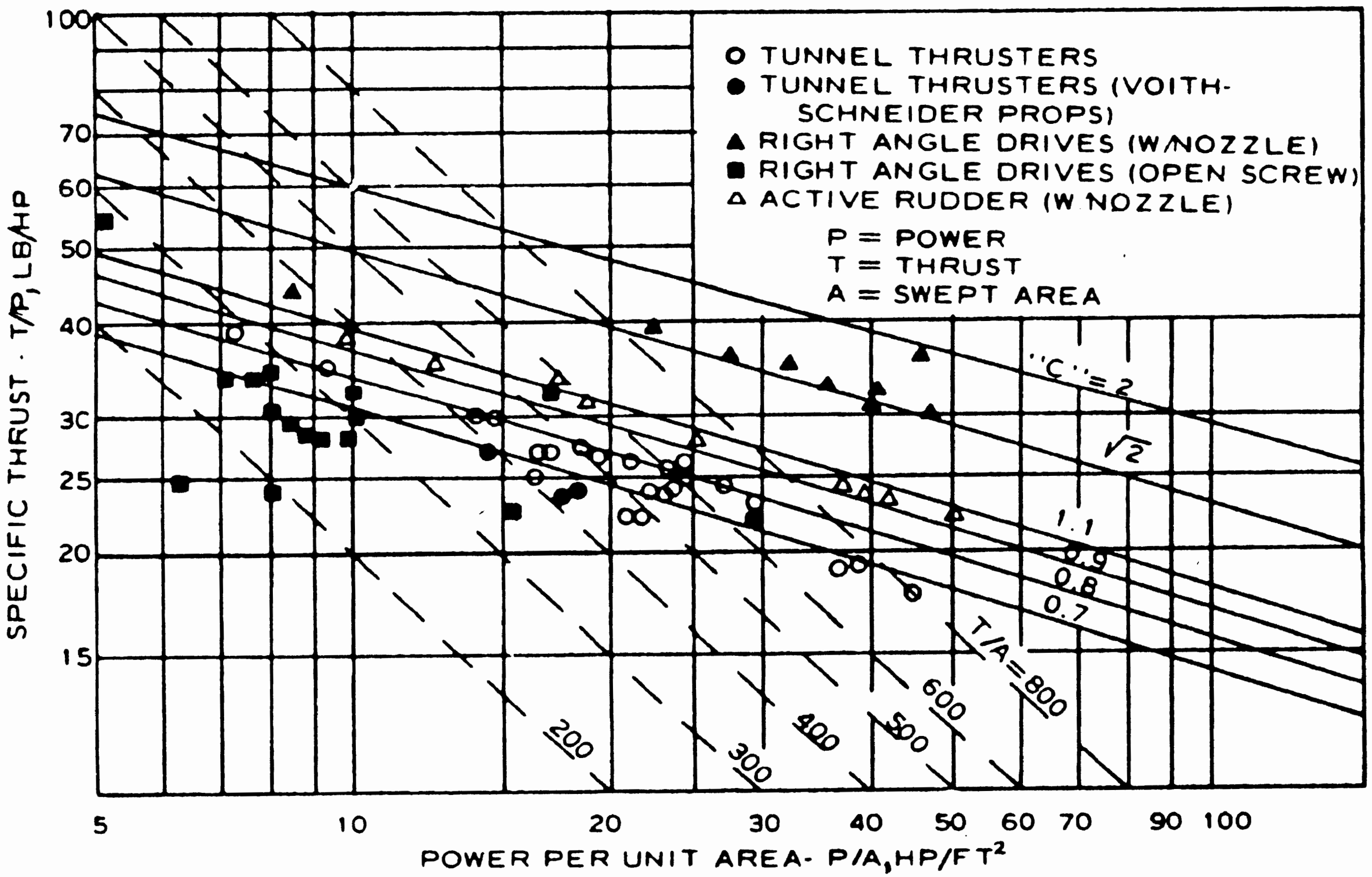
MANEUVERABILITY AND SHIP CONTROL

ACTIVE RUDDERS



MANEUVERABILITY AND SHIP CONTROL

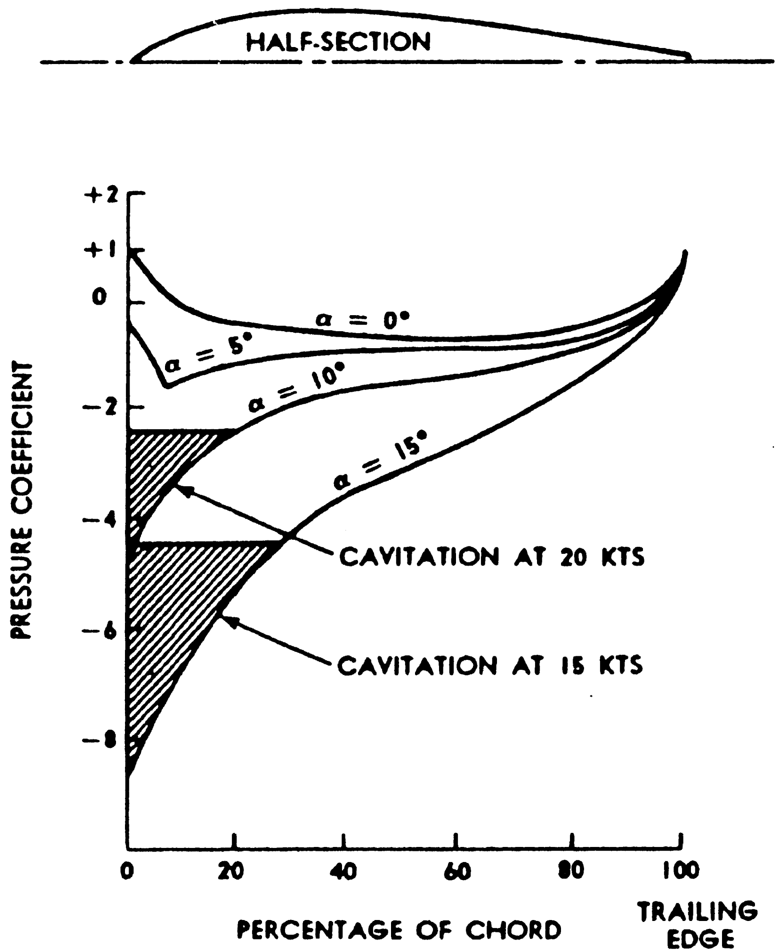
COMPARISON OF THRUSTER TYPES



GRAPHICS NOT USED IN PRESENTATION

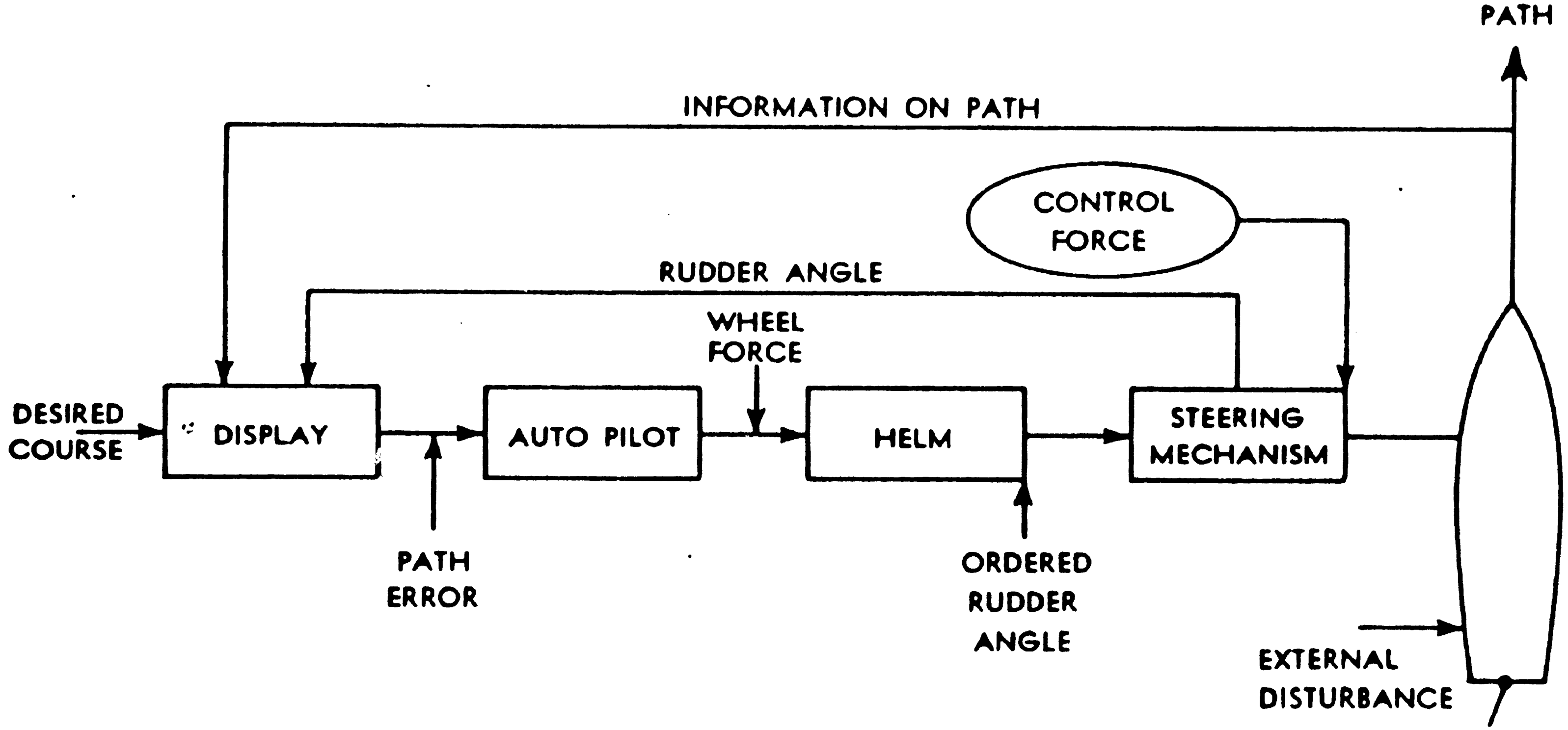
MANEUVERABILITY AND SHIP CONTROL

THE RUDDER - CAVITATION



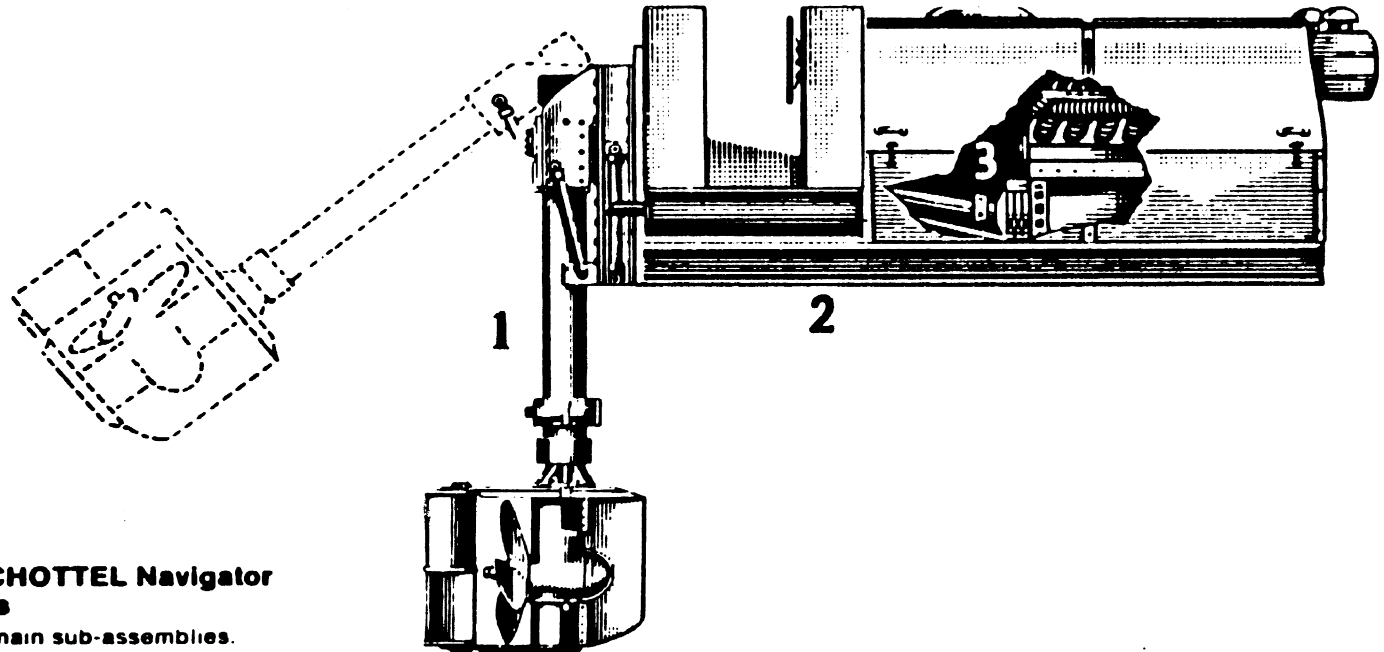
MANEUVERABILITY AND SHIP CONTROL

AUTO PILOT



MANEUVERABILITY AND SHIP CONTROL

Z-DRIVES

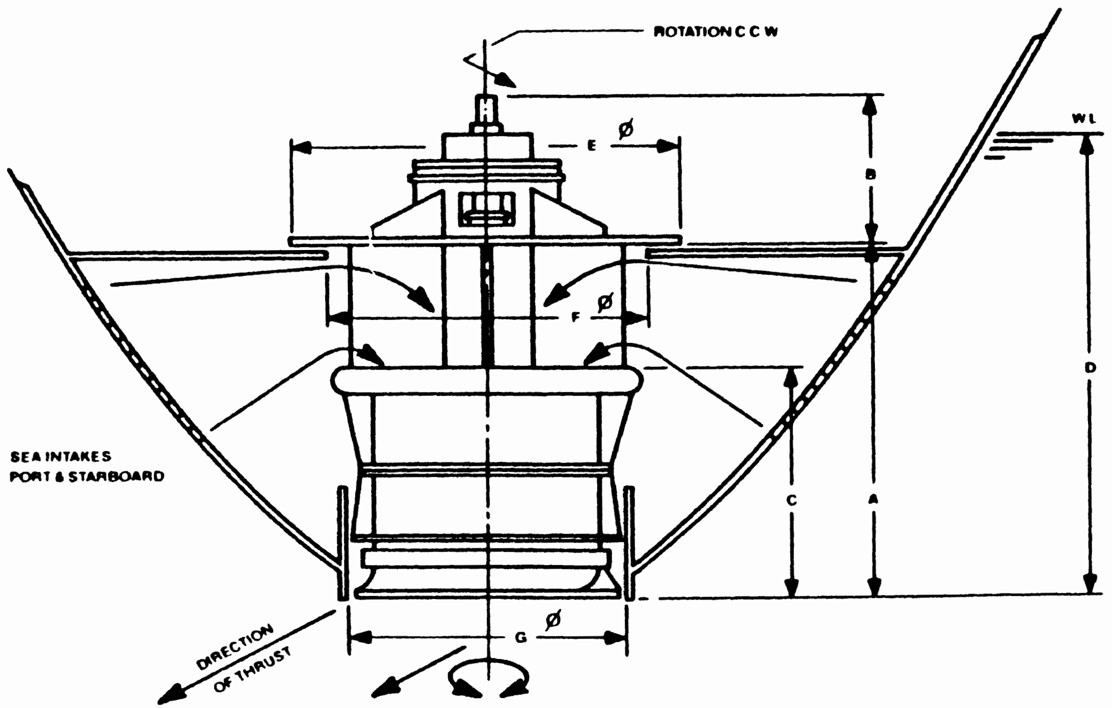


THE SCHOTTEL Navigator consists
of three main sub-assemblies.
1. SCHOTTEL Rudder-Propeller.
2. Bedplate.
3. Engine and clutch.

(SCHOTTEL-WERFT)

MANEUVERABILITY AND SHIP CONTROL

DIRECTIONAL THRUSTERS



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BASIC NAVAL ARCHITECTURE

Unit Number: 28

Title: The ship in motion with the sea - 1

Tape Running Time: 37^M 30^S

Reading Assignment: MSD, pp 235-243

Additional References: PNA, pp 607-627

INA, pp 254, 261

Scope:

The three rotational and three translational ship motions are defined. Basic concepts of sinusoidal and trochoidal gravity waves are introduced. The concept of a seaway spectrum is explained. Various ways of describing a seaway are described.

Key Points to Emphasize:

1. Student should be led to the concept of a seaway being a mix of wave energies of different frequencies. Fig. 11, PNA, pp 616 is important and should be stressed.

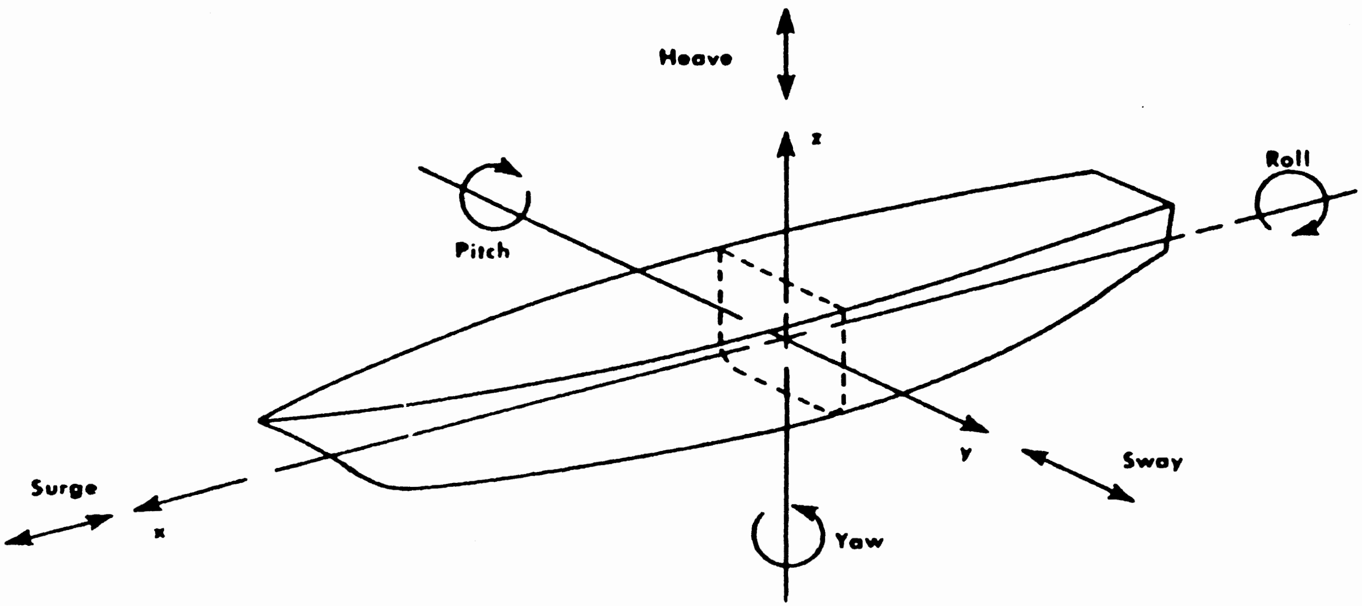
2. Meaning and usage of significant wave height, sea state and Beaufort Scale.

3. To give student an idea of scale, extreme or "episodic" waves in a seaway population may be 1.7 to 1.8 times as high as significant wave height. Relate to Sea State 7, which is a common design survival condition for naval combatants.

Suggested Problem Assignment: Select from previously unassigned problems.

THE SHIP IN MOTION WITH THE SEA

DEFINITION OF SHIP MOTIONS



THE SHIP IN MOTION WITH THE SEA

DEFINITION OF SHIP MOTIONS

ROTATIONAL MOTIONS		AXIS		TRANSLATIONAL MOTIONS
ROLL	---------	X-X AXIS	----------	SURGE
PITCH	---------	Y-Y AXIS	----------	SWAY
YAW	---------	Z-Z AXIS	----------	HEAVE

"VERTICAL PLANE MOTIONS"

PITCH
HEAVE
SURGE

NOTE: THE THREE ROTATIONAL MOTIONS AND THE THREE TRANSLATIONAL MOTIONS PROVIDE SIX DEGREES OF FREEDOM.

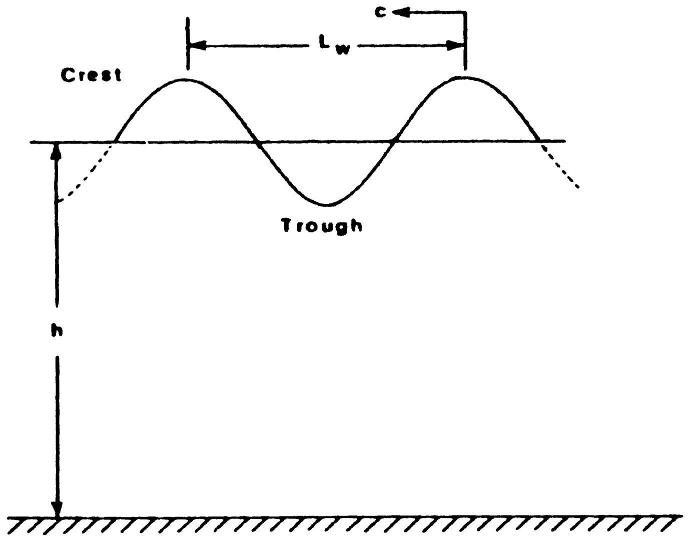
THE SHIP IN MOTION WITH THE SEA

"REGULAR" WAVES

- "REGULAR" WAVES ARE WAVES OF CONSTANT PERIOD, OR PERIODIC WAVES.
- THERE ARE A NUMBER OF WAVE THEORIES WHICH DESCRIBE PERIODIC WAVES.
- WE WILL ONLY ADDRESS,
  - SMALL AMPLITUDE SINUSOIDAL WAVES.
  - TROCHOIDAL WAVES.

THE SHIP IN MOTION WITH THE SEA

SINUSOIDAL WAVES



THE SHIP IN MOTION WITH THE SEA

SINUSOIDAL WAVES

- KEY RELATIONSHIPS:

$$T = \frac{L_W}{c}$$

$$c = 1.34 \sqrt{L_W}$$

$$T = .442 \sqrt{L_W}$$

$$L_W = .557\ c^2 = 5.118\ T^2$$

$$E = \left(\frac{\rho g}{8}\right) L_W\ a^2$$

WHERE

T = WAVE PERIOD, SEC

c = WAVE CELERITY (WAVE VELOCITY) KNOTS

L_W = WAVE LENGTH, FT.

a = WAVE HEIGHT, FT.

ρg = DENSITY OF WATER, LBS/FT^3

E = WAVE ENERGY PER FOOT OF WAVE BREADTH, $\frac{\text{FT-LBS}}{\text{FT.}}$

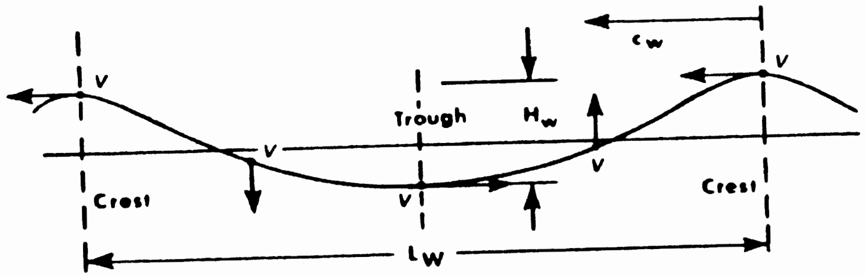
THE SHIP IN MOTION WITH THE SEA

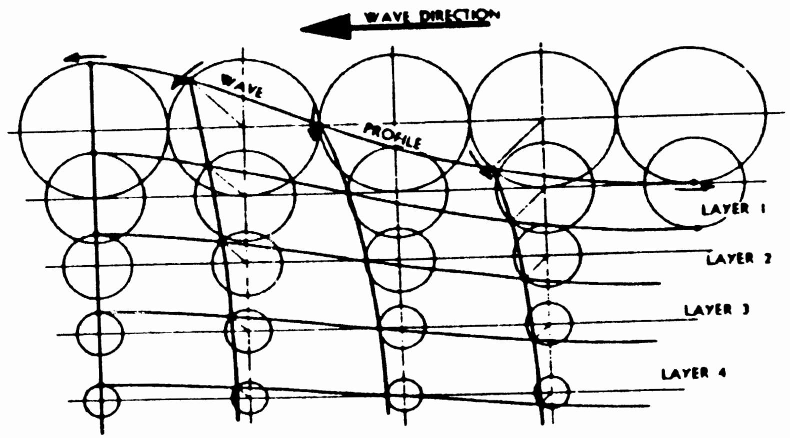
TROCHOIDAL WAVES

TROCHOIDAL WAVE THEORY GIVES A MORE REALISTIC REPRESENTATION OF THE PROFILE OF A PERIODIC WAVE THAN DOES A SINUSOIDAL WAVE, BUT BECAUSE IT IS REPRESENTED BY A PAIR OF PARAMETRIC EQUATIONS IT IS LESS CONVENIENT TO WORK WITH MATHEMATICALLY.

THE SHIP IN MOTION WITH THE SEA

TROCHOIDAL WAVES (CON'T)





THE SHIP IN MOTION WITH THE SEA

SEA SPECTRA

- RECALL THAT THE ENERGY PER FOOT OF WAVE BREADTH IS:

$$E = \frac{\rho g}{8} L_w a^2$$

- SINCE WAVE LENGTH, L_w, IS A FUNCTION OF WAVE PERIOD, T, OR WAVE FREQUENCY, f, THIS CAN ALSO BE WRITTEN,

$$E = \left(\frac{\rho g^2}{16\pi}\right) \cdot \left(\frac{a}{f}\right)^2 = \text{CONSTANT} \cdot \left(\frac{a}{f}\right)^2$$

WHERE a = WAVE HEIGHT
f = WAVE FREQUENCY, HERTZ, (CYCLES/SEC)

- WAVE ENERGY IS PROPORTIONAL TO THE SQUARE OF WAVE HEIGHT PER UNIT FREQUENCY.

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THE SHIP IN MOTION WITH THE SEA

ORBITAL MOTION OF WAVE PARTICLES

WATER PARTICLES MOVE IN APPROXIMATELY A CIRCULAR ORBIT. THIS ORBITAL MOTION HAS HYDRODYNAMIC EFFECTS ON THE PROPELLER AND THE RUDDER.

THE ORBITAL RADIUS DECREASES RAPIDLY WITH DEPTH. THERE IS VERY LITTLE MOTION LEFT AT A DEPTH OF $L_W/2$ AND PRACTICALLY NONE AT A DEPTH OF L_W.

THE SHIP IN MOTION WITH THE SEA

WIND GENERATED WAVES

- THE FRICTIONAL FORCE BETWEEN THE WIND AND THE WATER CAUSES WIND-GENERATED WAVES. THESE WAVES START AS SMALL WAVELETS AND BUILD UP TO VERY SEVERE SEAWAYS. THE MAJOR PARAMETERS ARE:
  - WIND FORCE (KNOTS).
  - DURATION OF STEADY WIND (HOURS).
  - FETCH IS THE DISTANCE OF OPEN OCEAN OVER WHICH THE STEADY WIND IS BLOWING.

- A WIND GENERATED SEAWAY CONTAINS A MIX OF WAVE HEIGHTS, WAVE LENGTHS AND WAVE DIRECTIONS.

THE SHIP IN MOTION WITH THE SEA

LONG-CRESTED WAVES

- LONG CRESTED WAVES, IN THEORY, ARE WAVES OF INFINITE BREADTH.
- LONG-CRESTED WAVES SELDOM OCCUR IN NATURE, BUT THE CONCEPT IS USEFUL IN ANALYZING SHIP MOTIONS.

THE SHIP IN MOTION WITH THE SEA

SHORT-CRESTED WAVES

- SHORT-CRESTED WAVES HAVE SHORT CRESTS AND ARE MORE REALISTIC. THEY OCCUR BECAUSE, IN NATURE, WAVES USUALLY COME FROM COMBINING WAVE SYSTEMS OF DIFFERING ENERGIES AND COMING FROM DIFFERING DIRECTIONS.

- SHORT CRESTED WAVES CAN BE REPRESENTED THEORETICALLY, BY COMBINING LONG-CRESTED WAVES COMING FROM DIFFERING DIRECTIONS. USUALLY THIS TYPE OF REPRESENTATION IS NOT WORTH THE ADDITIONAL COMPUTATIONAL COMPLEXITY.

THE SHIP IN MOTION WITH THE SEA

"IRREGULAR" WAVES

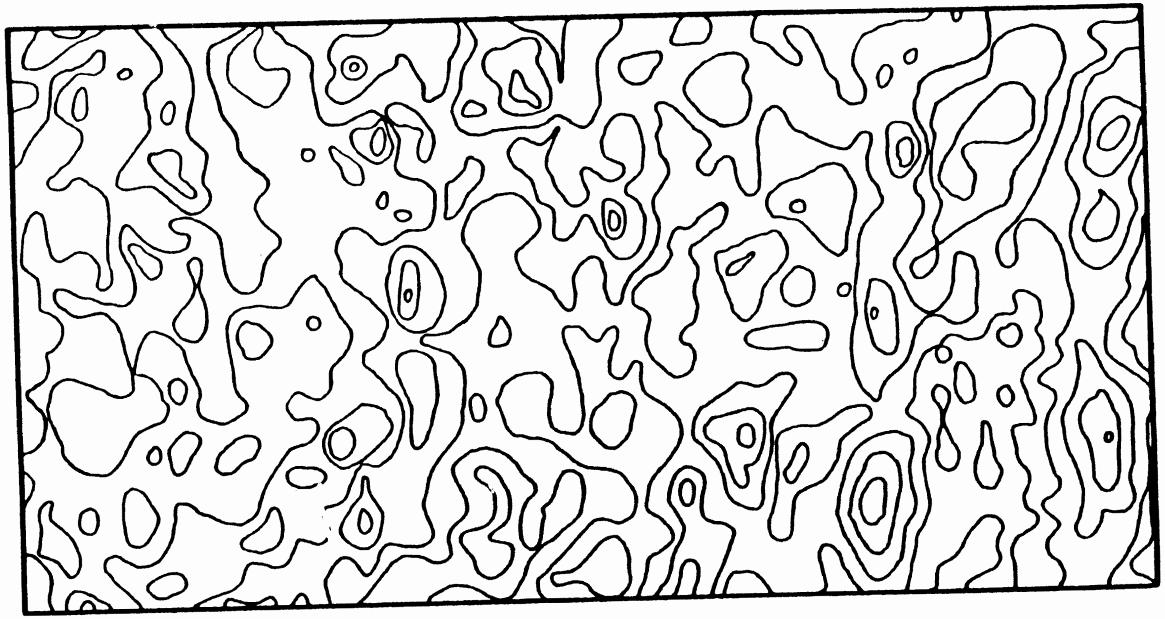
WAVES AT SEA ARE SELDOM REGULAR IN CHARACTER, BUT FORM AN IRREGULAR MIX OF WAVE HEIGHTS AND PERIODS AND ARE USUALLY SHORT CRESTED.

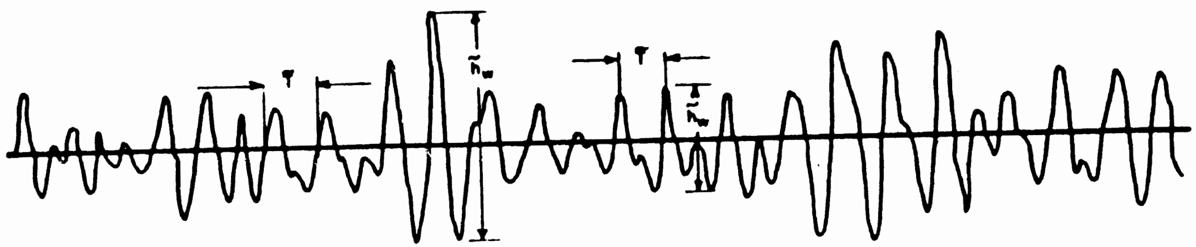
NEVERTHELESS, A LONG CRESTED IRREGULAR WAVE PATTERN GIVES A SUFFICIENTLY ACCURATE REPRESENTATION FOR MOST SHIP DESIGN PURPOSES.

2814

THE SHIP IN MOTION WITH THE SEA

"IRREGULAR" WAVES (CON'T)

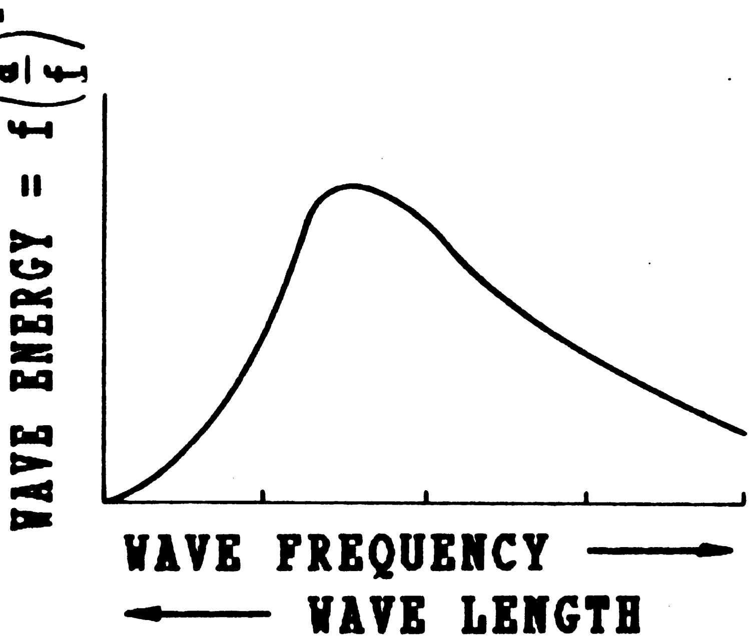




THE SHIP IN MOTION WITH THE SEA

SEA SPECTRA

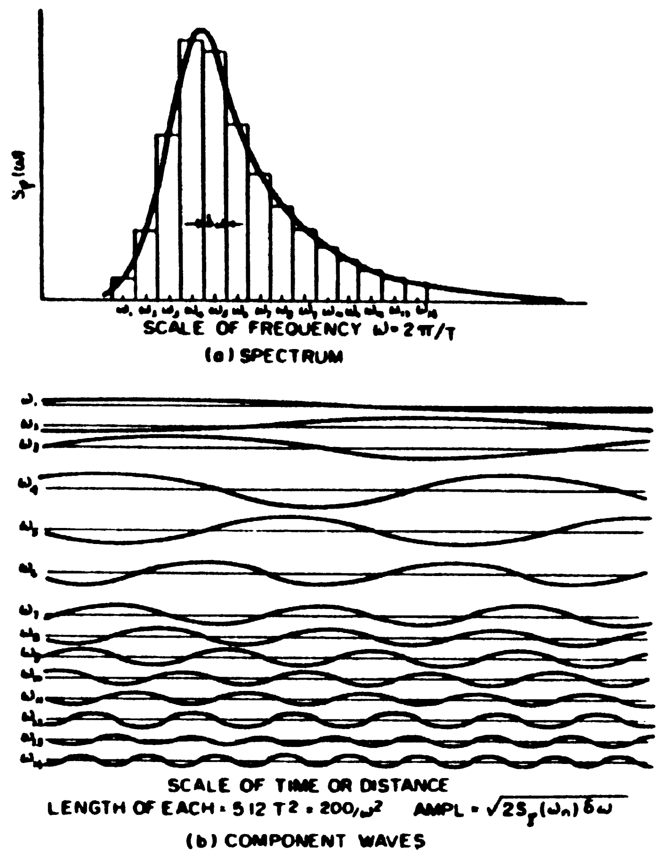
THE ENERGY IN AN IRREGULAR SEAWAY CAN BE REPRESENTED AS AN ENERGY SPECTRUM.



THE SHIP IN MOTION WITH THE SEA

SEA SPECTRA

THE ENERGY SPECTRUM CAN BE REPRESENTED AS THE SUM OF A NUMBER OF SINUSOIDAL COMPONENTS.



THE SHIP IN MOTION WITH THE SEA

SEAWAY DESCRIPTIONS

- **BEAUFORT SCALE** (USED BY SEAMEN)

WIND FORCE	WIND VELOCITY, KNOTS
3	7 - 10
4	11 - 16
5	17 - 21
6	22 - 27
7	28 - 33
8	34 - 40
9	41 - 47
10	48 - 55

- DESCRIPTIONS OF THE APPEARANCE OF THE SEA ARE PROVIDED FOR WIND FORCE.
- NOT VERY USEFUL FOR DESIGN.

THE SHIP IN MOTION WITH THE SEA

SEAWAY DESCRIPTIONS (CON'T)

- SIGNIFICANT WAVE HEIGHT

  COMPARISON OF VISUALLY ESTIMATED WAVE HEIGHTS INDICATES THAT THE WAVE HEIGHT THAT AN EXPERIENCED SEAMAN WILL ESTIMATE CORRELATES BEST WITH THE AVERAGE OF THE ONE-THIRD HIGHEST WAVES IN THE SEAWAY. THIS AVERAGE IS CALLED THE SIGNIFICANT WAVE HEIGHT.

- SIGNIFICANT WAVE HEIGHT IS USEFUL. SIGNIFICANT WAVE HEIGHT (AND SIGNIFICANT WAVE PERIOD) ARE USED IN THE FORMULAS FOR SEAWAY SPECTRA.

THE SHIP IN MOTION WITH THE SEA

SEAWAY DESCRIPTIONS (CON'T)

SEA STATES

USED IN SHIP PERFORMANCE SPECIFICATIONS

SEA STATE	SIGNIFICANT WAVE HEIGHT (FEET)	WIND VELOCITY (KNOTS)	FREQUENCY OF OCCURENCE (PERCENT)
1	0.0 TO 1.9	0 TO 10	7.5
2	1.9 TO 4.1	10 TO 14	25.0
3	4.1 TO 5.7	14 TO 17	12.5
4	5.7 TO 7.4	17 TO 20	8.0
5	7.4 TO 13.0	20 TO 25	39.5
6	13.0 TO 20.8	25 TO 32	6.6
7	20.8 TO 40.3	32 TO 44	<0.9
8	40.3 TO 61.6	44 TO 55	≈0.0

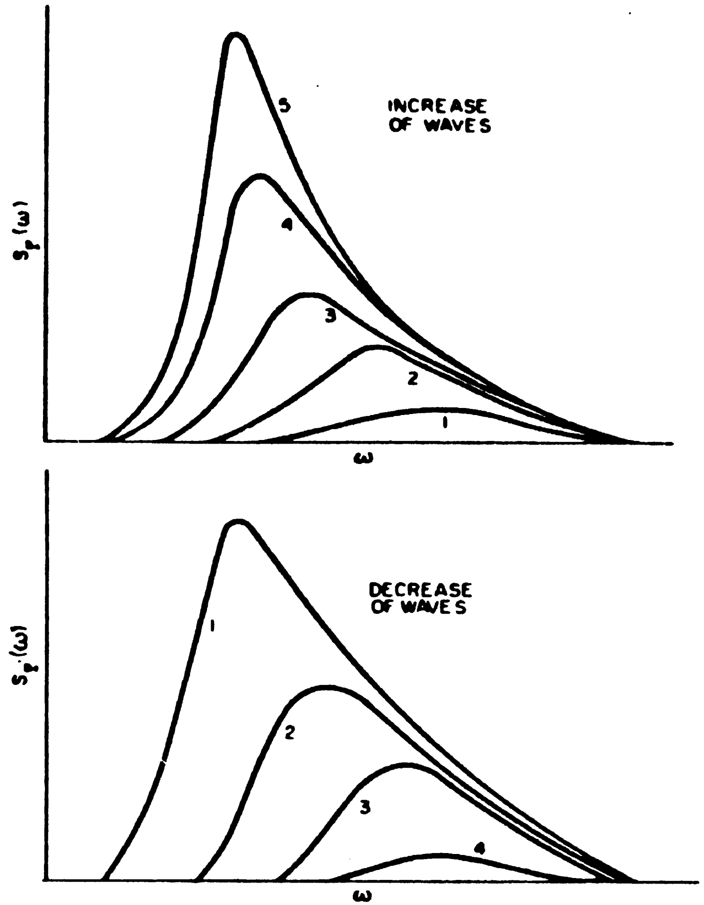
NOTE: FREQUENCY OF OCCURRENCE CITED ABOVE IS AN AVERAGE FOR ALL OCEANS, ALL TIMES OF YEAR. ACTUALLY, IT IS STRONGLY DEPENDENT ON AREA AND SEASON (FOR EXAMPLE: WINTER, NORTH ATLANTIC).

GRAPHICS NOT USED IN PRESENTATION

THE SHIP IN MOTION WITH THE SEA

SEA SPECTRA

GROWTH AND DECAY OF SEA SPECTRA.



BASIC NAVAL ARCHITECTURE

Unit Number: 29

Title: The ship in motion with the sea - 2

Tape Running Time: 35^M 30^S

Reading Assignment: MSD, pp 243-253

Additional References: PNA, pp 657-661, 669-681

INA, pp 260-272

Scope:

Rolling and pitching motions are discussed together with methods of controlling these motions. Yawing motions and broaching are described. Translational motions are outlined and described briefly. The SWATH ship concept as a means of modering ship motions is described.

Key Points to Emphasize:

1. Emphasize Fig. 13-13, INA, pp 264 as being the characteristic of damped exited vibrating systems. Use spring-mass-dashpot example, then apply to ship motions. Introduce the concepts of natural frequency, synchronism, resonance.

2. Stress rolling and pitching as worst motions and discuss design measures to control these motions. Discuss yawing and broaching.

3. Discuss translational motions briefly.

4. Explain how the SWATH ship concept reduces ship motions. Discuss advantages and disadvantages of SWATH ships.

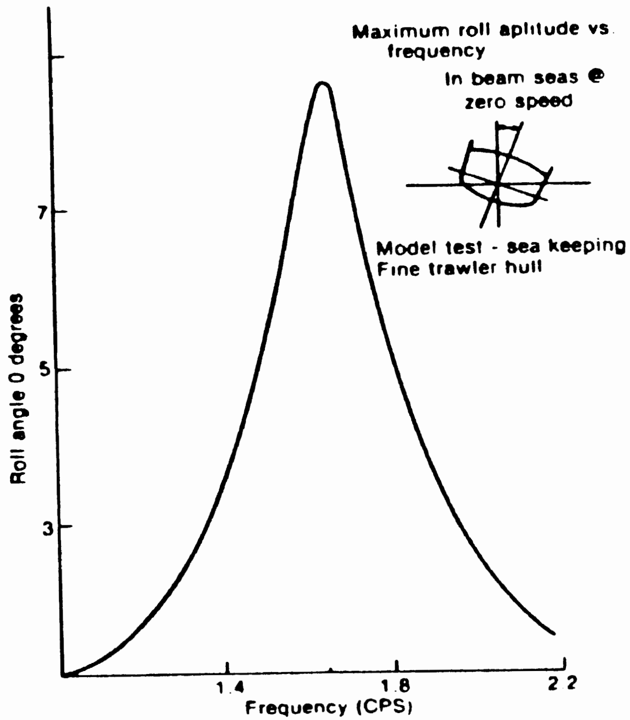
Suggested Problem Assignment: Select from previously unassigned problems. If desired to assign a problem in ship motions, consider 13-1 or 13-2, INA, pp 272-273 if the class can handle that level of problem.

THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS

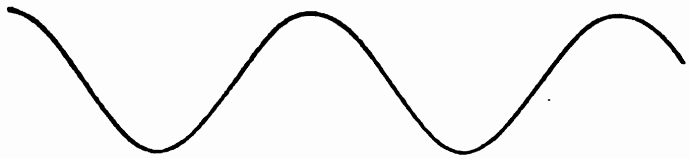
1. ROLLING

ROLLING IS A SHARPLY TUNED MOTION RESPONSE.

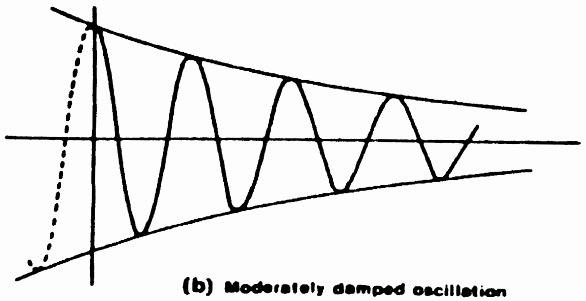


THE SHIP IN MOTION WITH THE SEA

RESONANCE AND DAMPING



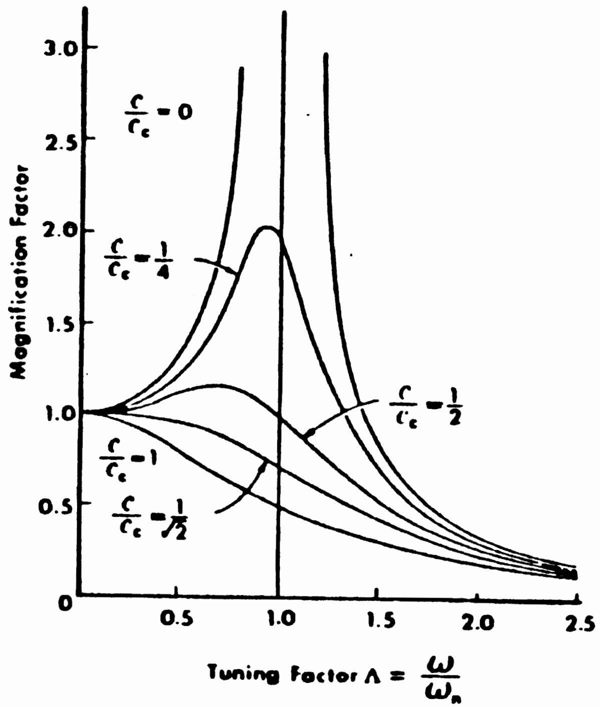
(a) Undamped oscillation



(b) Moderately damped oscillation

(c) Heavily damped oscillation

FREE MOTION WITH AND WITHOUT DAMPING



EXCITED MOTIONS WITH AND WITHOUT DAMPING

THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS

1. ROLLING

FORMULA FOR NATURAL ROLLING PERIOD:

$$T_r = \frac{1.108k}{\sqrt{GM}}$$

k = MASS RADIUS OF GYRATION IN ROLL, FT.

k VARIES FROM .38B TO .55B

k = .40B IS A COMMONLY USED VALUE

THEN,

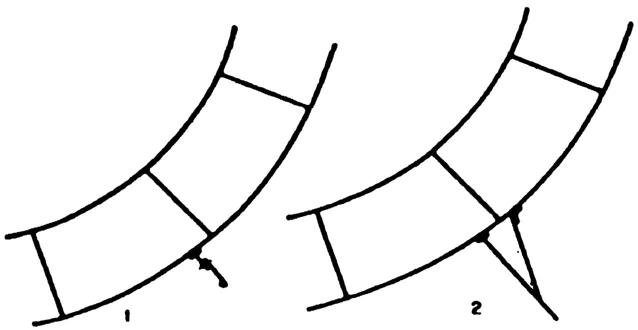
$$T_r = \frac{.44B}{\sqrt{GM}}$$

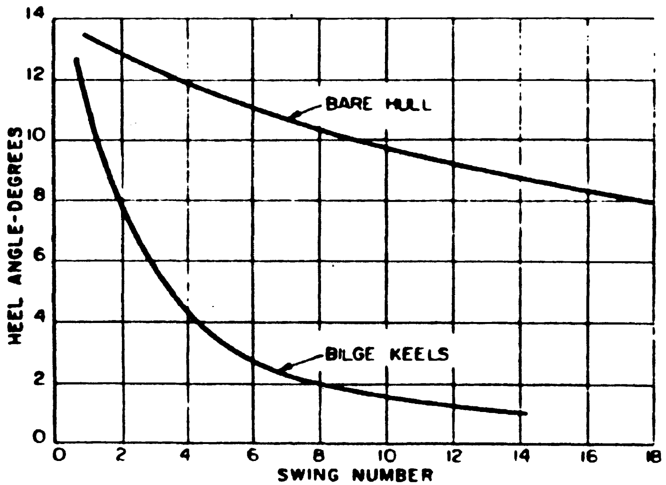
THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS

1. ROLLING - BILGE KEELS

BILGE KEELS ARE CHEAP AND FAIRLY EFFECTIVE. THEY DISSAPATE ROLLING ENERGY BY INCREASING ROLL DAMPING.



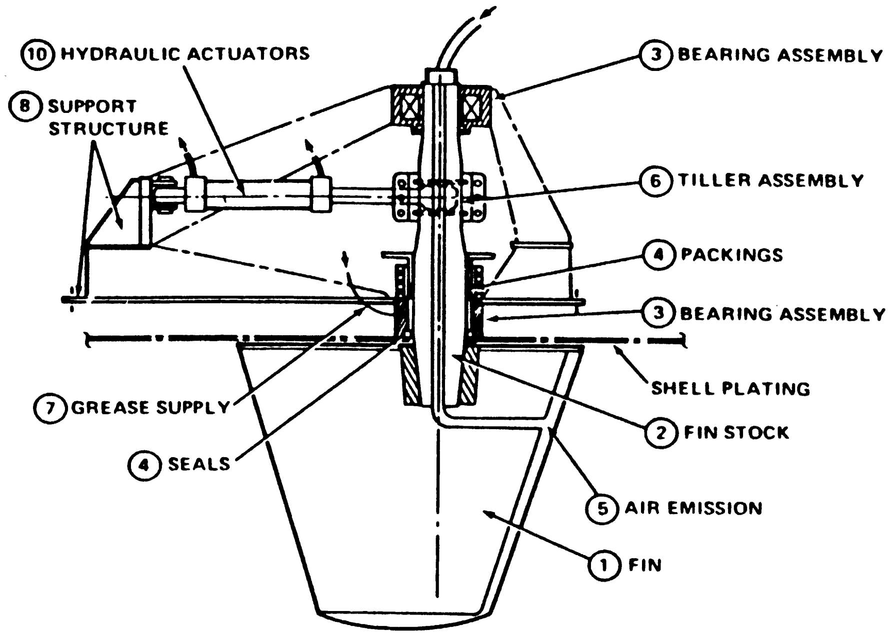


THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS

1. ROLLING - ANTI-ROLLING FINS

ANTI-ROLLING FINS ARE DYNAMICALLY CONTROLLED FINS WHICH, THROUGH THE LIFT GENERATED BY THE FINS, GENERATE ANTI-ROLLING MOMENTS.



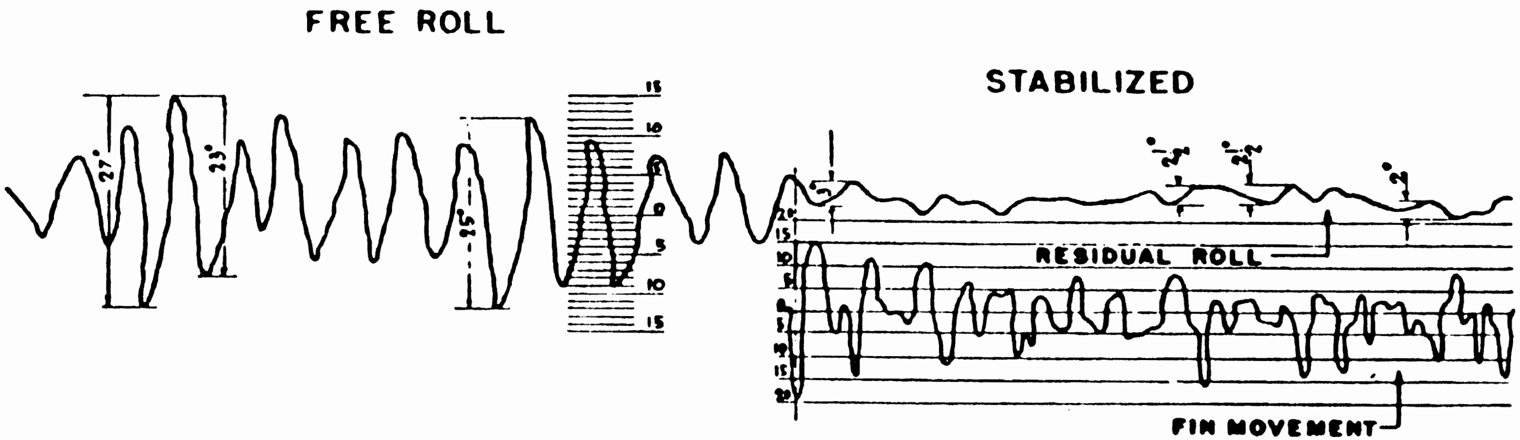
29.6

THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS

1. ROLLING - ANTI-ROLLING FINS

ANTI-ROLLING FINS ARE VERY EFFECTIVE IN SUPPRESSING ROLL AT NORMAL SHIP SPEEDS. THEY LOSE EFFECTIVENESS RAPIDLY AT LOW SPEEDS.



Denny-Brown Co.

THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS

1. ROLLING - ANTI-ROLLING TANKS

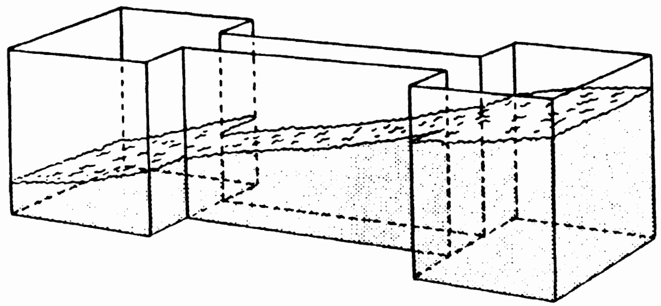
- ANTI-ROLLING TANKS ARE EFFECTIVE AT ANY SPEED, BUT ONLY OVER A SMALL RANGE OF FREQUENCIES.
- BY CONTROLLING THE FLOW RATE OF THE WATER FROM ONE SIDE TO THE OTHER THE WEIGHT SHIFT CAN BE MADE TO BE JUST OUT-OF-PHASE WITH THE ROLL MOTION, THUS GENERATING AN ANTI-ROLL MOMENT.
- ANTI-ROLL TANKS REQUIRE 1% TO 2% OF THE DISPLACEMENT AND LARGE INTERNAL VOLUME. THEY ALSO CONTRIBUTE TO THE FREE SURFACE RISE IN THE CENTER OF GRAVITY.

THE SHIP IN MOTION WITH THE SEA

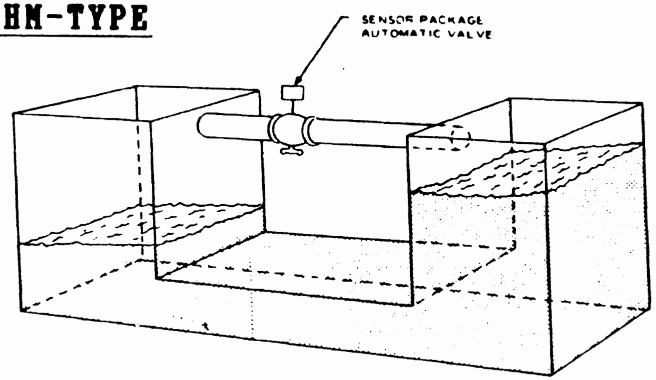
DESIGNING FOR SHIP MOTIONS

1. ROLLING - ANTI-ROLLING TANKS

PASSIVE TYPE



FROHM-TYPE

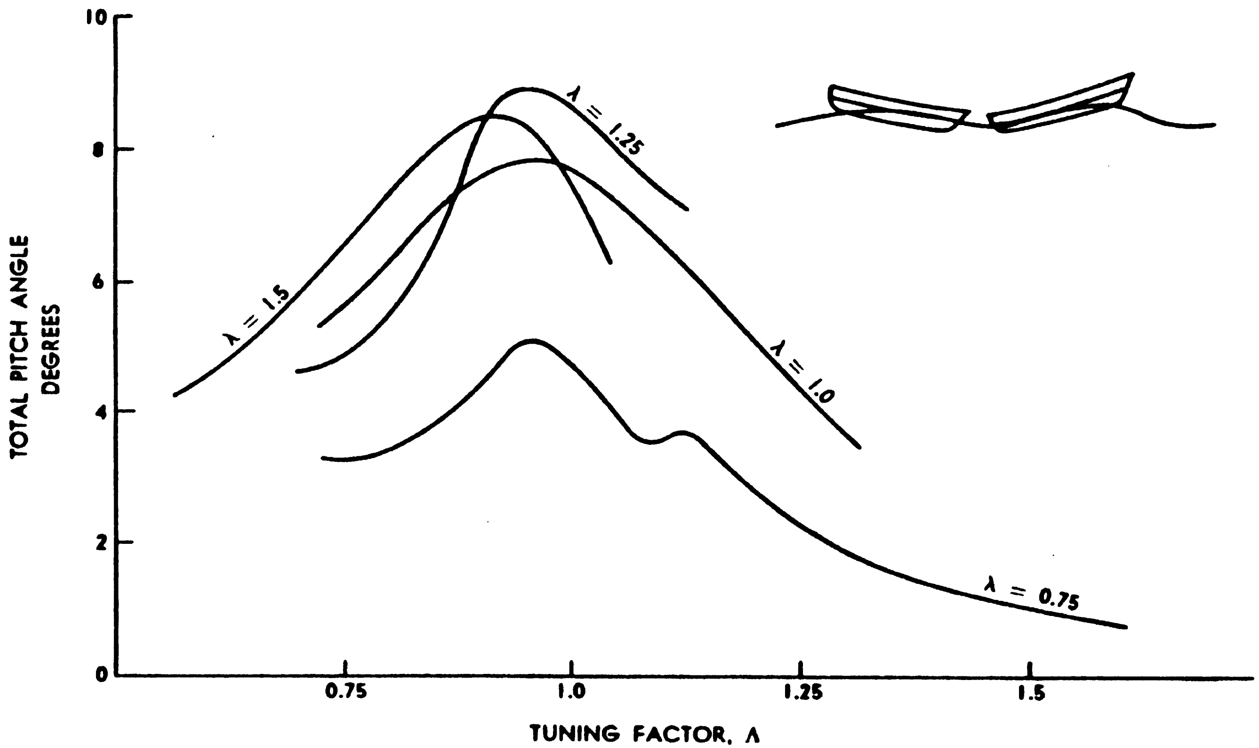


THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS

2. PITCHING

WORST PITCHING MOTIONS TEND TO OCCUR IN WAVES WHOSE LENGTH IS APPROXIMATELY EQUAL TO SHIP LENGTH.



DESIGNING OR SHIP MOTIONS

2. PITCHING

THE FORMULA FOR NATURAL PITCHING PERIOD IS:

$$T_p = \frac{1.108\ k_{yy}}{\sqrt{GM_L}}$$

(SAME FORMULA AS ROLLING PERIOD, BUT ...)

k_{yy} = RADIUS OF GYRATION IN PITCH

k_{yy} VARIES FROM .23L TO .28L

k_{yy} = .25L IS A COMMONLY USED VALUE,

THEN

$$T_p = \frac{.28\ L_{pp}}{\sqrt{GM_L}}$$

29-11

THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR MOTIONS

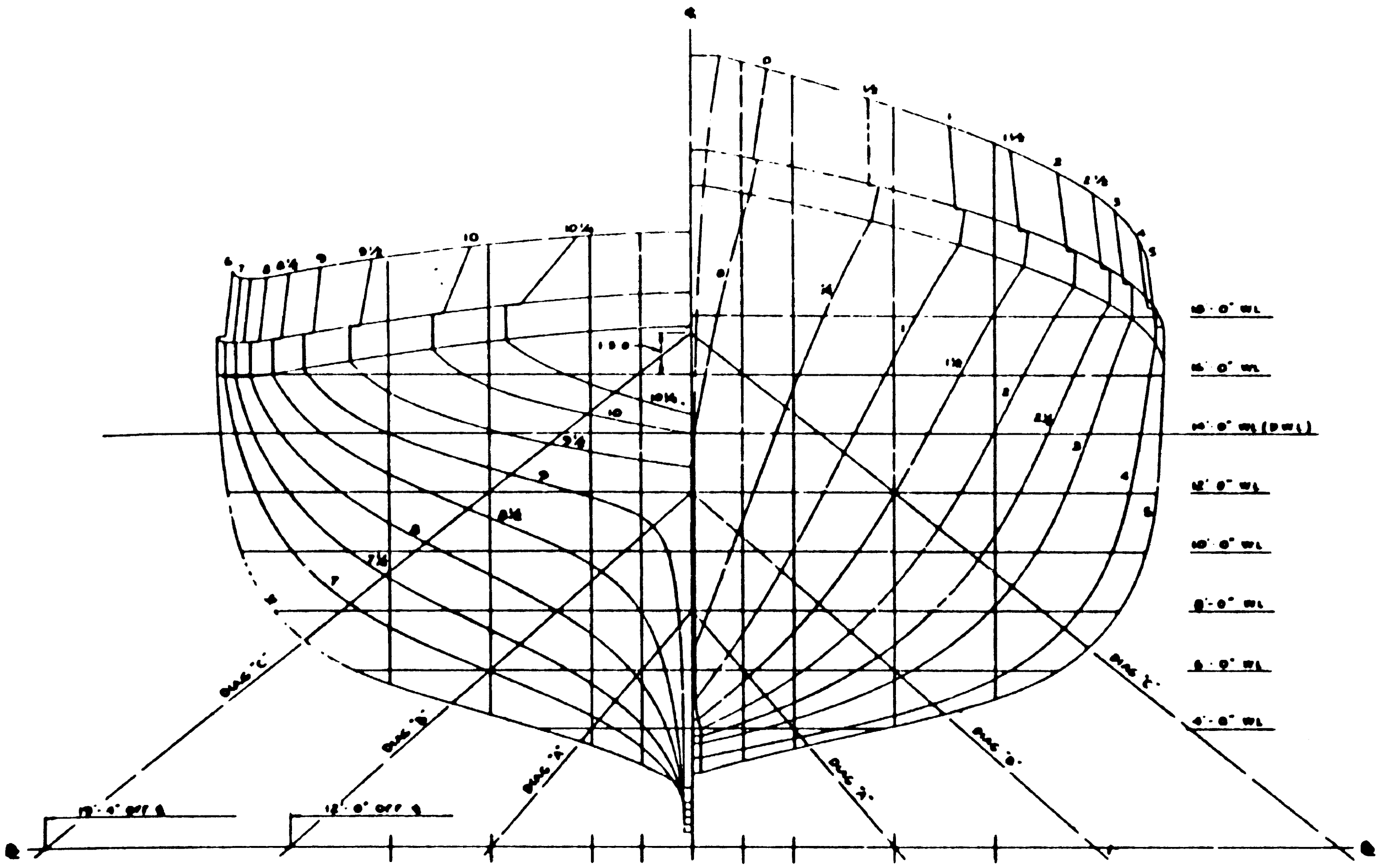
2. PITCHING - DESIGN MEASURES

- USE OF A KNUCKLE IN THE FOREBODY FLARE REGION MAY REDUCE DECK WETNESS.
- INCREASE OF FREEBOARD AT THE BOW WILL DECREASE DECK WETNESS.
- SHIFTING FROM U-SHAPED SECTIONS TO V-SHAPED SECTIONS IN THE FOREBODY GENERALLY LEADS TO MORE SEA-KINDLY SHIPS IN SMALL AND MEDIUM SIZE SHIP RANGE.

THE SHIP IN MOTION WITH THE SEA

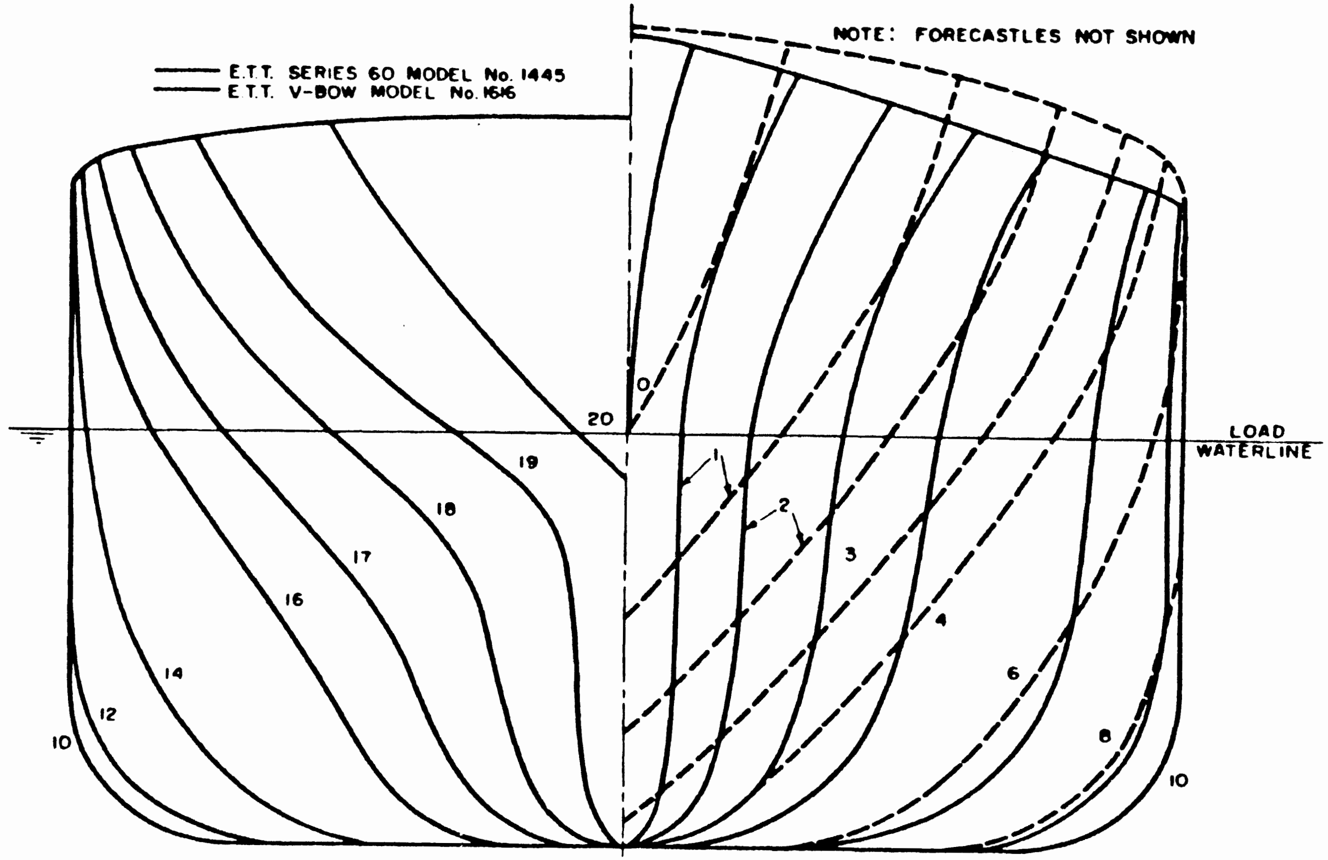
DESIGNING FOR SHIP MOTIONS

2. PITCHING - KNUCKLES



DESIGNING FOR SHIP MOTIONS

2. PITCHING - U-SHAPED AND V-SHAPED SECTIONS



THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS

2. PITCHING

- ANTI-PITCHING FINS HAVE BEEN TRIED AND HAVE NOT BEEN SUCCESSFUL. THEY TEND TO CAUSE STRONG TRANSVERSE SHUDDERS IN THE FOREBODY OF THE SHIP.

- LARGE BOW BULBS, OR DOMES HAVE SOME EFFECT IN SUPPRESSING PITCH, BUT SUPPRESSION OF PITCH MAY CAUSE INCREASE IN HEAVE AND MORE SEVERE SHIPPING OF GREEN WATER OVER THE BOW.

THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS

3. YAWING

- STRONGEST YAW MOTIONS OCCUR IN BOW SEAS AND IN QUARTERING AND FOLLOWING SEAS.
- IN BOW SEAS HELMSMAN MUST MAINTAIN A RUDDER ANGLE AGAINST THE SEAWAY AND CONTINUOUSLY STEER TO COUNTERACT YAWING TENDENCY.
- FOLLOWING AND QUARTERING SEAS AT LOW SHIP SPEEDS ARE A MORE SEVERE PROBLEM, PARTICULARLY WITH TRANSOM-STERN SHIPS.
- TENDENCY TO BROACH IS DANGEROUS. A LARGE WAVE CAN PICK UP THE STERN OF THE SHIP WHILE THE BOW IS BURIED IN THE WAVE AHEAD AND THROW THE SHIP AROUND INTO THE WAVE TROUGH.

DESIGNING FOR SHIP MOTIONS

3. YAWING

- DESIGN FEATURES TO MINIMIZE YAWING
  - INCREASE AREA OF DEADWOOD, OR
  - INCREASE AREA OF SKEGS
  - INCREASE SIZE OF RUDDERS
  - PROVIDE FASTER RUDDER RESPONSE (INCREASE POWER OF STEERING GEAR)
- RUDDERS ARE MORE EFFECTIVE IN CONTROLLING YAW (AND IN STEERING, GENERALLY) WHEN LOCTED IN THE PROPELLER RACE.

THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS

4. TRANSLATIONAL MOTIONS

- SURGE AND SWAY ARE SMALL MOTIONS AND NOT GENERALLY A PROBLEM.
- HEAVE MOTIONS CAN BE SIGNIFICANT AND CAN CONTRIBUTE TO UNCOMFORTABLE ACCELERATIONS, BUT THESE MOTIONS ARE SELDOM HAZARDOUS.
- LITTLE CAN BE DONE TO REDUCE HEAVING MOTIONS, OTHER THAN REDUCING WATERPLANE AREA, WHICH IS NOT OFTEN A DESIGN OPTION FOR CONVENTIONAL SHIPS.
- SWATH SHIPS DO REDUCE WATERPLANE AREA AND ACHIEVE ATTRACTIVE PITCH AND HEAVE MOTIONS - BUT AT A PRICE!

GRAPHICS NOT USED IN PRESENTATION

THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS

1. ROLLING - SALLYING THE SHIP

RECALL THAT THE INCLINING EXPERIMENT WAS USED TO MEASURE GM AND THUS KG.

ANOTHER METHOD OF MEASURING GM IS TO SALLY THE SHIP. THE CREW IS ASSEMBLED ON ONE SIDE OF THE SHIP, THEN THE CREW RUNS TO THE OTHER SIDE, BACK AGAIN, AND SO FORTH TO START THE SHIP ROLLING. THE ROLLING PERIOD IS MEASURED AND GM COMPUTED FROM THE ROLLING PERIOD FORMULA.

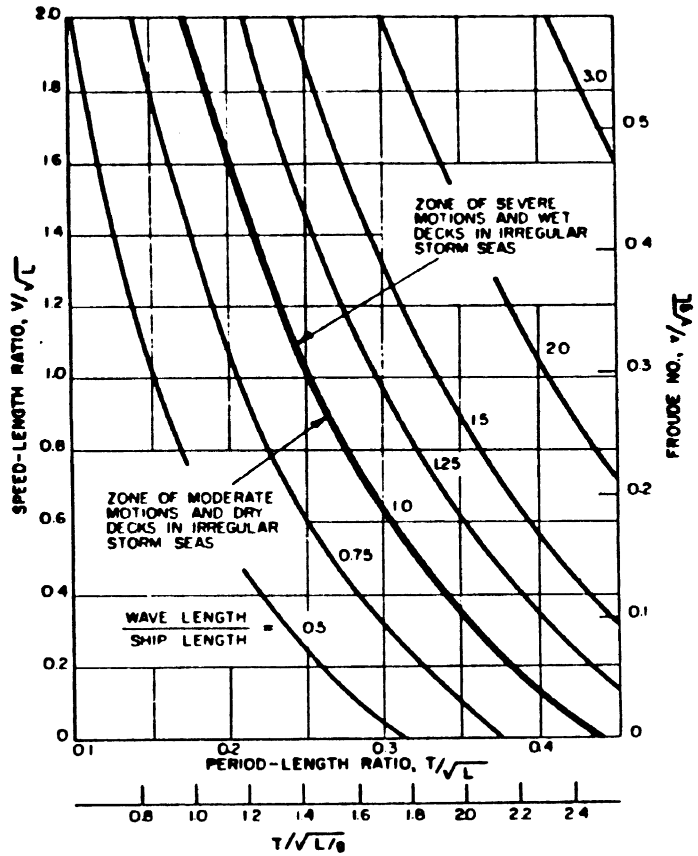
COMMENT: ONLY AS GOOD AS THE ESTIMATE OF k, THE GYRADIUS.

THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS

2. PITCHING

INFLUENCE OF PITCH PERIOD.



THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS

SWATH SHIPS

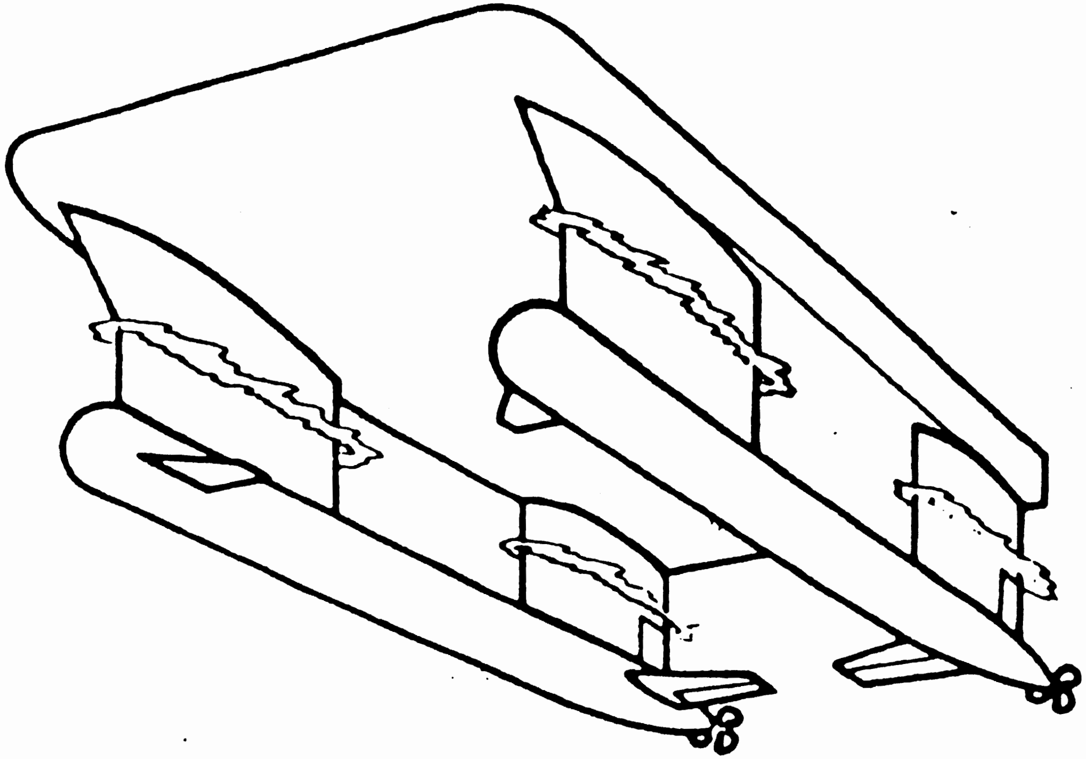
SMALL WATERPLANE AREA TWIN HULL SHIPS ARE DESIGNED SPECIFICALLY FOR FAVORABLE SHIP MOTIONS. THE SMALL WATERPLANE AREA LEADS TO LONG NATURAL PERIODS IN PITCH AND HEAVE, WELL REMOVED FROM THE PERIODS OF SEAWAY COMPONENTS WITH HIGH ENERGY.

MOTIONS ARE VERY SMALL IN HEAD AND BOW SEAS, MUCH MORE PROMINENT IN QUARTERING AND FOLLOWING SEAS.

FOR A GIVEN PAYLOAD SWATH SHIPS COST ROUGHLY 150% AS MUCH AS A MONOHULL.

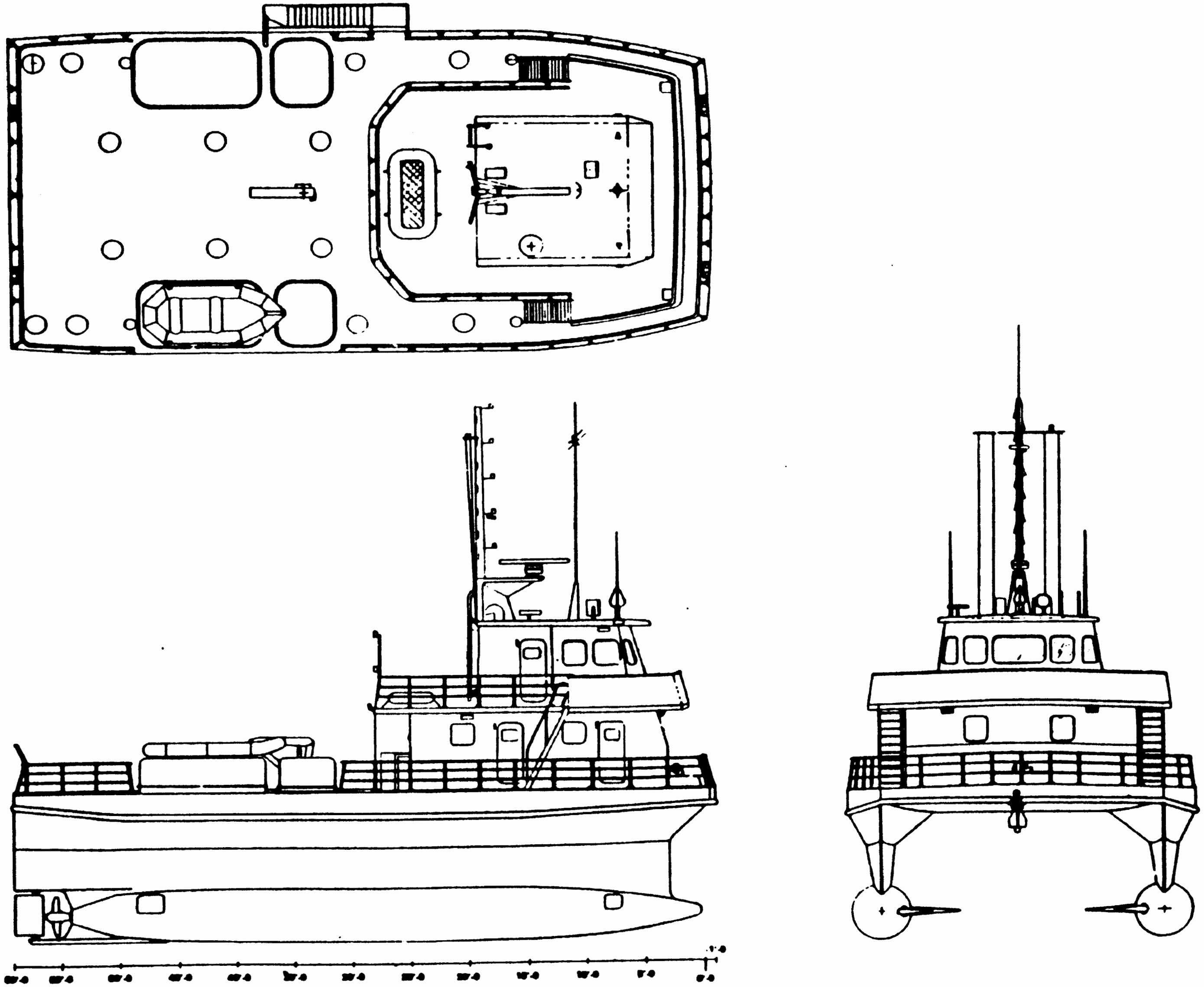
THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS



THE SHIP IN MOTION WITH THE SEA

DESIGNING FOR SHIP MOTIONS



THE SHIP IN MOTION WITH THE SEA

SHIP MOTION COMPUTER PROGRAMS

FREQUENCY DOMAIN COMPUTER PROGRAMS

- FREQUENCY DOMAIN PROGRAMS COMPUTE THE SHIP'S MOTION RESPONSES TO EACH OF THE COMPONENT FREQUENCIES IN THE SEAWAY ENERGY SPECTRUM, THEN COMBINE THE RESULTS TO MAKE A STATISTICAL PREDICTION OF THE SHIP MOTIONS.

- FREQUENCY DOMAIN PROGRAMS TEND TO GIVE GOOD PREDICTIONS IN HEAD AND BOW SEAS, FAIR TO POOR PREDICTIONS IN BEAM SEAS AND IN QUARTERING AND FOLLOWING SEAS.

THE SHIP IN MOTION WITH THE SEA

SHIP MOTION COMPUTER PROGRAMS

FREQUENCY DOMAIN COMPUTER PROGRAMS

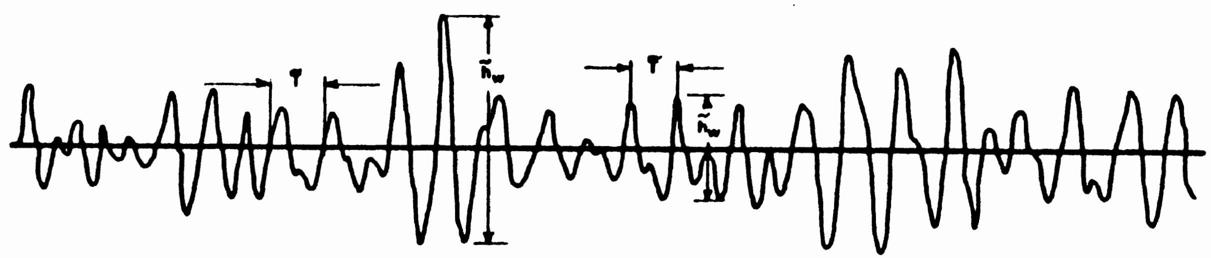
- EXAMPLES OF TYPES OF PREDICTIONS
  - AVERAGE OF 1/3 LARGEST _____ MOTIONS IN A SEAWAY OF ____ SIGNIFICANT WAVE HEIGHT.
  - NUMBER OF EXCEEDANCES OF A MOTION LEVEL IN 100,000 MOTION CYCLES (OR ANY GIVEN NUMBER OF CYCLES).
  - NUMBER OF TIMES PER HOUR GREEN WATER IS SHIPPED OVER FOREDECK.
  - NUMBER OF TIMES PER HOUR THE FOREFOOT EMERGES FROM THE WATER.
  - NUMBER OF TIMES IN THE SHIP'S LIFE CYCLE A GIVEN STRESS IN A STRUCTURAL DETAIL WILL BE EXCEEDED.

THE SHIP IN MOTION WITH THE SEA

SHIP MOTION COMPUTER PROGRAMS

TIME DOMAIN PROGRAMS

INPUT: A TIME HISTORY OF A LONG CRESTED IRREGULAR WAVE HEIGHT RECORD.



OUTPUT: A TIME HISTORY OF SHIP MOTIONS.

29.27

THE SHIP IN MOTION WITH THE SEA

SHIP MOTION COMPUTER PROGRAMS

- TIME DOMAIN PROGRAMS ARE STILL IN THE DEVELOPMENT STAGE. THEY REQUIRE A HUGE AMOUNT OF COMPUTER TIME.

- WITH FURTHER DEVELOPMENT, TIME DOMAIN PROGRAMS WILL PROVIDE THE MOST ACCURATE PREDICTION OF SHIP MOTIONS.

- IN TIME, WITH FASTER AND CHEAPER COMPUTING POWER, TIME DOMAIN PROGRAMS WILL BECOME USEFUL IN EXAMINING THE EFFECT OF CHANGES IN HULL FORM ON SHIP MOTIONS.

Unit Number: 30

Title: The strength and structure of ships - 1

Tape Running Time: 35^M 20^S

Reading Assignment: MSD, pp 205-207

Additional References: INA, pp 13-36, 60-74

Any standard text in "Strength and Materials" or "Mechanics of Deformable Bodies"

Scope:

Basic concepts of stress and strain, the stress-strain diagram and Hooke's Law are introduced. Neutral axis and basic beam concepts including the flexure formula are discussed. Section modulus is defined. Distribution of bending stresses and shear stresses in a beam in bending are described.

Key Points to Emphasize:

1. This is the first of ten units on the design of ship's structures. The purpose is to present an overview of the subject. However, since students are presumed not to have a background in Statics and Strength of Materials, elements in these subjects which are necessary to develop the structural topic are introduced, but only to a minimum level of detail. The instructor may wish to amplify this treatment in certain areas, but he should avoid the pitfall of trying to force two college courses in engineering into an overview presentation.

2. Introduce basic concepts of stress, strain, stress-strain diagram, Hooke's Law, and beam theory. Note that MSD uses older notation of f for stress.

3. Emphasize a physical feeling for difference between bending stress and shear stress. Use deck of cards analogy.

Suggested Problem Assignment: 56, 57

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - STRESS

STRESS IS THE FORCE APPLIED PER UNIT AREA, LBS/IN^2.

NORMAL STRESS - TENSILE STRESS OR COMPRESSIVE STRESS IS PRODUCED BY COLINEAR FORCES.

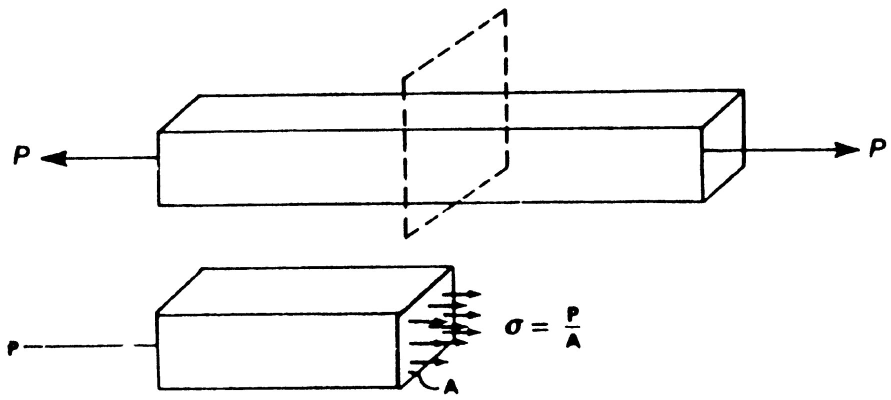
SHEAR STRESS IS PRODUCED BY TWO NON-COLINEAR FORCES ACTING IN OPPOSITE DIRECTIONS.

NOTATION: σ = NORMAL STRESS

τ = SHEAR STRESS

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - STRESS

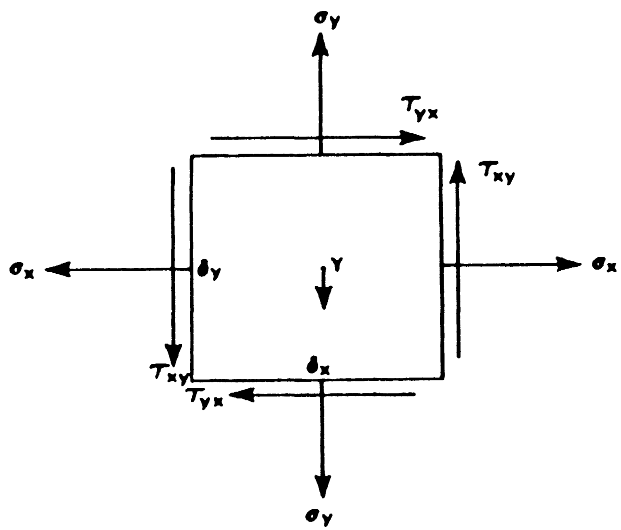


$$\sigma = \frac{P}{A} = \frac{\text{FORCE, LBS}}{\text{AREA, IN}^2}$$

THE FORCE P IS CALLED THE **LOAD**

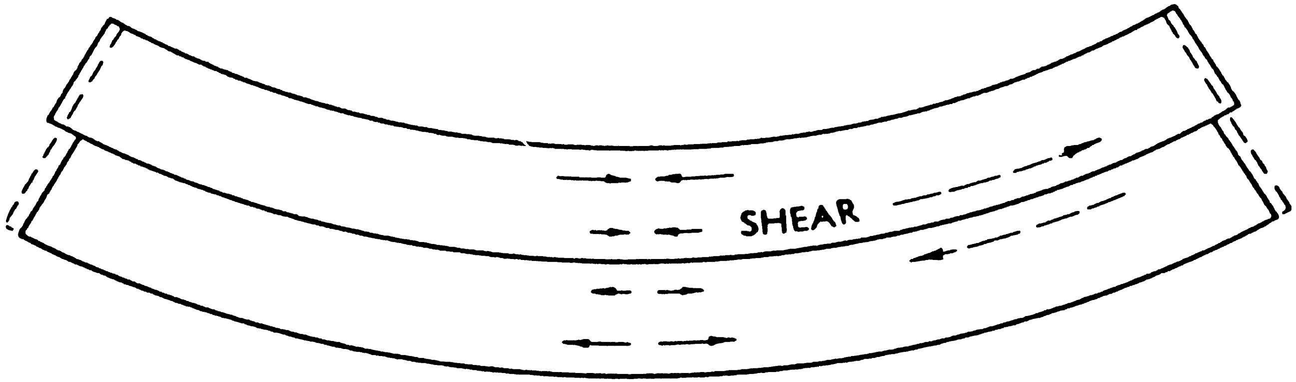
THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - STRESS



THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - SHEAR STRESS

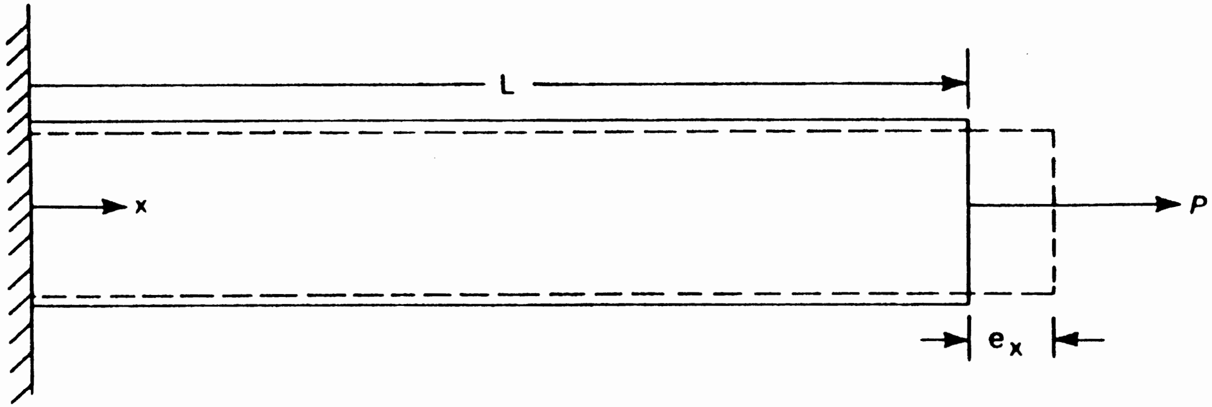


30.5

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - STRAIN

STRAIN IS DEFORMATION PER UNIT LENGTH IN THE MATERIAL RESULTING FROM STRESS, EXPRESSED IN INCHES PER INCH.



NOTATION

P = LOAD, LBS

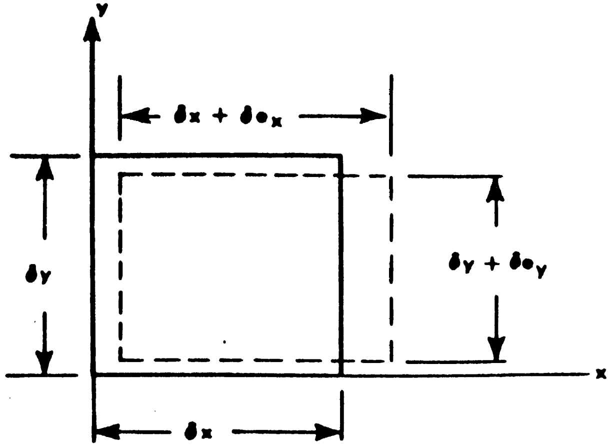
ε = STRAIN, IN/IN

$$\varepsilon_x = \frac{e_x}{L}, \frac{IN}{IN}$$

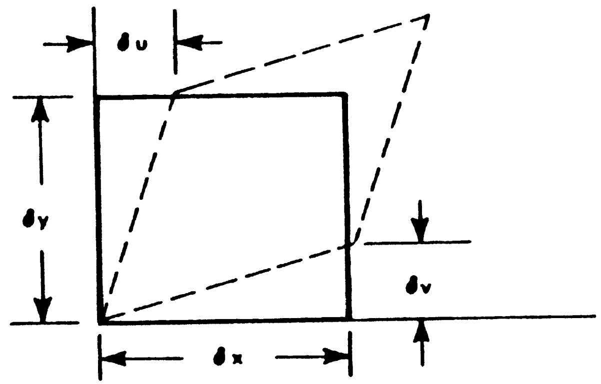
30-6

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - STRAIN



NORMAL
STRAIN

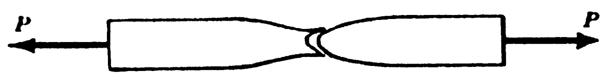


SHEARING
STRAIN

BASIC CONCEPTS - THE TENSILE TEST

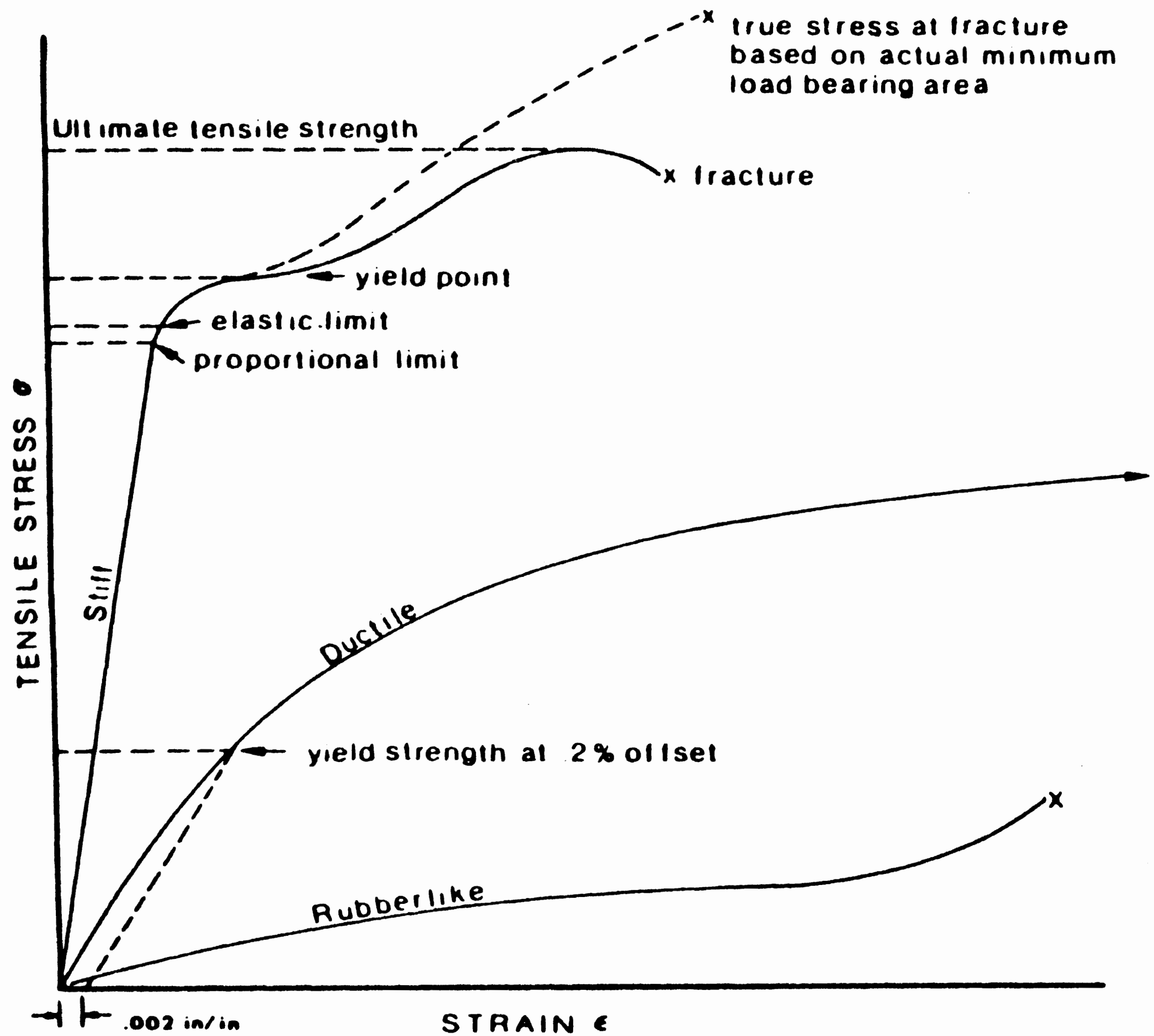
STANDARD SPECIMENS OF VARIOUS MATERIALS ARE TESTED IN A TENSILE-TESTING MACHINE. THE TENSION IS INCREASED CONTINUOUSLY AND THE EXTENSION OF THE SPECIMEN IS MEASURED CONTINUOUSLY UNTIL THE SPECIMEN FAILS.

THE RESULTS ARE PLOTTED ON A STRESS-STRAIN DIAGRAM.



THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - THE STRESS-STRAIN DIAGRAM



THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - STRESS AND STRAIN

IMPORTANT RELATIONSHIPS

HOOKES LAW:

"STRESS IS PROPORTIONAL TO STRAIN"

$$\sigma = E\varepsilon$$

σ = STRESS, LBS/IN^2

ε = STRAIN, IN/IN

E = YOUNG'S MODULUS, OR THE MODULUS OF ELASTICITY, LBS/IN^2

NOTE: APPLIES ONLY TO THE STRAIGHT LINE PORTION OF THE STRESS-STRAIN DIAGRAM.

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - NEUTRAL AXIS

FOR A BEAM IN PURE BENDING THERE IS A SURFACE ON WHICH THE LONGITUDINAL FIBERS DO NOT UNDERGO STRAIN. ON ONE SIDE OF THIS SURFACE THE FIBERS WILL BE IN TENSION AND ON THE OTHER SIDE THE FIBERS WILL BE IN COMPRESSION.

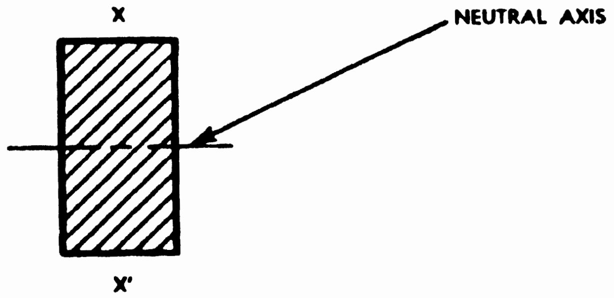
THIS SURFACE IS CALLED THE NEUTRAL SURFACE.

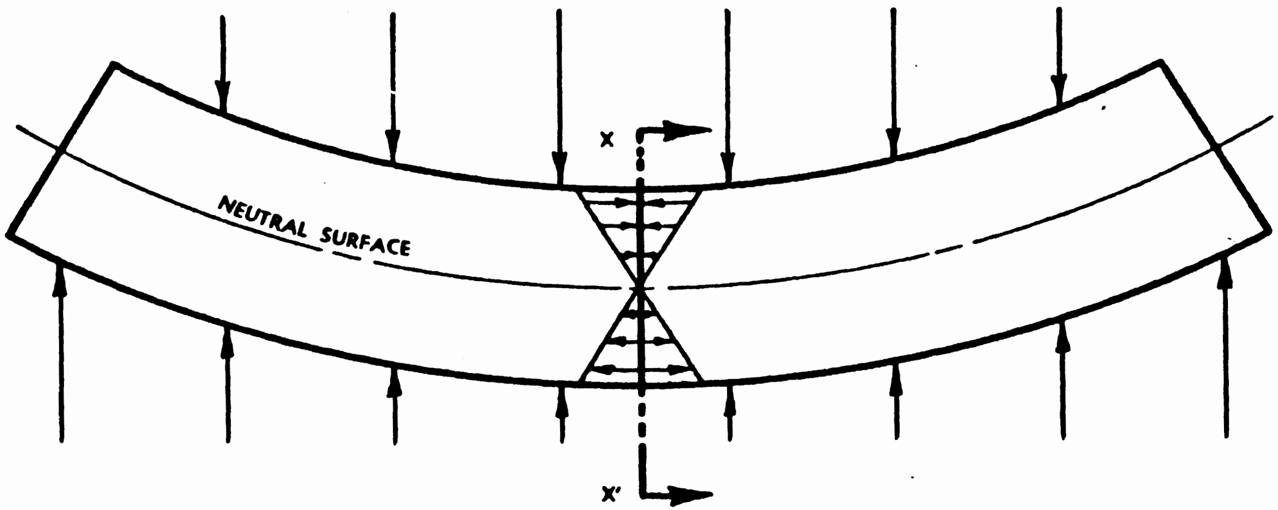
THE INTERSECTION OF THIS SURFACE WITH ANY TRANSVERSE SECTION THROUGH THE BEAM IS CALLED THE NEUTRAL AXIS.

FOR BEAMS OF A HOMOGENEOUS MATERIAL IT MAY BE SHOWN THAT THE NEUTRAL AXIS PASSES THROUGH THE CENTROID OF THE SECTION.

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - NEUTRAL AXIS





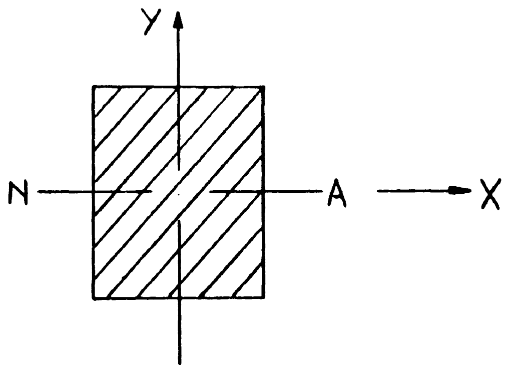
THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - THE FLEXURE FORMULA

VERY IMPORTANT FORMULA !!

THE BENDING STRESSES (NORMAL STRESSES) IN BEAM ARE GIVEN BY

$$\sigma = \frac{My}{I}$$



σ = BENDING STRESS, $\frac{LB}{IN^2}$

M = BENDING MOMENT, IN-LB

Y = DISTANCE FROM NEUTRAL AXIS, IN

I = MOMENT OF INERTIA OF SECTION ABOUT NEUTRAL AXIS, IN^4

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - SECTION MODULUS

THE MAXIMUM VALUE OF y IS CALLED c.

ACTUALLY THERE MAY BE DIFFERENT VALUES OF c FOR TOP AND BOTTOM.

THE SECTION MODULUS IS A GEOMETRIC PROPERTY OF THE BEAM SECTION.

$$S = \frac{I}{c}$$

THEN,

$$\sigma = \frac{M}{I/C} = \frac{M}{S}$$

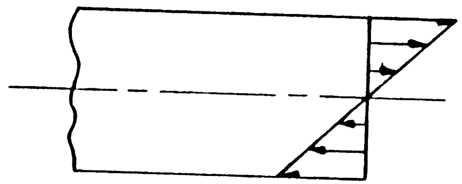
THERE WILL BE TWO VALUES FOR S CORRESPONDING TO THE TWO VALUES OF c.

IN TABLES OF BEAM SECTION PROPERTIES ONLY THE SMALLER VALUE OF SECTION MODULUS IS LISTED.

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - THE FLEXURE FORMULA

$$\sigma = \frac{M}{I} \cdot y$$

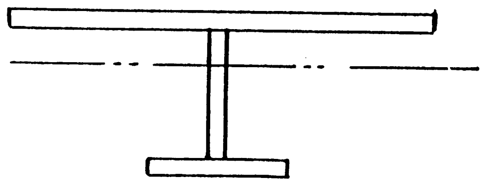


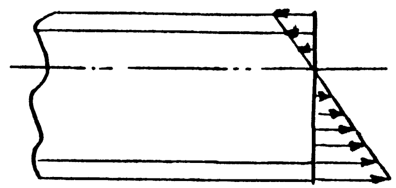
IMPORTANT FEATURES

BENDING STRESS IS MAXIMUM AT THE OUTER FIBERS WHERE y IS MAXIMUM.

THE BENDING STRESS IS ZERO AT THE NEUTRAL AXIS.

IF THE SECTION IS NOT SYMMETRICAL THE NEUTRAL AXIS WILL STILL PASS THROUGH THE CENTROID, BUT THIS MAY NOT BE IN THE MIDDLE OF THE BEAM.





THE STRENGTH AND STRUCTURE OF SHIPS

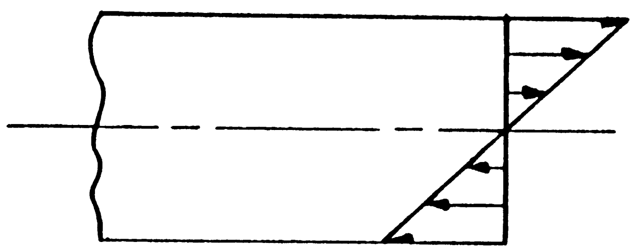
BASIC CONCEPTS - SHEAR STRESS

FOR A BEAM IN BENDING:

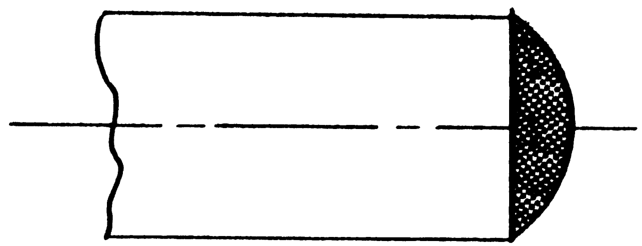
THE BENDING STRESS IS ZERO AT THE NEUTRAL AXIS AND MAXIMUM AT THE OUTER FIBERS.

HOWEVER, IT CAN BE SHOWN THAT,

THE SHEAR STRESS IS MAXIMUM AT THE NEUTRAL AXIS AND ZERO AT THE OUTER FIBERS.



BENDING STRESS



SHEAR STRESS

Unit Number: 31

Title: The strength and structure of ships - 2

Tape Running Time: 28^M 32^S

Reading Assignment: MSD, pp 208-209

Additional References: INA, pp 76-81

Any standard text in "Strength of Material" or "Mechanics of Deformable Bodies"

Scope:

Bending moment diagrams for simply supported and cantilevered beams are developed. The Manual fo Steel Construction (Steel Handbook) is cited as the source of information on bending moment diagrams, useful tables, and properties of steel sections.

Key Points to Emphasize:

1. Only four cases which can be developed using a very simple intuitive grasp of $\Sigma F = 0$ to determine reaction forces are presented. Other cases are referred to the Steel Handbook. Excerpts from the Steel Handbook are reprinted in the appendix to the problem set.

2. Try to straighten out the confusion on sign conventions, but note that there is lack of uniformity within the industry on this subject. Bending moments should be clearly labeled "hogging" or "sagging" and stresses should be labeled "compressive" or "tensile" regardless of the side of the baseline on which these quantities are plotted.

3. Emphasize graphical relationships between areas, ordinates, slopes and curvature.

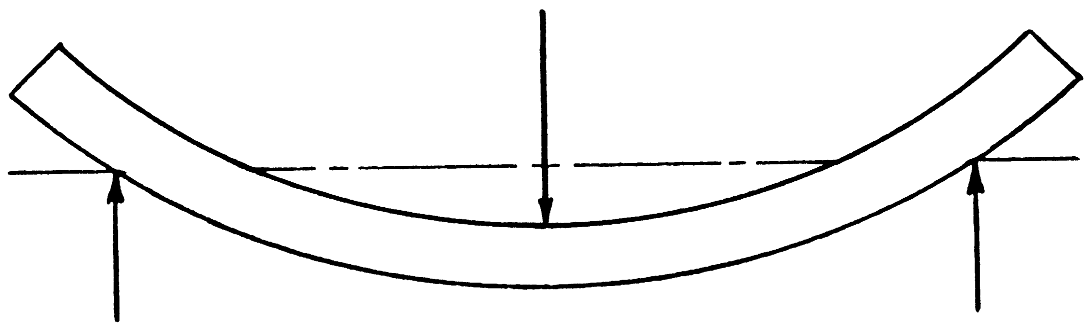
4. Select problems judiciously with background of class in mind. Each period introduce problems to be assigned for next period with some explanation. If necessary, replace problems in problem set with problems at even a more basic level.

Suggested Problem Assignment: 58, 59

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - BENDING MOMENT

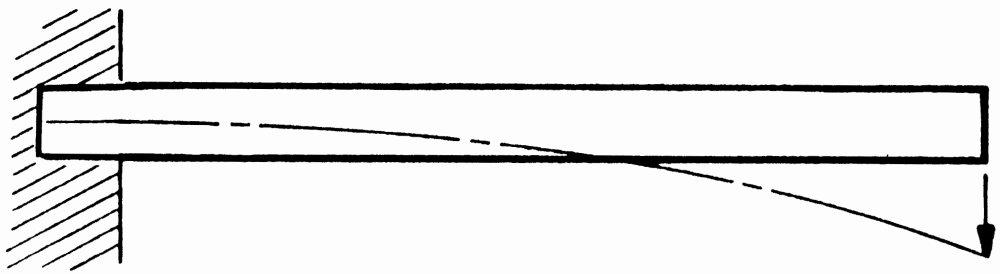
SIMPLE SUPPORTS ARE HINGES WHICH PERMIT THE BEAM TO ROTATE AT THE POINT OF SUPPORT.



THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - BENDING MOMENT

CANTILEVERED SUPPORTS (OR "BUILT-IN" SUPPORTS, OR "FIXED" SUPPORTS) DO NOT PERMIT ROTATION AT THE SUPPORT.



THE STRENGTH AND STRUCTURE OF SHIPS

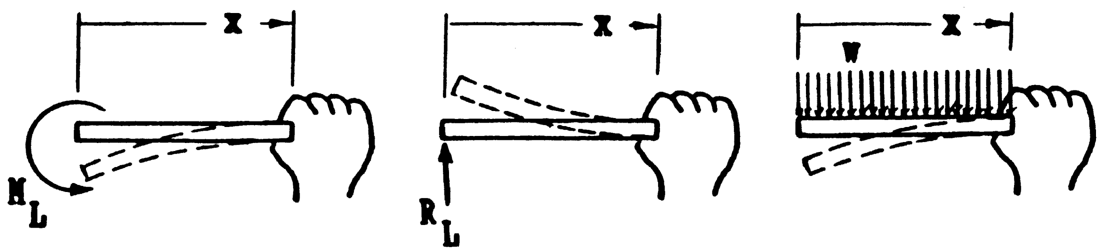
BASIC CONCEPTS - BENDING MOMENTS

SIGN CONVENTIONS

POSITIVE BENDING

NEGATIVE BENDING

TO ASSIGN SIGNS TO BENDING MOMENTS LOOK AT THE FORCES AND MOMENTS TO THE LEFT OF THE POINT IN QUESTION.



M_L IS NEGATIVE

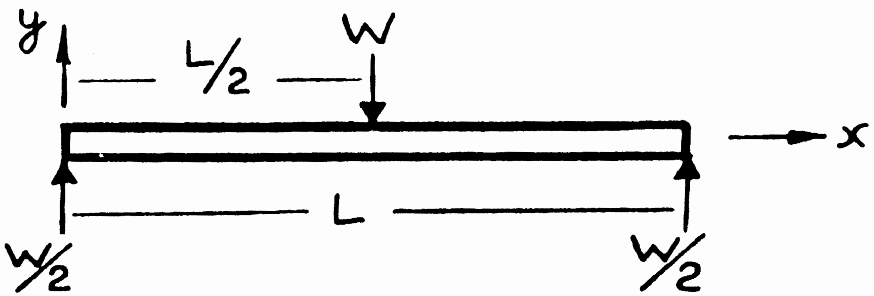
$R_L x$ IS POSITIVE

$(wx)(\frac{x}{2})$ IS NEGATIVE

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - BENDING MOMENT

CONSIDER A SIMPLY SUPPORTED BEAM WITH A CENTER CONCENTRATED LOAD.



THE BENDING MOMENT AT ANY POINT, x, IS THE SUM OF THE MOMENTS TO THE LEFT OF THAT POINT.

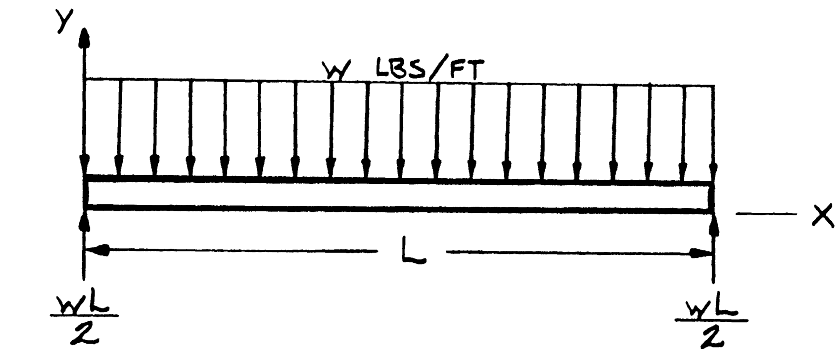
FROM $x = 0$ TO $x = L/2$, $M = \frac{W}{2} \cdot x$

FROM $x = L/2$ TO $x = L$, $M = \frac{W}{2} \cdot x - W\left(x - \frac{L}{2}\right)$

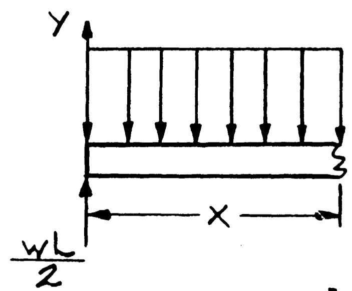
THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - BENDING MOMENT

CONSIDER A SIMPLY SUPPORTED BEAM WITH A UNIFORMLY DISTRIBUTED LOAD.



THE BENDING MOMENT AT ANY POINT, x IS NOW

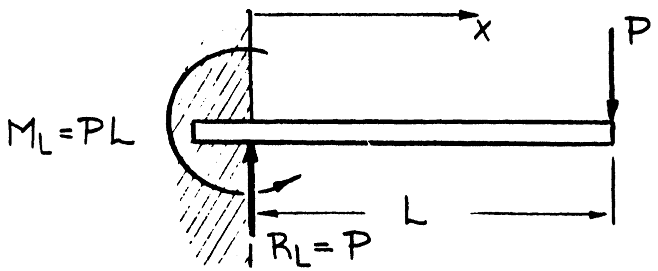


$$M = \left(\frac{WL}{2}\right)(x) - (wx)\left(\frac{x}{2}\right)$$

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - BENDING MOMENTS

CONSIDER A CANTILEVERED BEAM WITH A CONCENTRATED LOAD.



FOR THE BEAM TO BE IN EQUILIBRIUM THERE MUST BE A REACTION FORCE, R_L, AT THE LEFT AND EQUAL TO THE TOTAL LOAD, P.

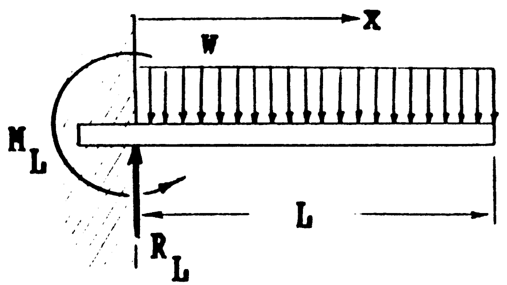
$$R_L = P$$

THE BUILT-IN END MUST ALSO PROVIDE A MOMENT, $M_L = PL$, TO PREVENT ROTATION.

THEN FROM $x = 0$ TO $x = L$ $\quad M = -PL + Px$

BASIC CONCEPTS - BENDING MOMENTS

CONSIDER A CANTILEVERED BEAM WITH A UNIFORMLY DISTRIBUTED LOAD.



THE REACTION FORCE AT THE LEFT END MUST BE EQUAL TO THE TOTAL LOAD

$$R_L = wL$$

THE MOMENT AT THE LEFT END, M_L, WILL BE:

$$M_L = (wL)\left(\frac{L}{2}\right) = \frac{wL^2}{2}$$

THEN FROM $x = 0$ TO $x = L$,

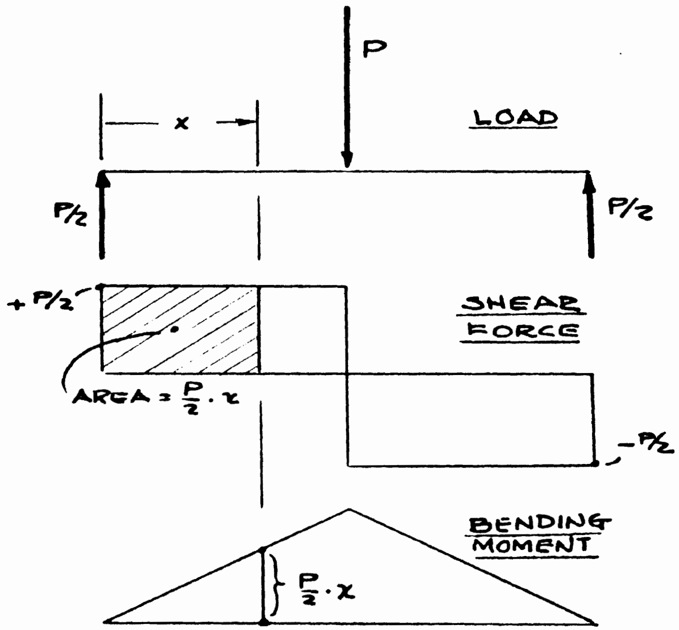
$$M = -\frac{wL^2}{2} + (wL)(x) - (wx)\left(\frac{x}{2}\right)$$

$$M = -\frac{wL^2}{2} + wLx - \frac{wx^2}{2}$$

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - BENDING MOMENT AND SHEAR FORCE DIAGRAMS

CONSIDER A SIMPLY SUPPORTED BEAM WITH A CONCENTRATED LOAD.



IMPORTANT

THE ORDINATE OF THE BENDING MOMENT DIAGRAM EQUALS THE TOTAL AREA TO THE LEFT OF THE POINT ON THE SHEAR FORCE DIAGRAM

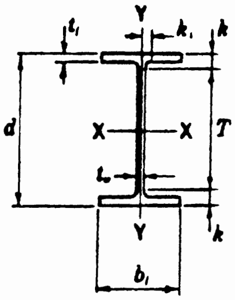
STEEL HANDBOOK

A GOOD SOURCE OF INFORMATION ON STEEL STRUCTURES IS MANUAL OF STEEL CONSTRUCTION, EIGHTH EDITION, AMERICAN INSTITUTE OF STEEL CONSTRUCTION. THERE ARE OTHER HANDBOOKS THAT CONTAIN SIMILAR INFORMATION.

THE HANDBOOK CONTAINS INFORMATION ON -

- DIMENSIONS AND PROPERTIES OF STRUCTURAL SHAPES
- BEAM AND GIRDER DESIGN
- SHEAR FORCE AND BENDING MOMENT DIAGRAMS AND FORMULAE
- COLUMN DESIGN
- DESIGN OF CONNECTIONS
- SPECIFICATIONS FOR STEEL BUILDING CONSTRUCT.
- PROPERTIES OF GEOMETRIC SECTIONS
- OTHER USEFUL TABLES

STEEL HANDBOOK



W SHAPES
Dimensions

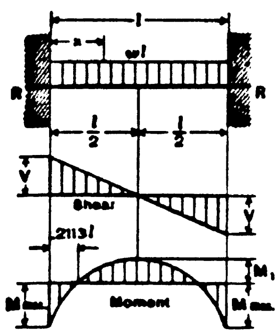
Designation	Area A	Depth d		Web Thickness t_w		Web $\frac{t_w}{2}$	Flange Width b_f		Flange Thickness t_f		Distance T	Distance k	Distance k_1
	$in.^2$	in.		in.		in.	in.		in.		in.	in.	in.
W 36x300	88.3	36.74	36 3/4	0.945	15/16	1/2	16.655	16 5/8	1.680	1 11/16	31 1/8	2 13/16	1 1/2
x280	82.4	36.52	36 1/2	0.885	7/8	7/16	16.595	16 5/8	1.570	1 9/16	31 1/8	2 11/16	1 1/2
x260	76.5	36.26	36 1/4	0.840	13/16	7/16	16.550	16 1/2	1.440	1 7/16	31 1/8	2 9/16	1 1/2
x245	72.1	36.08	36 1/8	0.800	13/16	7/16	16.510	16 1/2	1.350	1 3/8	31 1/8	2 1/2	1 7/16
x230	67.6	35.90	35 7/8	0.760	3/4	3/8	16.470	16 1/2	1.260	1 1/4	31 1/8	2 3/8	1 7/16
W 36x210	61.8	36.69	36 3/4	0.830	13/16	7/16	12.180	12 1/8	1.360	1 3/8	32 1/8	2 5/16	1 1/4
x194	57.0	36.49	36 1/2	0.765	3/4	3/8	12.115	12 1/8	1.260	1 1/4	32 1/8	2 3/16	1 3/16
x182	53.6	36.33	36 3/8	0.725	3/4	3/8	12.075	12 1/8	1.180	1 3/16	32 1/8	2 1/8	1 3/16
x170	50.0	36.17	36 1/8	0.680	11/16	3/8	12.030	12	1.100	1 1/8	32 1/8	2	1 3/16
x160	47.0	36.01	36	0.650	5/8	5/16	12.000	12	1.020	1	32 1/8	1 15/16	1 1/8
x150	44.2	35.85	35 7/8	0.625	5/8	5/16	11.975	12	0.940	15/16	32 1/8	1 7/8	1 1/8
x135	39.7	35.55	35 1/2	0.600	5/8	5/16	11.950	12	0.790	13/16	32 1/8	1 11/16	1 1/8
W 33x241	70.9	34.18	34 1/8	0.830	13/16	7/16	15.860	15 7/8	1.400	1 3/8	29 3/4	2 3/16	1 3/16
x221	65.0	33.93	33 7/8	0.775	3/4	3/8	15.805	15 3/4	1.275	1 1/4	29 3/4	2 1/16	1 3/16
x201	59.1	33.68	33 5/8	0.715	11/16	3/8	15.745	15 3/4	1.150	1 1/8	29 3/4	1 15/16	1 1/8
W 33x152	44.7	33.49	33 1/2	0.635	5/8	5/16	11.565	11 5/8	1.055	1 1/16	29 3/4	1 7/8	1 1/8
x141	41.6	33.30	33 1/4	0.605	5/8	5/16	11.535	11 1/2	0.960	15/16	29 3/4	1 3/4	1 1/16
x130	38.3	33.09	33 1/8	0.580	9/16	5/16	11.510	11 1/2	0.855	7/8	29 3/4	1 11/16	1 1/16
x118	34.7	32.86	32 7/8	0.550	9/16	5/16	11.480	11 1/2	0.740	3/4	29 3/4	1 9/16	1 1/16
W 30x211	62.0	30.94	31	0.775	3/4	3/8	15.105	15 1/8	1.315	1 5/16	26 3/4	2 1/8	1 1/8
x191	56.1	30.68	30 5/8	0.710	11/16	3/8	15.040	15	1.185	1 3/16	26 3/4	1 15/16	1 1/16
x173	50.8	30.44	30 1/2	0.655	5/8	5/16	14.985	15	1.065	1 1/16	26 3/4	1 7/8	1 1/16
W 30x132	38.9	30.31	30 1/4	0.615	5/8	5/16	10.545	10 1/2	1.000	1	26 3/4	1 3/4	1 1/16
x124	36.5	30.17	30 1/8	0.585	9/16	5/16	10.515	10 1/2	0.930	15/16	26 3/4	1 11/16	1
x116	34.2	30.01	30	0.565	9/16	5/16	10.495	10 1/2	0.850	7/8	26 3/4	1 5/8	1
x108	31.7	29.83	29 7/8	0.545	9/16	5/16	10.475	10 1/2	0.760	3/4	26 3/4	1 9/16	1
x 99	29.1	29.65	29 5/8	0.520	1/2	1/4	10.450	10 1/2	0.670	11/16	26 3/4	1 7/16	1

BEAM DIAGRAMS AND FORMULAS

For various static loading conditions

For meaning of symbols, see page 2·111.

15. BEAM FIXED AT BOTH ENDS—UNIFORMLY DISTRIBUTED LOADS



Total Equiv. Uniform Load . . . . . $= \frac{2wl}{3}$

R = V . . . . $= \frac{wl}{2}$

V_x . . . . $= w\left(\frac{l}{2} - x\right)$

M max. (at ends) . . . . . . $= \frac{wl^2}{12}$

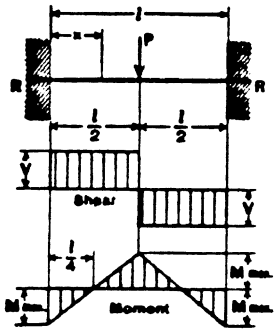
M_1 (at center) . . . . . . $= \frac{wl^2}{24}$

M_x . . . . $= \frac{w}{12}(6lx - l^2 - 6x^2)$

Δmax. (at center) . . . . . . $= \frac{wl^4}{384EI}$

Δ_x . . . . $= \frac{wx^2}{24EI}(l - x)^2$

16. BEAM FIXED AT BOTH ENDS—CONCENTRATED LOAD AT CENTER



Total Equiv. Uniform Load . . . . . = P

R = V . . . . $= \frac{P}{2}$

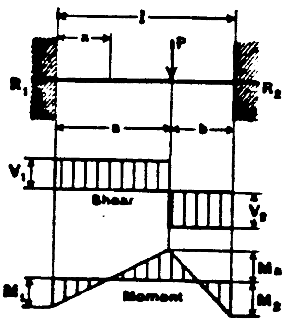
M max. (at center and ends) . . . . $= \frac{Pl}{8}$

M_x (when $x < \frac{l}{2}$) . . . . . $= \frac{P}{8}(4x - l)$

Δmax. (at center) . . . . . . $= \frac{Pl^3}{192EI}$

Δ_x (when $x < \frac{l}{2}$) . . . . . $= \frac{Px^2}{48EI}(3l - 4x)$

17. BEAM FIXED AT BOTH ENDS—CONCENTRATED LOAD AT ANY POINT



$R_1 = V_1$ (max. when a < b) . . . . $= \frac{Pb^2}{l^3}(3a + b)$

$R_2 = V_2$ (max. when a > b) . . . . $= \frac{Pa^2}{l^3}(a + 3b)$

M_1 (max. when a < b) . . . . $= \frac{Pab^2}{l^2}$

M_2 (max. when a > b) . . . . $= \frac{Pa^2b}{l^2}$

M_a (at point of load) . . . . $= \frac{2Pa^2b^2}{l^3}$

M_x (when x < a) . . . . . . $= R_1x - \frac{Pab^2}{l^2}$

Δmax. (when a > b at $x = \frac{2al}{3a + b}$) . $= \frac{2Pa^3b^2}{3EI(3a + b)^2}$

Δ_a (at point of load) . . . . $= \frac{Pa^3b^3}{3EIl^3}$

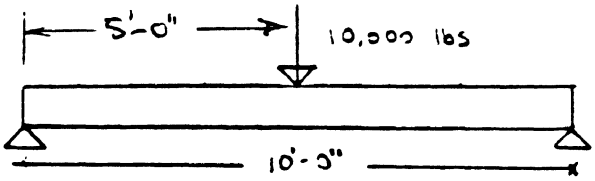
Δ_x (when x < a) . . . . . . $= \frac{Pb^2x^2}{6EIl^3}(3al - 3ax - bx)$

Problem 58

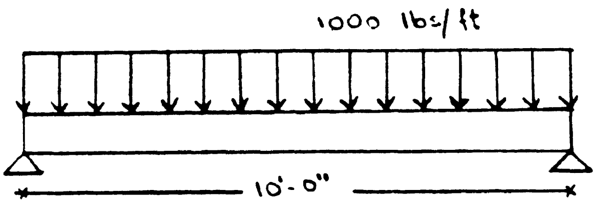
Problem Level: Basic

Construct shear force and bending moment diagrams for the beams and loadings shown below. Indicate on the diagrams the maximum values of shear force and bending moment.

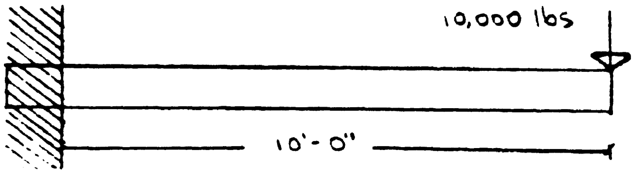
(a) Simply supported, concentrated load



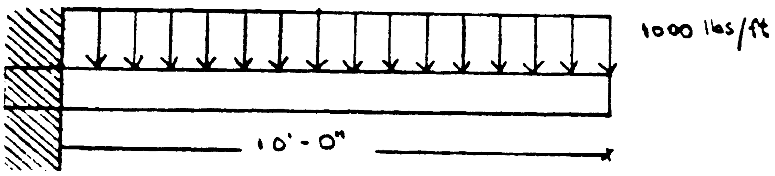
(b) Simply supported, uniform load



(c) Cantilevered, concentrated load



(d) Cantilevered, uniform load



(e) Find the location and magnitude of the maximum bending stress in each of the above beams if each is a W10 x 45 section. The properties of the section in the table in the appendix taken from the Steel Construction Manual.

Problem 59

Problem Level: Basic

A W-shape steel beam has the following characteristics as listed in the AISC Manual of Steel Construction, Eighth Edition.

Designation:	W 12 x 58
Area, in^2:	17.0
Depth, in:	12.19
Wt per ft, lb/ft:	58
I_{xx}, in^4:	475
S, in^3:	78.0

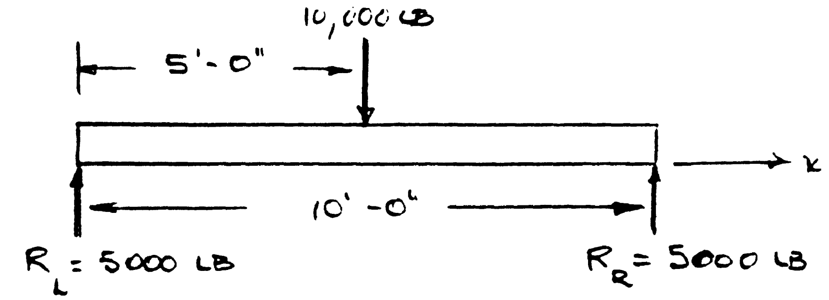
Find the maximum uniform load in lbs/ft that the beam can support without exceeding an allowable stress of 18,000 lbs/in^2.

(a) on a 30-foot simply supported span

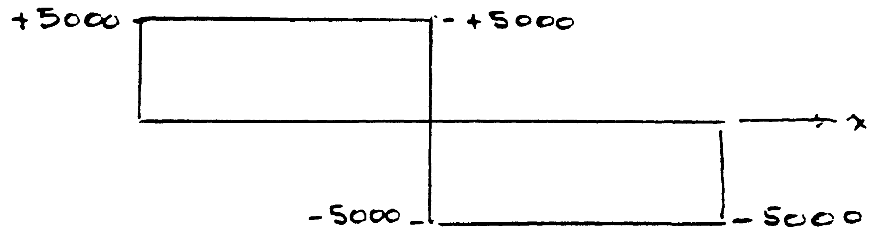
(b) on a 25-foot simply supported span

(c) on a 20-foot simply supported span

(a)

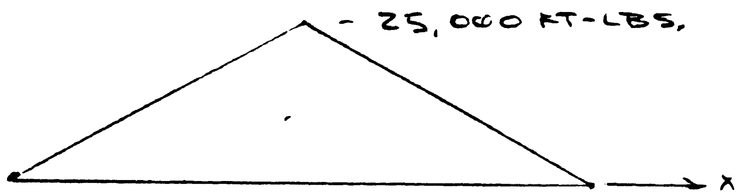


SHEAR FORCE:



FROM x = 0 TO x = +5 FT | SF = 5000 LBS
FROM x = 5 TO x = 10 FT | SF = -5000 LBS

BENDING MOMENT:

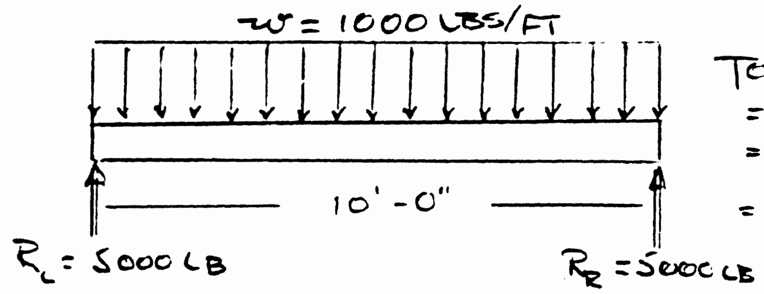


FROM x = 0 TO x = 5 FT, BM = (5000 LBS)(x)
FROM x = 5 FT TO x = 10 FT, BM = (5000 LBS)(x) - (10,000 LBS)(x-5)

BM_{MAX} AT MIDPOINT. BM_{MAX} = (5000 LBS)(5 FT)

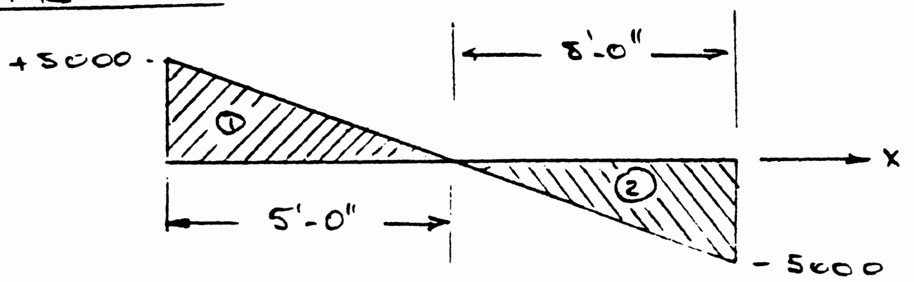
BM_{MAX} = 25,000 FT-LBS.

(b)



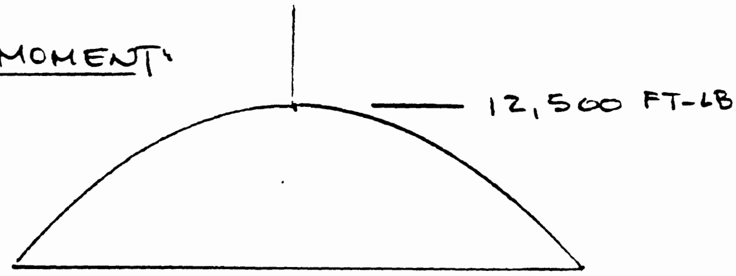
TOTAL LOAD
$= wl$
$= (1000 \frac{LBS}{FT})(10\ FT)$
$= 10{,}000\ LB$

SHEAR FORCE:



AT $x = 0$, $SF = +5000\ LBS$
FROM $x = 0$ TO $x = 10$, $SF = (5000)(x) - (1000 \frac{LBS}{FT})(x)$
AT $x = 10$, $SF = -5000\ LBS.$

BENDING MOMENT:



FROM $x = 0$ TO $x = 10$ $M(x) = (5000\ LB)(x\ FT) - (1000 \frac{LB}{FT})(x\ FT)(\frac{x}{2}\ FT)$

BM_{MAX} AT $x = 5$; $BM_5 = (5000\ LB)(5\ FT) - (1000 \frac{LB}{FT})(5\ FT)(\frac{5}{2}\ FT)$

$BM_{MAX} = 12{,}500\ FT\text{-}LBS$

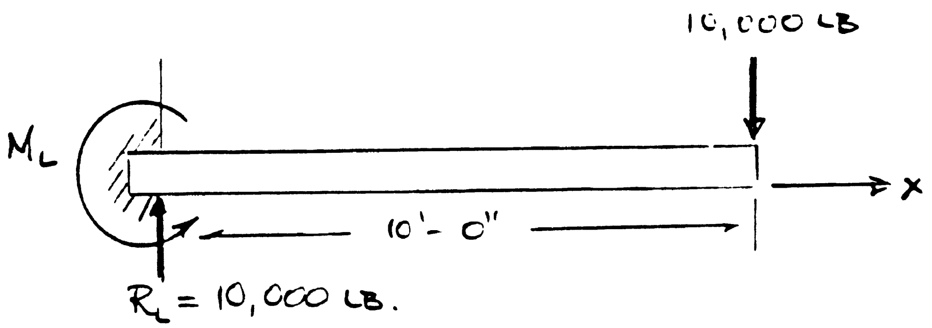
BY AREA METHOD, BM_{MAX} OCCURS WHERE $SF = 0$

AREA UNDER SF DIAGRAM TO LEFT OF MIDPOINT
$= BM_{MAX}$

$BM_{MAX} = (\frac{1}{2})(5000\ LB)(5\ FT)$

$BM_{MAX} = 12{,}500\ LBS/IN^2$

(c)

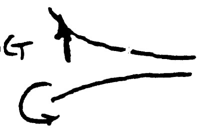


FOR EQUILIBRIUM, $R_L = 10,000$ LB AND $M_L = -(10,000 \text{ LB})(10 \text{ FT})$

$M_L = -100,000$ FT-LB

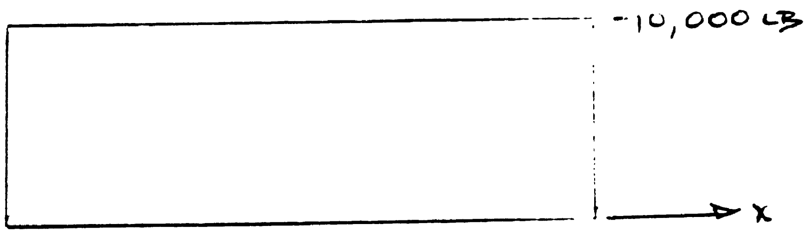
R_L WILL CREATE POSITIVE BENDING

M_L WILL CREATE NEGATIVE B



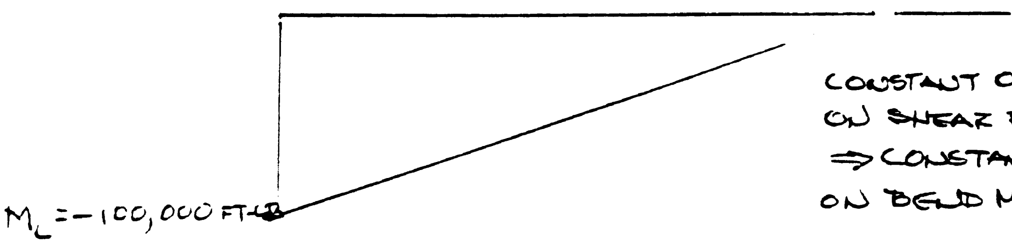
SHEAR FORCE DIAGRAM:

NOTE THAT M_L DOES NOT APPEAR.



FROM X = 0 TO X = 10, SF = 10,000 LB.

BENDING MOMENT DIAGRAM



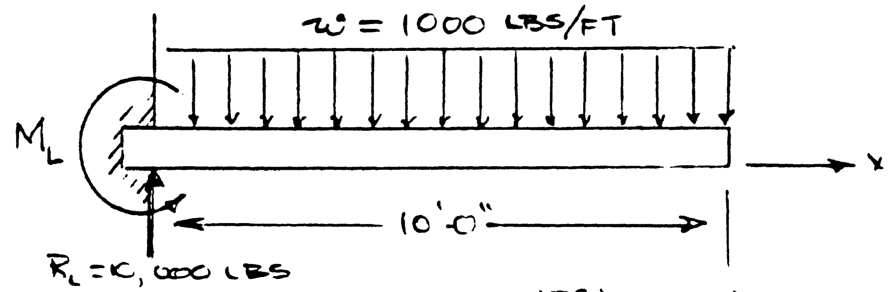
CONSTANT ORDINATE ON SHEAR FORCE DIAG ⇒ CONSTANT SLOPE ON BEND MOM'T DIAGRAM

FROM X = 0 TO X = 10, $M(x) = -100,000 \text{ FT-LBS} + (10,000 \text{ LB})(x \text{ FT})$

NOTE THAT CONCENTRATED MOMENT AT LEFT END APPEARS AS DISCONTINUITY IN BENDING MOMENT DIAGRAM. THE DIAGRAM IS SIMPLY DISPLACED BY THE MAGNITUDE OF M_L.

BM_{MAX} AT X = 0 = 100,000 FT-LBS.

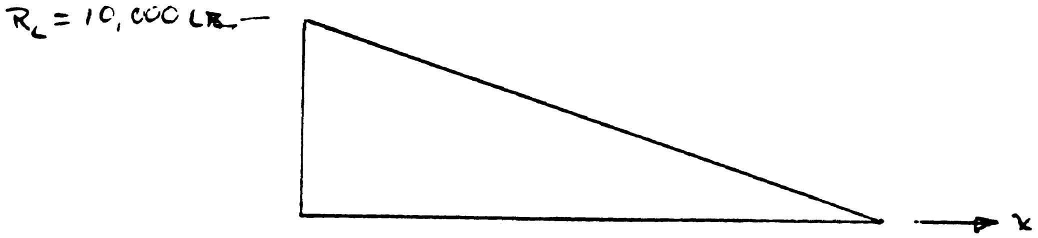
(d)



FOR EQUILIBRIUM, $R_L = (1000 \frac{LBS}{FT})(10\ FT) = 10,000\ LBS$

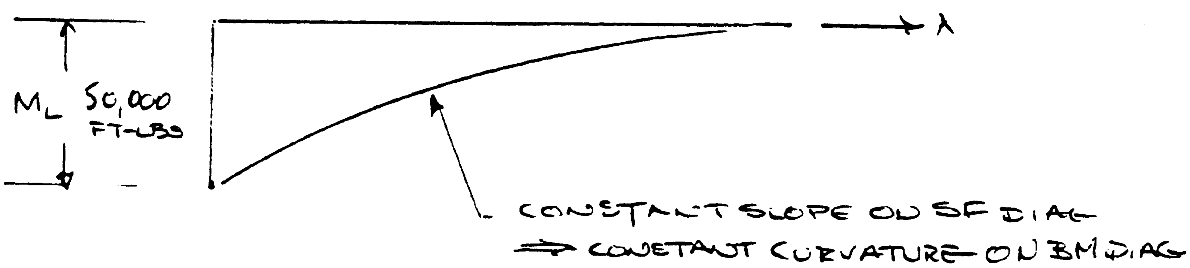
$M_L = (1000 \frac{LBS}{FT})(10\ FT)(\frac{10\ FT}{2}) = 50,000\ FT\text{-}LBS.$

SHEAR FORCE DIAGRAM:



FROM $x = 0$ TO $x = 10$, $SF = 10,000\ LB - (1000 \frac{LB}{FT})(x\ FT)(\frac{x}{2}\ FT)$

BENDING MOMENT DIAGRAM:



FROM $x = 0$ TO $x = 10$, $BM = -(50,000\ FT\text{-}LBS) + (10,000\ LB)(x\ FT) - (1000 \frac{LB}{FT})(x\ FT)(\frac{x}{2}\ FT)$

$BM_{MAX} = M_L$ AT LEFT END $= 50,000\ FT\text{-}LB.$

(e) FROM APPENDIX TO PROBLEM SET, SEE PAGES 1-26 AND 1-27 OF MANUAL OF STEEL CONSTRUCTION

FOR W 10×45 SECTION ABOUT AXIS X-X: S (SECTION MODULUS)

$$S_{x-x} = 49.1 \text{ IN}^3$$

$$\sigma = \frac{M}{I/c} = \frac{M}{S}$$

(a) SIMPLY SUPPORTED, CONCENTRATED LOAD BM_{MAX} = 25,000 FT-LBS. NOTE THAT UNITS MUST BE CONVERTED TO IN-LB!

$$\sigma_{MAX} = \frac{25{,}000 \text{ FT-LB} \times 12 \text{ IN/FT}}{49.1 \text{ IN}^3}$$

σ_{MAX} = 6110 LBS/IN² AT MIDPOINT (IN OUTER FIBERS OF FLANGE)

(b) SIMPLY SUPPORTED, UNIFORM LOAD, BM_{MAX} = 12,500 FT-LB AT MIDPOINT

$$\sigma_{MAX} = \frac{12{,}500 \text{ FT-LB} \times 12 \text{ IN/FT}}{49.1 \text{ IN}^3}$$

σ_{MAX} = 3055 LBS/IN² AT MIDPOINT

(c) CANTILEVERED, CONCENTRATED LOAD, BM_{MAX} = 100,000 FT-LB AT LEFT END.

$$\sigma_{MAX} = \frac{100{,}000 \text{ FT-LB} \times 12 \text{ IN/FT}}{49.1 \text{ IN}^3}$$

σ_{MAX} = 24,440 LBS/IN² AT LEFT END.

(d) CANTILEVERED, UNIFORM LOAD, BM_{MAX} = 50,000 FT-LBS AT LEFT END

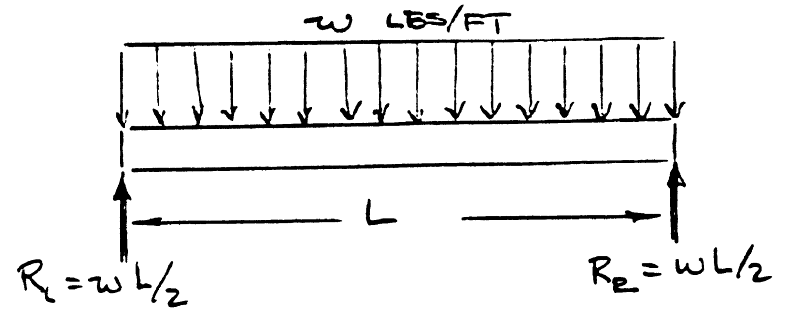
$$\sigma_{MAX} = \frac{50{,}000 \text{ FT-LB} \times 12 \text{ IN/FT}}{49.1 \text{ IN}^3}$$

σ_{MAX} = 12,220 LBS/IN² AT LEFT END

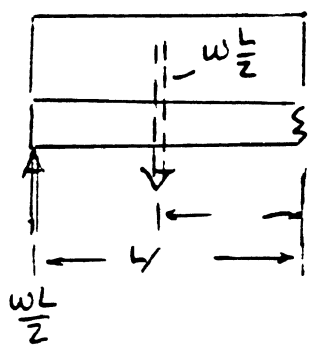
GIVEN: SIMPLY SUPPORTED UNIFORMLY LOADED BEAM OF LENGTH, L

$\sigma_{all} = 18{,}000$ LBS/IN²

FIND: MAX LOAD PER FOOT FOR L = 30, 25, 20



MAX BM OCCURS AT MIDPOINT.



$$BM_{MAX} = \left(\frac{wL}{2}\right)\left(\frac{L}{2}\right) - \left(\frac{wL}{2}\right)\left(\frac{L}{4}\right)$$

$$BM_{MAX} = \frac{wL^2}{8}$$

$$\sigma = \frac{M}{I/c} = \frac{M}{S} \qquad S = \text{SECTION MODULUS.}$$

OF ALL THE PROPERTIES GIVEN WE WILL ONLY NEED S

$$18{,}000 \frac{\text{LBS}}{\text{IN}^2} = \frac{\left(\frac{wL^2}{8}\text{ FT-LB}\right)\left(12\frac{\text{IN}}{\text{FT}}\right)}{78.0 \text{ IN}^3}$$

$$w\frac{\text{LB}}{\text{FT}} = \frac{\left(18{,}000\frac{\text{LBS}}{\text{IN}^2}\right)(8)(78.0\text{ IN}^3)}{(L\text{ FT})^2(12\text{ IN/FT})} = \frac{936{,}000\text{ FT-LBS}}{(L\text{ FT})^2}$$

(a) $w = \frac{936{,}000 \text{ FT-LBS}}{(30)^2\text{ FT}^2}$; $w = 1040 \frac{\text{LBS}}{\text{FT}}$, L=30'

(b) $w = \frac{936{,}000 \text{ FT-LBS}}{(25)^2\text{ FT}^2}$, $w = 1498 \frac{\text{LBS}}{\text{FT}}$, L=25'

(c) $w = \frac{936{,}000 \text{ FT-LBS}}{(20)^2\text{ FT}^2}$ $w = 2340 \frac{\text{LBS}}{\text{FT}}$, L=20'

MESSAGE: LOAD CARRYING CAPABILITY OF A GIVEN BEAM VARIES INVERSELY AS THE SQUARE OF THE SPAN

Unit Number: 32

Title: The strength and structure of ships - 3

Tape Running Time: 32^{M} 11^{S}

Reading Assignment: No new material

Additional References: PNA, pp 167-171, 181-185

Scope:

Calculation of the moment of inertia and the section modulus of a structural section using a tabular format is presented. Application of the Transfer of Axes Theorem is explained. An example of stress analysis is developed using a typical structure found on ships.

Key Points to Emphasize:

1. Go over the Transfer of Axes formula carefully. This is always a source of confusion. Minimum inertia (for a homogeneous material) always occurs at the centroidal axis.

2. Go over the example of the calculation of the section modulus in detail. Emphasize tabular format. Motivator is calculation of ship section modulus (although the units of I are different). See Fig., 15, 16, PNA, pp 183.

3. Go over stress analysis example. Explain why the bracket and connections lead to modeling the structure with built-in ends.

4. Review the information given in Steel Handbook, "Beam Diagrams and Formulas", pp 2-114 to 2-125. Discuss other information that can be obtained from this source.

5. Explain the calculation of maximum stress and where it occurs. Ask class whether it is comprehensive or tensile.

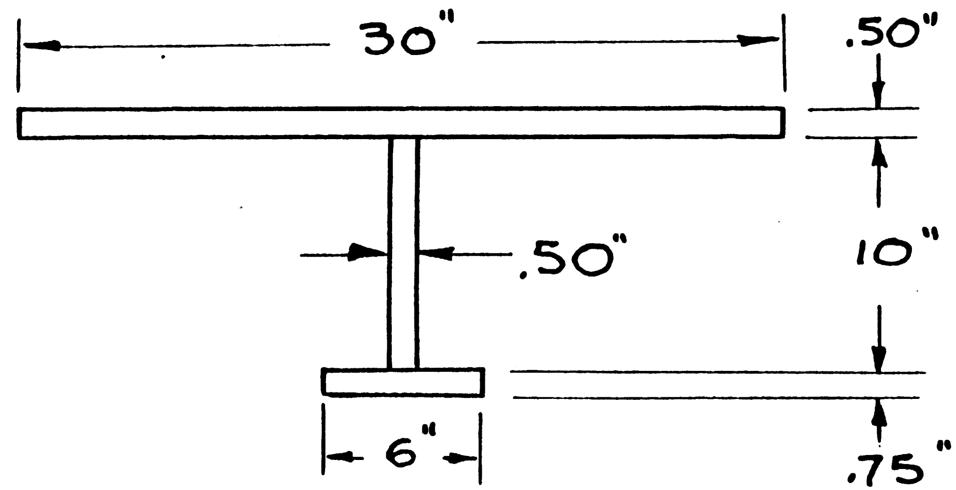
Suggested Problem Assignment: 60, 61

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - EXAMPLE

THE SECTION SHOWN BELOW CONSISTS OF A 30-INCH PANEL OF DECK PLATING WITH A BUILT-UP TEE STIFFENER OF THE DIMENSIONS SHOWN.

FIND THE SECTION MODULUS.



THE STRENGTH AND STRUCTURE OF SHIPS

MOMENT OF INERTIA - TRANSFER OF AXES

THE MOMENT OF INERTIA OF AN AREA IS ALWAYS MINIMUM ABOUT AN AXIS THROUGH ITS CENTROID.

THE MOMENT OF INERTIA MAY BE TRANSFERRED TO A PARALLEL AXIS THROUGH A TRANSFER DISTANCE, y, BY THE TRANSFER OF AXES FORMULA

$$I_{x-x} = I_o + Ay^2$$

I_o = MOMENT OF INERTIA ABOUT AXIS THROUGH CENTROID

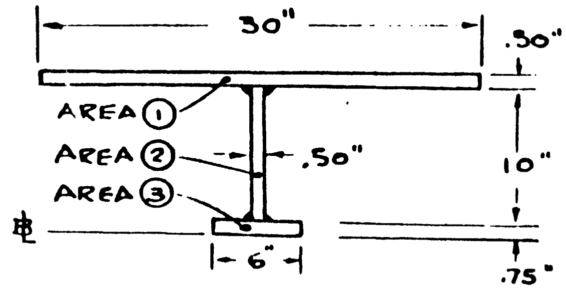
I_{x-x} = MOMENT OF INERTIA ABOUT AXIS PARALLEL TO AXIS THROUGH CENTROID

A = AREA OF SECTION

y = TRANSFER DISTANCE FROM CENTROID TO x-x.

BASIC CONCEPTS - EXAMPLE

SOLUTION



USE TABULAR FORMAT!

ITEM	SCANTLING	AREA, A IN^2	LVR, y IN	MOM'T Ay IN^3	TRANSFER Ay^2 IN^4	I_o IN^4
ASSUMED NEUTRAL AXIS: ℄						
①	.50" × 30"	15.0	11.00	165.0	1815.0	-
②	10" × .50"	5.0	5.75	28.8	165.0	41.6
③	.75" × 6"	4.5	0.38	1.7	0.6	-
		24.5	7.98	195.5	1980.9 +41.6 $I_{℄}$ = 2022.5	41.6

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - EXAMPLE

SOLUTION (CON'T)

- THE AREA IS: 24.5 IN^2
- THE HEIGHT OF THE NEUTRAL AXIS IS:
  7.98 IN. ABOVE THE BL
- THE MOMENT OF INERTIA IS: 2022.5 IN^4 ABOUT THE BL

BUT THE MOMENT OF INERTIA MUST BE TRANSFERRED TO THE NEUTRAL AXIS (CENTROID).

USE THE TRANSFER OF AXES FORMULA AGAIN

$$I_O = I_{BL} - Ay^2$$

WHERE I_O = MOMENT OF INERTIA ABOUT CENTROID.
I_{BL} = MOMENT OF INERTIA ABOUT BL .
A = AREA OF SECTION.
y = TRANSFER DISTANCE FROM BL TO CENTROID.

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - EXAMPLE

SOLUTION (CON'T)

THEN, $I_{NA} = I_{\text{℄}} - Ay^2$

$$I_{NA} = 2022.5 \text{ IN}^4 - (24.5 \text{ IN}^2)(7.98 \text{ IN})^2$$

$$I_{NA} = 2022.5 \text{ IN}^4 - 1560.2 \text{ IN}^4$$

$$I_{NA} = 462.3 \text{ IN}^4$$

ALSO THE DISTANCE, c, TO THE BOTTOM FLANGE IS

$$c_{BOT} = 7.98 \text{ IN}$$

SO THAT $c_{TOP} = 11.25 \text{ IN} - 7.98 \text{ IN} = 3.27 \text{ IN.}$

THEN

$$S_{BOT} = \frac{I}{c_{BOT}} = \frac{462.3 \text{ IN}^4}{7.98 \text{ IN}} = \underline{\underline{57.9 \text{ IN}^3}}$$

$$S_{TOP} = \frac{I}{c_{TOP}} = \frac{462.3 \text{ IN}^4}{3.27 \text{ IN}} = \underline{\underline{141.4 \text{ IN}^3}}$$

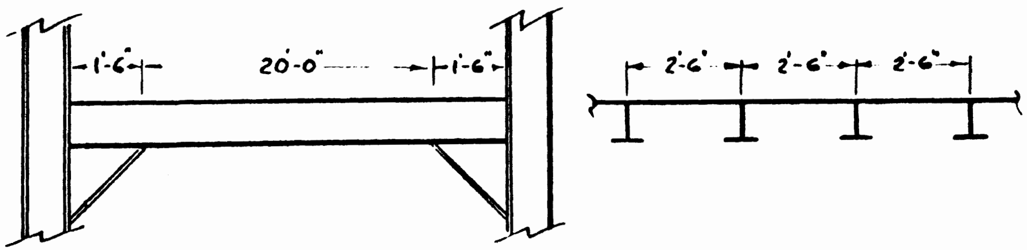
THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - EXAMPLE

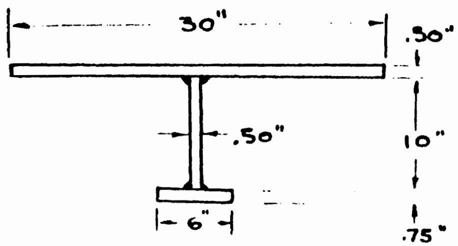
THE DECK SHOWN BELOW IS TO BE DESIGNED FOR A HEAD OF SALTWATER OF 15 FT.

THE ALLOWABLE STRESS FOR THIS STRUCTURE IS σ_{ALL} = 20,000 LBS/IN².

FIND THE LOCATION AND MAGNITUDE OF THE MAXIMUM BENDING STRESSES AND WHETHER OR NOT THESE STRESSES WILL EXCEED THE ALLOWABLE STRESS.

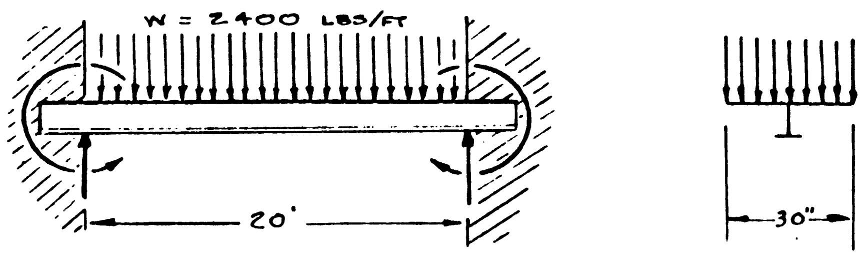


THE PLATING AND STIFFENERS SHOWN ARE THOSE OF THE PREVIOUS EXAMPLE.



BASIC CONCEPTS - EXAMPLE

THE BRACKETS AT EACH END OF THE SPAN ARE HEAVY AND WILL EFFECTIVELY PREVENT ROTATION. MODEL EACH END AS "BUILT-IN".



SALT WATER WEIGHS 64 LBS/FT^3. A COLUMN OF SALT WATER 1 FT^2 x 15 FT HIGH WILL EXERT A PRESSURE OF

$$64\ LBS/FT^3 \times 15\ FT = 960\ LBS/FT^2$$

EACH PANEL IS 30", OR 2.5 FT IN WIDTH. THE PANEL WILL HAVE TO SUPPORT:

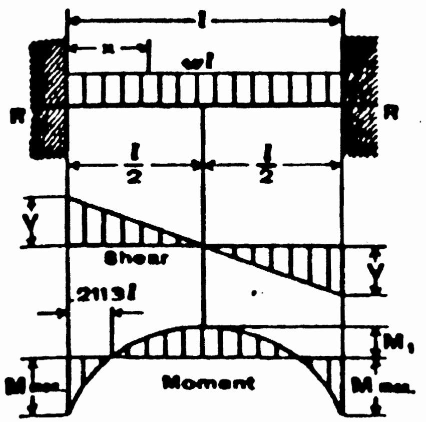
$$960\ LBS/FT^2 \times 2.5\ FT = 2,400\ LBS/FT.$$

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - EXAMPLE

FROM THE MANUAL OF STEEL CONSTRUCTION THE FOLLOWING INFORMATION IS OBTAINED:

15. BEAM FIXED AT BOTH ENDS—UNIFORMLY DISTRIBUTED LOADS



Total Equiv. Uniform Load	$= \frac{2wl}{3}$
$R = V$	$= \frac{wl}{2}$
V_x	$= w\left(\frac{l}{2} - x\right)$
M max. (at ends)	$= \frac{wl^2}{12}$
M_1 (at center)	$= \frac{wl^2}{24}$
M_x	$= \frac{w}{12}(6lx - l^2 - 6x^2)$
Δmax. (at center)	$= \frac{wl^4}{384EI}$
Δ_x	$= \frac{wx^2}{24EI}(l - x)^2$

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - EXAMPLE

CAUTION! IN STRUCTURAL PROBLEMS YOU WILL FIND A STRANGE MIX OF UNITS - TONS, TONS/FT, TONS/FT^2, LBS, LBS/FT, LBS/FT^2, LBS/IN^2, IN, IN^2, IN^3, IN^4, IN^2-FT^2, AND SO ON.

JUST BE CAREFUL TO KEEP YOUR UNITS STRAIGHT!

THE STRENGTH AND STRUCTURE OF SHIPS

BASIC CONCEPTS - EXAMPLE

SINCE THE SECTION MODULUS IS CONSTANT ACROSS THE SPAN, THE MAXIMUM STRESS WILL OCCUR AT THE LOCATION OF THE MAXIMUM BENDING MOMENT. IN THIS CASE, THE MAXIMUM BENDING MOMENT OCCURS AT THE ENDS AND IS:

$$M_{MAX} = \frac{wL^2}{12}$$

THE KEY RELATIONSHIP IS

$$\sigma = \frac{M}{I/c} = \frac{M}{S}$$

THE SMALLER VALUE OF S WILL GIVE THE LARGER STRESS. THIS WAS

$$S_{BOT} = 57.9 \text{ IN}^3$$

BASIC CONCEPTS - EXAMPLE

CONCLUSION

$$M = \frac{wL^2}{12}$$

w = 2400 LBS/FT

L = 20.0 FT (BETWEEN TOES OF BRACKET)

$$M = \frac{(2400 \frac{\text{LBS}}{\text{FT}})(20.0 \text{ FT})^2}{12}$$

$$M = 80{,}000 \ \text{FT-LBS}$$

$$M = 80{,}000 \ \text{FT-LBS} \times \frac{12 \text{ IN}}{1 \text{ FT}} = 960{,}000 \ \text{IN-LB}$$

$$\sigma = \frac{M}{I/c} = \frac{M}{S} = \frac{960{,}000 \text{ IN-LB}}{57.9 \text{ IN}^3} = 16{,}580 \ \frac{\text{LBS}}{\text{IN}^2}$$

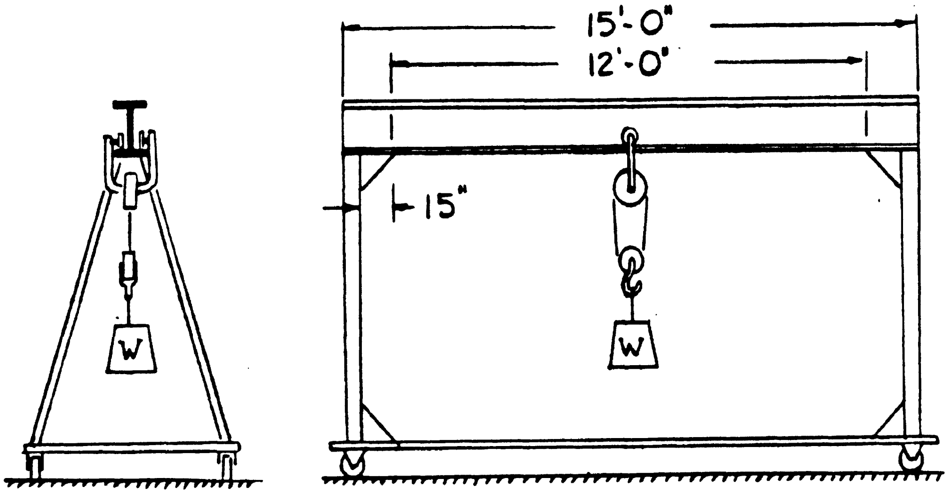
THE MAXIMUM BENDING STRESS WILL OCCUR AT THE TOES OF THE SUPPORT BRACKETS IN THE FLANGE OF THE STIFFENER AND IS BELOW THE ALLOWABLE STRESS OS 20,000 LBS/IN^2.

BASIC NAVAL ARCHITECTURE

Problem 60

Problem Level: Basic

A shop gantry supports a chain hoist. The gantry beam is a mild steel W10 x 30 with a yield strength of σy = 32,000. Find the maximum load the chain hoist can lift with a factor of safety (on yield strength) of 1.5. Neglect the weight of the beam and the chain hoist.



Question: What end conditions will you assume in your analysis?

Note: The properties of the section may be found from tables in the appendix taken from Manual of Steel Construction.

Problem 61

Problem Level: Basic

For each of the following shapes find:

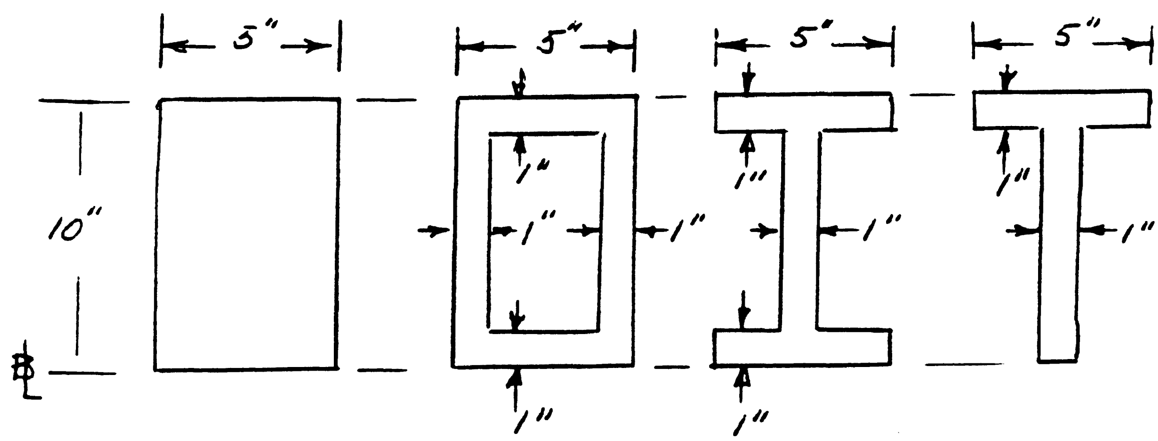
(a) the cross sectional area in in^2,

(b) the location of the neutral axis above the base line in inches,

(c) the moment of inertia of the section about the neutral axis in in^4,

(d) the section modulus of the section 1) to the upper flange, and 2) to the base line,

(e) The weight of each shape is proportional to its cross sectional area. By comparing the section modulus (smaller) to the cross sectional area infer which section is most efficient in terms of strength per unit weight and which section is least efficient.



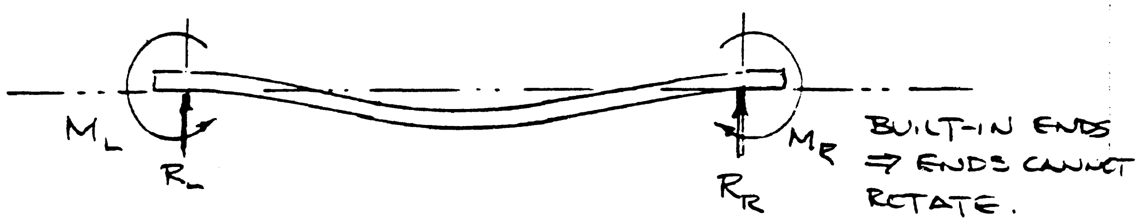
COMMENT ON PROBLEM

THE REAL ISSUE IN THIS PROBLEM IS WHAT END CONDITIONS TO ASSUME -- SIMPLY SUPPORTED OR BUILT-IN. FROM THE GEOMETRY GIVEN THE LEGS MUST EACH BE 3" DEEP, THEY SUPPORT A 15" BRACKET TO THE BEAM AT EACH END.

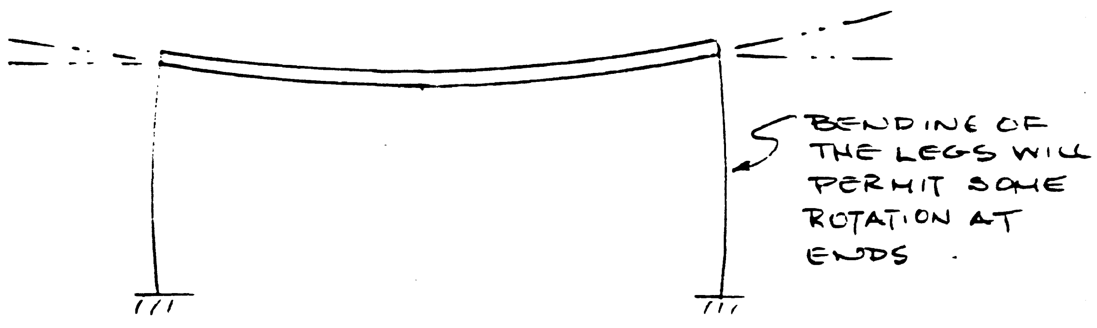
THE DECISION IS BASED ON THE AMOUNT OF ROTATION THAT THE END SUPPORTS WILL PERMIT AT THE ENDS OF THE BEAM.

IF THE END SUPPORTS ARE COMPLETELY INEFFECTIVE IN PREVENTING ROTATION, THEN THE BEAM ACTS LIKE A SIMPLY SUPPORTED BEAM

IF THE END SUPPORTS ARE COMPLETELY EFFECTIVE IN PREVENTING ROTATION THEN THE BEAM ACTS LIKE A BEAM WITH BUILT-IN ENDS.



IN OUR CASE THE ENDS ARE BRACKETED WHICH TENDS TO PREVENT ROTATION. ON THE OTHER HAND THE LEGS ARE SLENDER AND MUCH LESS STIFF THAN THE BEAM. THE STRUCTURE COULD DEFORM AS SHOWN BELOW

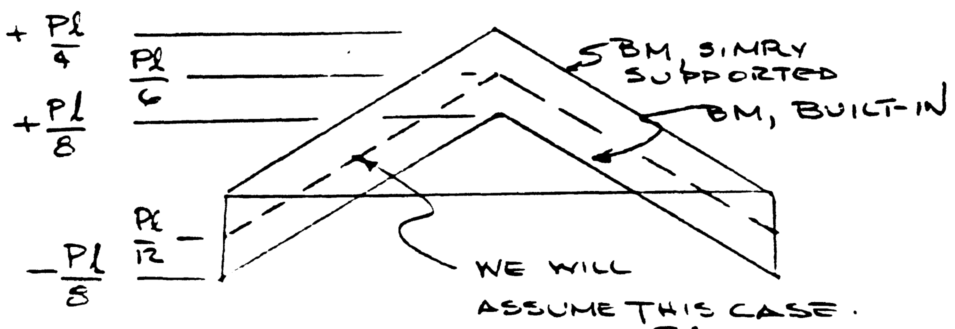


IN OTHERWORDS OUR CASE, AS IS THE CASE WITH MANY STRUCTURES, IS INTERMEDIATE BETWEEN THE TWO EXTREMES. WE DESCRIBE THIS BY SAYING THE ENDS HAVE AN INTERMEDIATE DEGREE OF FIXITY.

SO, HOW MUCH IS INTERMEDIATE? THERE ARE MOMENT DISTRIBUTION METHODS OF ANALYSIS AND OTHER METHODS TAUGHT IN ADVANCED STRUCTURAL COURSE, BUT FOR SIMPL STRUCTURES SUCH AS THIS IT IS COMMON TO ESTIMATE A FIXITY FACTOR BASED ON A FEW VERY SIMPLE RULES.

FOR THIS PROBLEM WE WILL ASSUME A FIXITY FACTOR OF 50% - THAT IS HALF-WAY BETWEEN SIMPLY SUPPORTED AND BUILT-IN ENDS.

NEXT, IN THE EXCERPTS FROM THE MANUAL OF STEEL CONSTRUCTION, BEAM DIAGRAMS AND FORMULAS, CASE 7 AND 16 (pp 2-116, 2-119) GIVE THE FORMULAS FOR THE TWO CASES APPLICABLE HERE.



$BM_{MAX} = \frac{Pl}{6}$

$BM_{ENDS} = \frac{Pl}{12}$

NOTE THAT THE EFFECT OF BUILDING IN THE ENDS IS TO SHIFT THE DIAGRAM DOWNWARD - THAT IS TO DISTRIBUTE SOME OF THE BENDING MOMENT TO THE ENDS.

WHAT'S RIGHT AND WHAT'S WRONG: IF YOU ASSUME 100% SIMPLY SUPPORTED YOU SHOULD BE CONSERVATIVE IN YOUR ESTIMATE OF THE LOAD CARRYING CAPABILITY OF THE STRUCTURE. IF YOU ASSUME 100% BUILT-IN YOU ARE NOT BEING CONSERVATIVE ENOUGH.

WE WILL DO ALL THREE CASES, $BM_{MAX} = \frac{Pl}{4}, \frac{Pl}{6}$, AND $\frac{Pl}{8}$ FOR ILLUSTRATION.

SOLUTION

FOR A W10x30 THE SECTION MODULUS GIVEN IN THE HANDBOOK IS —

$$S = 32.4 \text{ IN}^4$$

GIVEN: $\sigma_y = 32{,}000 \text{ LBS/IN}^2$

FACTOR OF SAFETY = 1.5

$$\text{THEN } \sigma_{all} = \frac{32{,}000 \text{ LBS/IN}^2}{1.5} = 21{,}333 \text{ LBS/IN}^2$$

$$\sigma_{all} = \frac{M_{all}}{S}$$

$$M_{all} = \frac{P\ell}{c} \quad c = 4, 6, 8.$$

$$P = \frac{M_{all} \times c}{\ell} = \frac{\sigma_{all} \times S' \times c}{\ell}$$

CHOICE OF SPAN

SIMPLE SUPPORT - TO MIDPOINTS OF LEGS, $\ell = 14'\text{-}9'' = 177''$

50% FIXITY - TO POINTS HALFWAY BETWEEN TOE OF BRKT AND END OF BEAM, $\ell = 13'\text{-}6'' = 162''$

BUILT-IN - BETWEEN THE TOES OF THE BRACKETS $\ell = 12'\text{-}0'' = 144''$

(a) THEN, FOR SIMPLE SUPPORTS $P_{all} = \dfrac{21{,}333 \frac{\text{LBS}}{\text{IN}^2} \times 32.4 \text{ IN}^3 \times 4}{177 \text{ IN}}$

$$P_{all} = 15{,}620 \text{ LB.}$$

(b) FOR 50% FIXITY $P_{all} = \dfrac{21{,}333 \frac{\text{LBS}}{\text{IN}^2} \times 32.4 \times 6}{162 \text{ IN}}$

$$P_{all} = 25{,}600 \text{ LB.}$$

(c) FOR BUILT-IN SUPPORTS $P_{all} = \dfrac{21{,}333 \frac{\text{LBS}}{\text{IN}^2} \times 32.4 \times 8}{144 \text{ IN}}$

$$P_{all} = 38{,}399 \text{ LB}$$

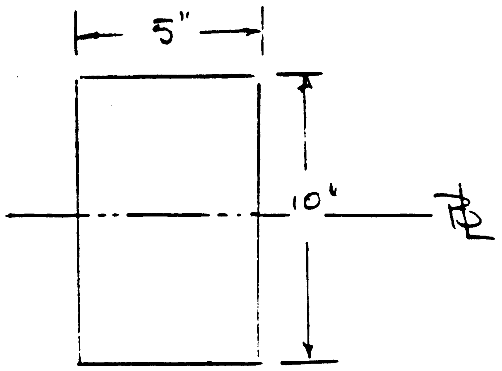
(b) IS RECOMMENDED, (a) IS O.K, (c) IS NO.

GIVEN: FOUR SHAPES.

FIND: $A, \bar{y}, I \quad S_{top}, S_{bot}$
COMPARE STRUCTURAL EFFICIENCIES OF SECTIONS

NOTE: USE TABULAR FORMAT IN ALL SECTION PROPERTY CALCULATIONS

(1) RECTANGLE



USING TABULAR FORMAT FOR A SIMPLE RECTANGLE IS REALLY A FORCE FORCE FIT!

PUT THE ℄ THROUGH THE CENTROID TO AVOID TRANSFERS

$I_{na} = I_{℄}$

FOR RECTANGLE, $I = \frac{bh^3}{12}$

ITEM	SCANTLING IN x IN	AREA A IN^2	LVR $\bar{y}$ IN	MOM'T $A\bar{y}$ IN^3	TRANSFER $A\bar{y}^2$ IN^4	INERTIA i_o IN^4
RECTANGLE	5.0 x 10.0	50.0	0	0	0	416.7
		50.0	0	0	0	416.7

$C_{TOP} = 5.00$

$C_{BOT} = 5.00$

416.7

TRANSFER $I_{℄} = 416.7$

TRANSFER TO NEUTRAL AXIS 0

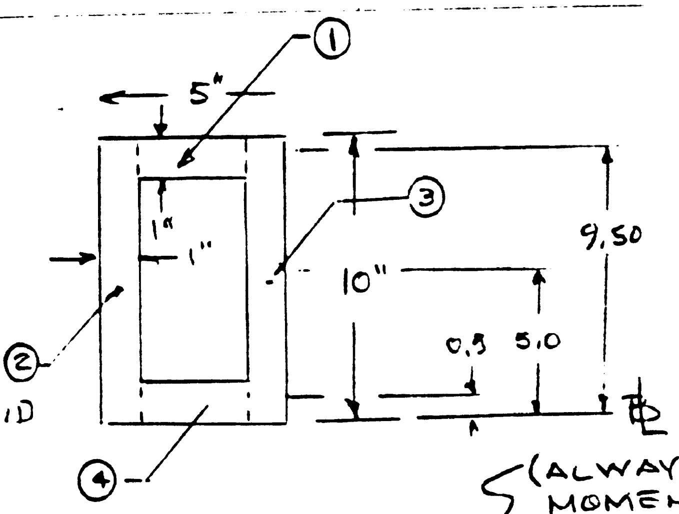
$I_{na} = 416.7$

SECTION MODULUS, $S_{TOP} = S_{BOT} = \frac{416.7 \text{ IN}^4}{5.0 \text{ IN}} = 83.3 \text{ IN}^3$

WE WILL OBTAIN A MEASURE OF HOW MUCH SECTION MODULUS WE ARE OBTAINING FOR A GIVEN AREA BY TAKING THE RATIO,

$$\frac{S_{(LESSER)}}{A} = \frac{83.3 \text{ IN}^3}{50.0 \text{ IN}^2} = 1.67 \text{ IN}$$

(2) HOLLOW RECTANGLE



WE COULD SIMPLIFY THIS ONE BY ALSO PUTTING THE ℄ THROUGH THE CENTROID WHICH WE KNOW BY SYMMETRY, BUT SET IT AT THE BOTTOM FOR ILLUSTRATION

(ALWAYS DEFINE MOMENT AXIS)

TAKE MOMENTS ABOUT ℄

ITEM	SCANTLING IN x IN	AREA A IN^2	LVR $\bar{y}$ IN	MOM'T $A\bar{y}$ IN^3	TRANSFER $A\bar{y}^2$ IN^4	INERTIA i_o IN^4
①	3.0 x 1.0	3.0	9.50	28.5	270.8	0.3 *
②	1.0 x 10.0	10.0	5.00	50.0	250.0	83.3
③	1.0 x 10.0	10.0	5.00	50.0	250.0	83.3
④	3.0 x 1.0	3.0	0.50	1.5	0.8	0.3 *
①+②+③+④		26.0	5.00	130.0	771.6	167.2

$C_{top} = 5.00$

$C_{bot} = 5.00$

771.6
+ 167.2

$I_{℄} = 938.8 \text{ IN}^4$

$$\text{TRANSFER INERTIA TO N.A.} = \underbrace{(26.0\text{ IN}^2)}_{A}\underbrace{(5.00\text{ IN})^2}_{\bar{y}^2} = 650.0 \text{ IN}^4$$

$I_{na} = 288.8 \text{ IN}^4$

$$\text{SECTION MODULUS} = \frac{I}{C_{top}} = \frac{288.8\text{ IN}^4}{5.0\text{ IN}} = 57.76\text{ IN}^3$$

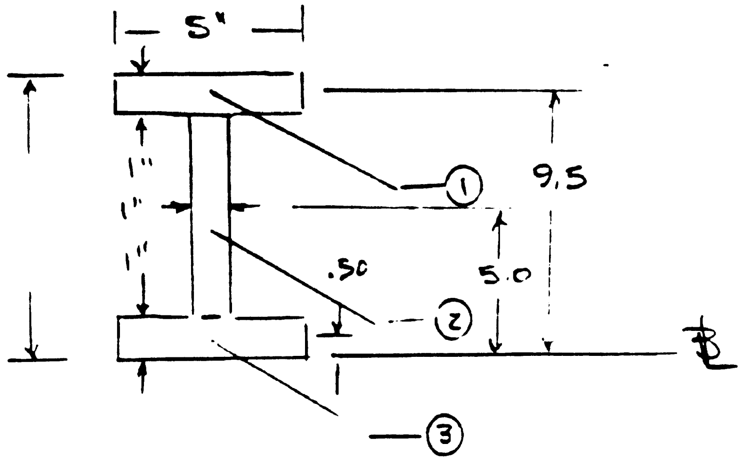
$$\frac{I}{C_{bot}} = \frac{288.8\text{ IN}^4}{5.0\text{ IN}} = 57.76\text{ IN}^3$$

$$\text{RATIO, } \frac{S}{A} = \frac{57.76\text{ IN}^3}{26.0\text{ IN}^2} = \underline{2.22\text{ IN}}$$

* NOTES: HORIZONTAL FLAT PLATES, e.g. DECK PLATING, BY THE TIME YOU CUBE A SMALL THICKNESS, DIVIDE BY 12 AND MULTIPLY BY THE WIDTH YOU ARE LEFT WITH SUCH A SMALL NUMBER THAT YOU MIGHT AS WELL NEGLECT IT.

(3) I BEAM

TAKE MOM'TS ABT ℄



ITEM	SCANTLING IN x IN	AREA A IN²	LVR $\bar{y}$ IN	MOM'T $A\bar{y}$ IN³	TRANSFER $A\bar{y}^2$ IN⁴	INERTIA i_o IN⁴
① TOP FLG	5.0 x 1.0	5.0	9.5	47.5	451.3	0.8 *
② WEB	1.0 x 8.0	8.0	5.0	40.0	200.0	42.7
③ BOT FLG.	5.0 x 1.0	5.0	0.5	2.5	1.3	0.8 *
①+②+③		18.0	5.0	90.0	652.6	44.3

44.3

$C_{TOP} = 5.0$

$C_{BOT} = 5.0$

$I_{℄} = 696.9 \text{ IN}^4$

TRANSFER TO N.A. = $(18.0 \text{ IN}^2)(5.0 \text{ IN})^2 = 450.0 \text{ IN}^4$

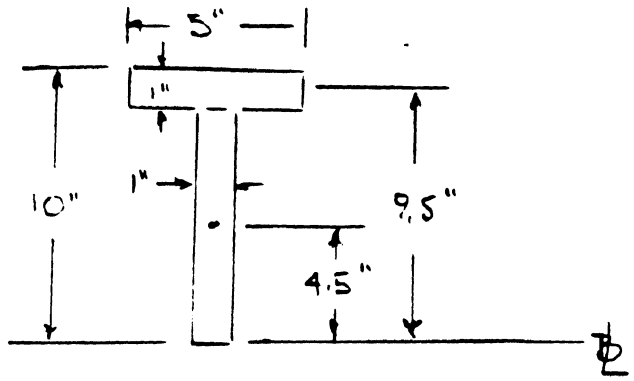
$I_{na} = 246.9 \text{ IN}^4$

SECTION MODULUS, $\frac{I}{C_{TOP}} = \frac{I}{C_{BOT}} = \frac{246.9 \text{ IN}^4}{5.0 \text{ IN}} = 49.4 \text{ IN}^3$

RATIO, $\frac{S}{A} = \frac{49.4 \text{ IN}^3}{18.0 \text{ IN}^2} = 2.74 \text{ IN}$

* SEE NOTE ABOUT THIN HORIZONTAL MEMBERS NO. (2) CASE.

(4) TEE BEAM



TAKE MOM'TS ABT ℄

ITEM	SCANTLING IN x IN	AREA A IN^2	LVR $\bar{y}$ IN	MOM'T $A\bar{y}$ IN^3	TRANSFER $A\bar{y}^2$ IN^4	INERTIA I_o IN^4
TOP FLG	5.0 x 1.0	5.0	9.5	47.5	451.3	0.8 *
WEB	1.0 x 9.0	9.0	4.5	40.5	182.3	60.8
TEE		14.0	6.29	88.0	633.6	61.6
					61.6 ✓	

$C_{bot} = 6.29$

$C_{top} = 3.71$

$I_{℄} = 695.2 \ IN^4$

TRANSFER TO N.A. $= (14.0 \ in^2)(6.29)^2 = 553.9 \ IN^4$

$I_{na} = 141.3 \ IN^4$

SECTION MODULUS, TOP $= \dfrac{I_{na}}{C_{top}} = \dfrac{141.3 \ in^4}{3.71 \ in^3} = 38.1 \ in^3$

SECTION MODULUS, BOT $= \dfrac{I_{na}}{C_{bot}} = \dfrac{141.3 \ in^4}{6.29 \ in^3} = 22.5 \ in^3$

RATIO, $\dfrac{S_{top}}{A} = \dfrac{38.1 \ in^3}{14.0 \ in^2} = 2.72 \ in$

RATIO, $\dfrac{S_{bot}}{A} = \dfrac{22.5 \ in^3}{14.0 \ in^2} = 1.61 \ in$

COMPARISON		S/A
	(1) RECTANGLE	1.67 in
	(2) HOLLOW RECTANGLE	2.22 in
	(3) I-BEAM	2.74 in
	(4) T-BEAM	1.61 in

THE I-BEAM IS MOST EFFICIENT BECAUSE OF ITS SYMMETRICAL DISTRIBUTION OF AREA IN THE FLANGES. TEE BEAM IS LEAST EFFICIENT (BY ITSELF) BECAUSE OF UNSYMMETRICAL DISTRIBUTION.

BASIC NAVAL ARCHITECTURE

Unit Number: 33

Title: The strength and structure of ships - 4

Tape Running Time: 34^{M} 22^{S}

Reading Assignment: MSD, pp 210-212

Additional References: INA, pp 82-91

PNA, pp 168-171 (repeated)

Scope:

Strength curves for a barge example are developed. Classification of loads by type is discussed. The key events in the structural design cycle are described. ABS Rules are introduced.

Key Points to Emphasize:

1. Go over the barge strength curve example in detail. Try to straighten out the sign convention mess in the student's mind. Again, emphasize physical meaning -- hogging, sagging, tension, compression.

2. As in previous examples emphasize graphical interpretation of curves -- area, ordinate, slope, curvature.

3. Make the point at this stage -- maximum bending stresses usually occur in the midships region in the deck and on the quarter points at the neutral axis which is oftentimes in the vicinity of the waterline.

4. Review classification of loads and key events in the design cycle. Emphasize iterative nature of design cycle.

5. At this stage the only point to be made about ABS Rules is that they exist. Show ABS Rule Book in class but don't go into much detail.

Suggested Problem Assignment: 62 or 63, 64

THE STRENGTH AND STRUCTURE OF SHIPS

LOADS ON THE SHIP'S STRUCTURE

CLASSIFICATION OF LOADS

- PRIMARY LOADS - DOMINANT LOADS WHICH DRIVE THE OVERALL STRUCTURAL DESIGN, E.G., WAVE-INDUCED LONGITUDINAL BENDING LOADS

- SECONDARY LOADS - SIGNIFICANT LOADS WHICH AFFECT LARGE LOCAL AREAS OF THE STRUCTURAL DESIGN, E.G., HYDROSTATIC LOADS

- TERTIARY LOADS - SMALLER LOADS WHICH AFFECT SMALLER LOCAL AREAS AND STRUCTURAL DETAILS, E.G., EFFECT OF MACHINERY WEIGHTS ON STRUCTURAL FOUNDATIONS

THE STRENGTH AND STRUCTURE OF SHIPS

LOADS ON THE SHIP'S STRUCTURE

CLASSIFICATION OF LOADS BY DYNAMIC TYPE

1. STATIC LOADS.

   - LONGITUDINAL BENDING MOMENTS ARISING FROM DIFFERENCE IN DISTRIBUTION OF WEIGHT AND BUOYANCY IN STILL WATER
   - WEIGHTS OF STRUCTURE, EQUIPMENT AND MACHINERY
   - CARGO WEIGHT
   - DRYDOCKING LOADS
   - THERMAL LOADS

THE STRENGTH AND STRUCTURE OF SHIPS

LOADS ON THE SHIP'S STRUCTURE

CLASSIFICATION OF LOADS BY DYNAMIC TYPE

2. SLOWLY VARYING LOADS.

   - WAVE-INDUCED LONGITUDINAL BENDING MOMENTS
   - WAVE-INDUCED LATERAL BENDING MOMENTS AND TORSIONAL MOMENTS
   - WAVE SLAP LOADS
   - INERTIAL LOADS DUE TO THE ACCELERATIONS A SHIP EXPERIENCES IN A SEAWAY
   - SHIPPING OF GREEN WATER ON THE FOREDECK
   - LAUNCHING LOADS
   - ICEBREAKING LOADS

LOADS ON THE SHIP'S STRUCTURE

CLASSIFICATION OF LOADS BY DYNAMIC TYPE

3. RAPIDLY VARYING LOADS

- SLAMMING LOADS:
  - FOREFOOT
  - BOW FLARE
- PROPELLER-INDUCED VIBRATORY LOADS
- SPRINGING VIBRATIONS
- UNDERWATER EXPLOSIONS
- GUN BLASTS AND MISSILE-LAUNCHING LOADS
- COLLISIONS AND GROUNDINGS

THE STRENGTH AND STRUCTURE OF SHIPS

THE STRUCTURAL DESIGN CYCLE

THE KEY EVENTS ARE:

1. ESTIMATE PRIMARY AND SECONDARY LOADS
2. DEVELOP STRUCTURAL DESIGN (FIRST CYCLE)
3. ANALYZE STRESSES IN PRIMARY STRUCTURE
4. ADJUST PRIMARY STRUCTURAL DESIGN
5. ANALYZE STRESSES RESULTING FROM SECONDARY LOADS
6. ESTIMATE TERTIARY LOADS
7. MAKE FINAL ADJUSTMENTS TO STRUCTURAL DESIGN

CLASSIFICATION SOCIETIES - EXAMPLE OF STRUCTURAL RULES

11.7 Deck Girders and Transverses Clear of Tanks

11.7.1 Deck Girders Clear of Tanks

Each deck girder clear of tanks, similar to that shown in Figure 11.1, is to have a section modulus *SM* as obtained from the following equation.

$$SM = 4.74cbhl^2 \text{ cm}^3 \qquad SM = 0.0025cbhl^2 \text{ in.}^3$$

c = 1.0
b = mean breadth of the area of deck supported in m or ft
h = height as required by Section 10 for the beams supported, in m or ft
l = span between centers of supporting pillars, or between pillar and bulkhead, in m or ft. Where an effective bracket in accordance with 9.3.3 is fitted at the bulkhead, the length l may be modified.

11.7.2 Deck Transverses Clear of Tanks

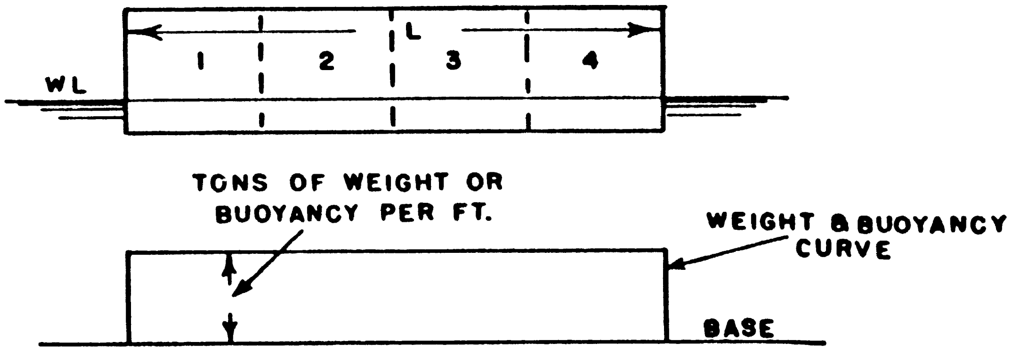
Each deck transverse supporting a longitudinal deck beam is to have a section modulus *SM* as obtained from the equations in 11.7.1 where

c = 1.0
b = spacing of deck transverses in m or ft
h = height as required by Section 10 for the beams supported, in m or ft
l = span between supporting girders or bulkheads, or between girder and side frame, in m or ft. Where an effective bracket is fitted at the side frame, the length l may be modified. See 9.3.3.

THE STRENGTH AND STRUCTURE OF SHIPS

LONGITUDINAL BENDING MOMENT IN STILL WATER

CONSIDER AN IDEALIZED RECTANGULAR BARGE UNIFORMLY LOADED IN STILL WATER.

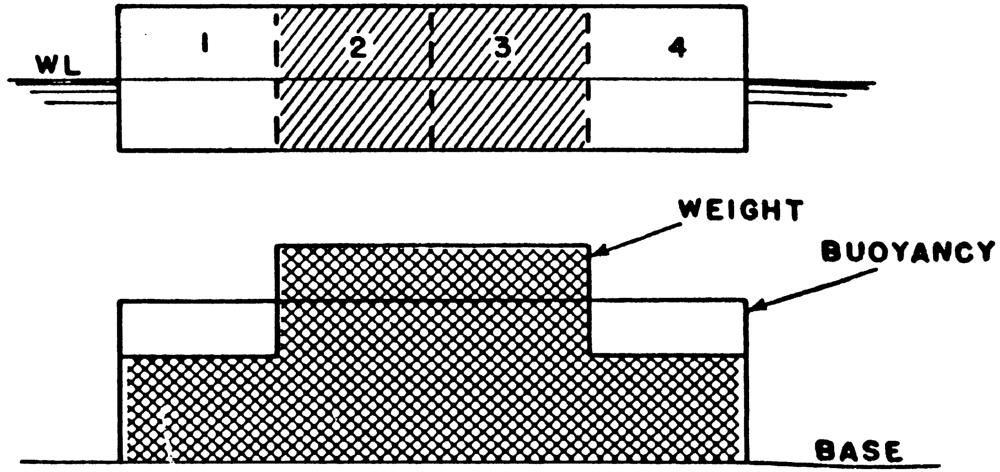


THERE IS NO DIFFERENCE BETWEEN THE WEIGHT LOAD AND THE BUOYANT SUPPORT, THUS THERE IS NO BENDING MOMENT.

37.8.

LONGITUDINAL BENDING MOMENT IN STILL WATER

NEXT, CONSIDER THE SAME BARGE LOADED WITH CARGO IN HOLDS NO. 2 AND 3.

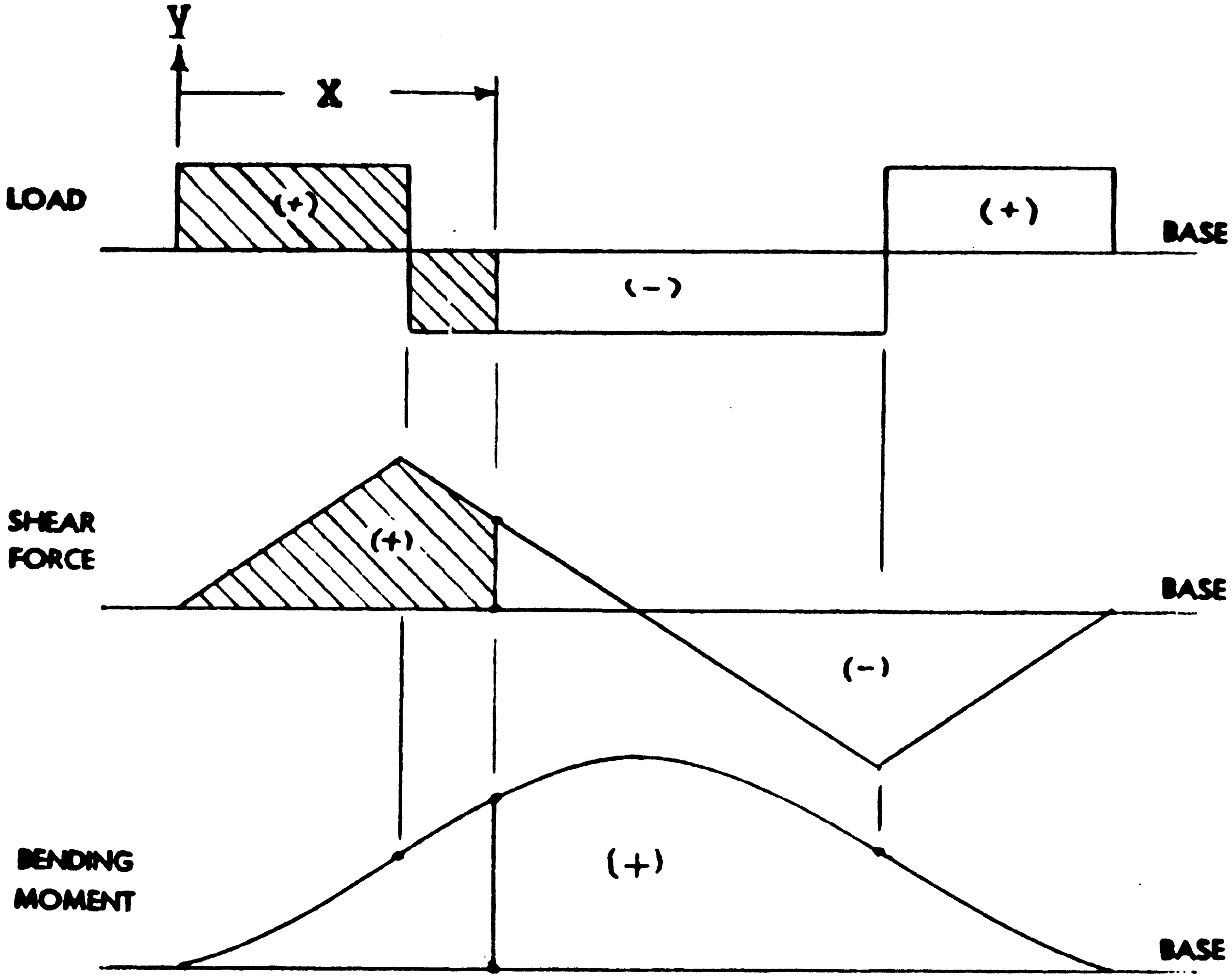


CONDITIONS FOR EQUILIBRIUM:

- THE TOTAL AREA UNDER THE WEIGHT CURVE MUST EQUAL THE TOTAL AREA UNDER THE BUOYANCY CURVE.
- THE CENTROID OF THE AREA UNDER THE WEIGHT CURVE (LCG) MUST BE IN THE SAME LONGITUDINAL LOCATION AS THE CENTROID OF THE BUOYANCY CURVE (LCB).

THE STRENGTH AND STRUCTURE OF SHIPS

LONGITUDINAL BENDING MOMENT IN STILL WATER

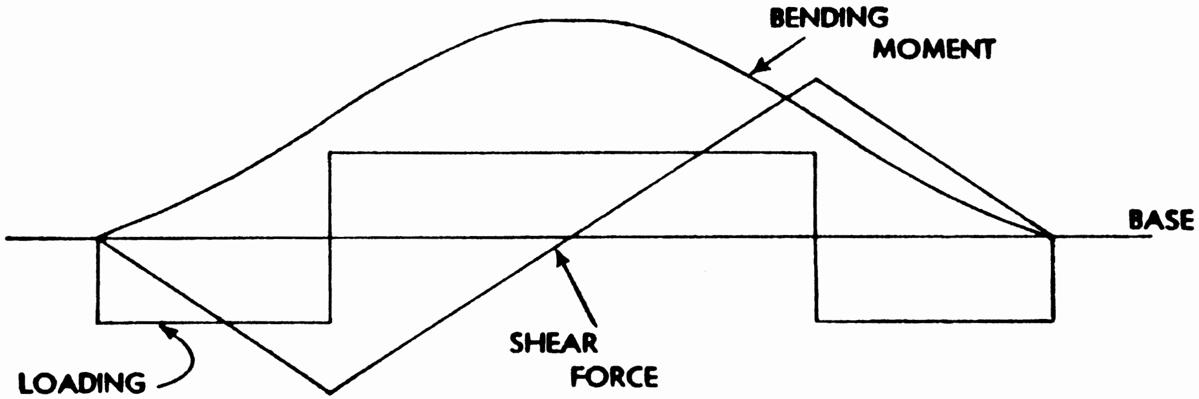


THE STRENGTH AND STRUCTURE OF SHIPS

LONGITUDINAL BENDING MOMENT IN STILL WATER

THE ORDINATE OF THE SHEAR FORCE CURVE AT A POINT IS EQUAL TO THE TOTAL AREA (POSITIVE AND NEGATIVE) TO THE LEFT OF THE POINT ON THE LOAD CURVE.

THE ORDINATE OF THE BENDING MOMENT CURVE AT A POINT IS EQUAL TO THE TOTAL AREA (POSITIVE AND NEGATIVE) TO THE LEFT OF THE POINT IN THE SHEAR FORCE CURVE.



THE STRENGTH AND STRUCTURE OF SHIPS

RECTANGULAR BARGE EXAMPLE (MSD pp 212)

CONSIDER A RECTANGULAR BARGE:

$L = 100'\text{-}0''$

$B = 25'\text{-}0''$

$D = 6'\text{-}0''$

$T_f = T_a = 2'\text{-}0''$ EMPTY.

THE TWO CENTER COMPARTMENTS ARE FILLED WITH FRESH WATER TO 30% CAPACITY.

THE STRENGTH AND STRUCTURE OF SHIPS

RECTANGULAR BARGE EXAMPLE

1. PLOT WEIGHT, BUOYANCY, LOAD, SHEAR FORCE, AND BENDING MOMENT CURVES.
2. PLOT THE STRESS IN THE DECK AND THE BOTTOM IF THE MOMENT OF INERTIA AND HEIGHT OF NEUTRAL AXIS ARE UNIFORM OVER THE LENGTH:

$$I_{NA} = 480.0 \text{ IN}^2\text{-FT}^2$$

$$c_{TOP} = 3.25 \text{ FT}$$

$$c_{BOT} = 2.75 \text{ FT}$$

RECTANGULAR BARGE EXAMPLE (CON'T)

SOLUTION

ASSUME THE WEIGHT PER FOOT OF THE BARGE BEFORE LOADING IS CONSTANT.

STEP 1. FIND THE WEIGHT PER FOOT OF THE EMPTY BARGE.

$$W_1 = \Delta_1 = \frac{L \times B \times T}{35} = \frac{100\text{ FT} \times 25\text{ FT} \times 2\text{ FT}}{35\text{ FT}^3/\text{TON}}$$

$$W_1 = 143.0 \text{ LT}$$

$$WT/FT = \frac{W_1}{L} = \frac{143.0}{100} \frac{\text{TONS}}{\text{FT}}$$

$$WT/FT = 1.43 \text{ TONS/FT}$$

THE STRENGTH AND STRUCTURE OF SHIPS

RECTANGULAR BARGE EXAMPLE (CON'T)

STEP 2. FIND THE BUOYANCY PER FOOT OF THE BARGE AFTER LOADING.

THE LENGTH OF EACH COMPARTMENT IS

$$100.0 \text{ FT}/4 = 25.0 \text{ FT}$$

THE TANK WILL BE LOADED TO A DEPTH OF

$$6.0 \text{ FT} \times .30 = 1.8 \text{ FT}.$$

TAKE THE SPECIFIC VOLUME OF FRESH WATER TO BE 36 FT3/TON. THEN THE WEIGHT OF THE WATER IN EACH TANK IS:

$$W = \frac{25.0 \text{ FT} \times 25.0 \text{ FT} \times 1.8 \text{ FT}}{\text{FT}^3/\text{TON}}$$

$$W = 31.25 \text{ LT}$$

RECTANGULAR BARGE EXAMPLE (CON'T)

STEP 2. (CON'T) THE WEIGHT PER FOOT OF THE WATER IN THE TANK WILL BE:

$$WT/FT = \frac{31.25}{25} \frac{TONS}{FT}$$

$$WT/FT = 1.25 \ TONS/FT$$

THEN

$$\Delta = 143.0 \ (\text{EMPTY WEIGHT})$$
$$+ \ 31.25 \ (\text{LOAD})$$
$$+ \ 31.25 \ (\text{LOAD})$$
$$\Delta = 205.5 \ LT.$$

AND THE BUOYANCY PER FOOT WILL BE

$$BUOY./FT = \frac{205.5}{100.0} \frac{TONS}{FT} = \underline{\underline{2.055 \ TONS/FT}}$$

RECTANGULAR BARGE EXAMPLE (CON'T)

STEP 3. FIND ORDINATES OF LOAD DIAGRAM. SIGN CONVENTION: TAKE BUOYANCY POSITIVE, WEIGHT NEGATIVE (NOTE DIFFERENT SIGN CONVENTION IN BOOK)

LOAD/FT = BUOY/FT - WT/FT.

END TANKS:

LOAD/FT. = + 2.055 TONS/FT (BUOYANCY)
− 1.43 TONS/FT (EMPTY WEIGHT)

LOAD/FT. = + 0.625 TONS/FT

CENTER TANKS:

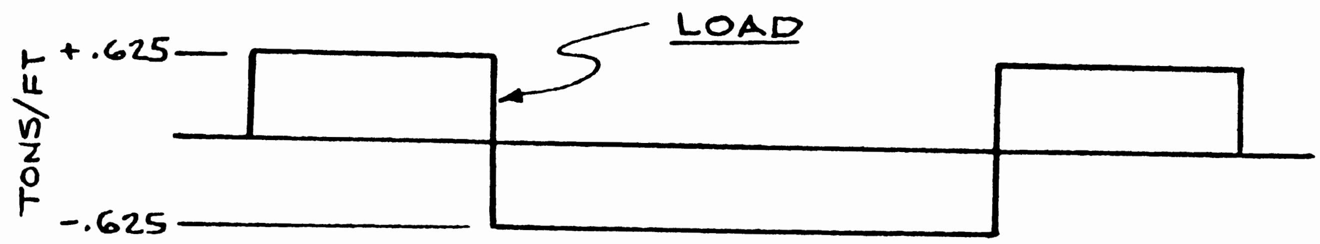
LOAD/FT = + 2.055 TONS/FT (BUOYANCY)
− 1.43 TONS/FT (EMPTY WEIGHT)
− 1.25 TONS/FT (WATER LOAD)

LOAD/FT = − 0.625 TONS/FT

THE STRENGTH AND STRUCTURE OF SHIPS

RECTANGULAR BARGE EXAMPLE (CON'T)

STEP 4. PLOT THE LOAD DIAGRAM



RECTANGULAR BARGE EXAMPLE (CON'T)

STEP 5. FIND THE ORDINATES OF THE SHEAR FORCE DIAGRAM.

SHEAR FORCE AT 75'-0" BULKHEAD = AREA UNDER LOAD DIAGRAM

$S.F._{75} = +0.625 \text{ TONS/FT} \times 25.0 \text{ FT}$

$S.F._{75} = +15.625 \text{ TONS}$

AT THE ⅋ BULKHEAD:

$S.F._{⅋} = +15.625 \text{ TONS} - 0.625 \text{ TONS/FT} \times 25.0 \text{ FT}$

$S.F._{⅋} = 0.0 \text{ TONS}$

AT THE 25'-0" BULKHEAD:

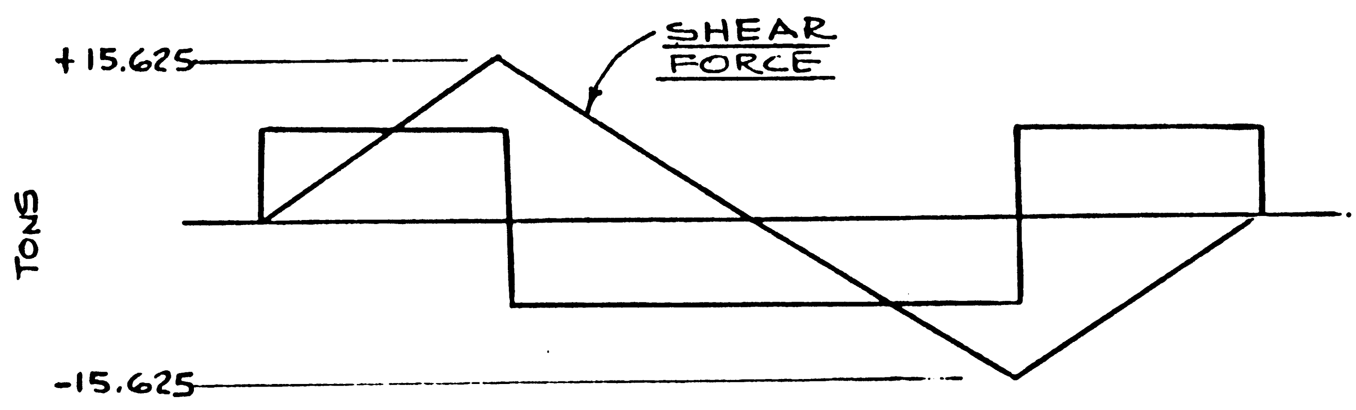
$S.F._{25} = 0.0 \text{ TONS} - 0.625 \text{ TONS/FT} \times 25.0 \text{ FT.}$

$S.F._{25} = -15.625 \text{ TONS}$

THE STRENGTH AND STRUCTURE OF SHIPS

RECTANGULAR BARGE EXAMPLE (CON'T)

STEP 6. PLOT THE SHEAR FORCE DIAGRAM



RECTANGULAR BARGE EXAMPLE (CON'T)

STEP 7. FIND THE ORDINATES OF THE BENDING MOMENT DIAGRAM.

BENDING MOMENT AT 75'-0" BULKHEAD = AREA UNDER SHEAR FORCE DIAGRAM.

$$B.M._{75} = \frac{1}{2} \times 15.625 \text{ TONS} \times 25.0 \text{ FT}$$

$$B.M._{75} = +195.3 \text{ FT-TONS}$$

AT THE ⊗ BHD:

$$B.M._{⊗} = +195.3 \text{ FT-TONS} + \frac{1}{2} \times 15.625 \text{ TONS} \times 25.0 \text{ FT.}$$

$$B.M._{⊗} = +390.6 \text{ FT-TONS}$$

AT THE 25'-0" BHD:

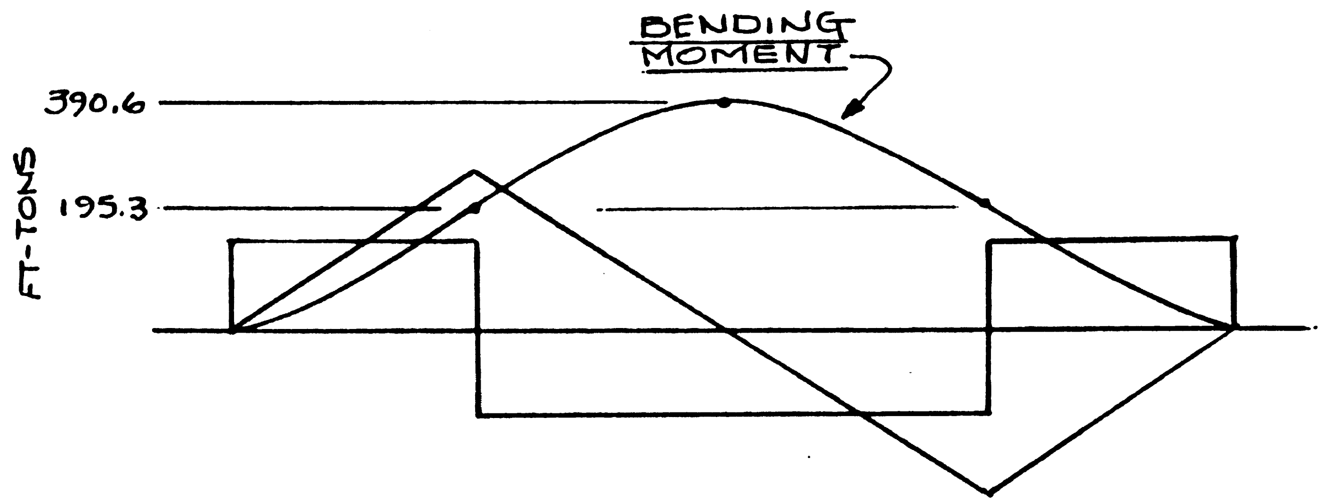
$$B.M._{25} = +390.6 \text{ FT-TONS} - \frac{1}{2} \times 15.625 \text{ TONS} \times 25.0 \text{ FT}$$

$$B.M._{25} = +195.3 \text{ FT-TONS}$$

THE STRENGTH AND STRUCTURE OF SHIPS

RECTANGULAR BARGE EXAMPLE (CON'T)

STEP 8. PLOT THE BENDING MOMENT DIAGRAM.



RECTANGULAR BARGE EXAMPLE (CON'T)

STEP 9. FIND THE STRESSES IN DECK AND BOTTOM.

$$\sigma = \frac{M}{I/c} = \frac{M}{S}$$

$$\left.\begin{array}{l} I = 480.0 \ IN^2\text{-}FT^2 \\ C_{TOP} = 3.25 \ FT \\ C_{BOT} = 2.75 \ FT \end{array}\right\} \text{GIVEN}$$

THEN

$$S_{TOP} = \frac{480.0}{3.25} \frac{IN^2\text{-}FT^2}{FT}$$

$$S_{TOP} = 147.7 \ IN^2\text{-}FT$$

$$S_{BOT} = \frac{480.0}{2.75} \frac{IN^2\text{-}FT^2}{FT}$$

$$S_{BOT} = 174.55 \ IN^2\text{-}FT$$

RECTANGULAR BARGE EXAMPLE (CON'T)

STEP 9. (CON'T)

AT THE 75'-0" BHD:

$$\sigma_{DK} = \frac{M_{75}}{S_{TOP}} = \frac{+195.3}{147.7}\ \frac{\text{FT-TONS}}{\text{IN}^2\text{-FT}} \times \frac{2240\ \text{LBS}}{1\ \text{TON}}$$

$$\sigma_{DK} = 2{,}962\ \text{LBS/IN}^2\ \text{(COMPRESSION)}$$

$$\sigma_{BOT} = \frac{M_{75}}{S_{BOT}} = \frac{+195.3}{174.55}\ \frac{\text{FT-TONS}}{\text{IN}^2\text{-FT}} \times \frac{2240\ \text{LBS}}{1\ \text{TON}}$$

$$\sigma_{BOT} = 2{,}506\ \text{LBS/IN}^2\ \text{(TENSION)}$$

THE STRENGTH AND STRUCTURE OF SHIPS

RECTANGULAR BARGE EXAMPLE (CON'T)

STEP 9. (CON'T)

AT THE ⨂ BHD:

$$\sigma_{DK} = \frac{+390.6}{147.7} \frac{\text{FT-TONS}}{\text{IN}^2\text{-FT}} \times \frac{2240 \text{ LBS}}{1 \text{ TON}} = 5{,}924 \frac{\text{LBS}}{\text{IN}^2} \text{ (C)}$$

$$\sigma_{BOT} = \frac{+390.6}{174.55} \frac{\text{FT-TONS}}{\text{IN}^2\text{-FT}} \times \frac{2240 \text{ LBS}}{1 \text{ TON}} = 5{,}013 \frac{\text{LBS}}{\text{IN}^2} \text{ (T)}$$

AT THE 25'-0" BHD:

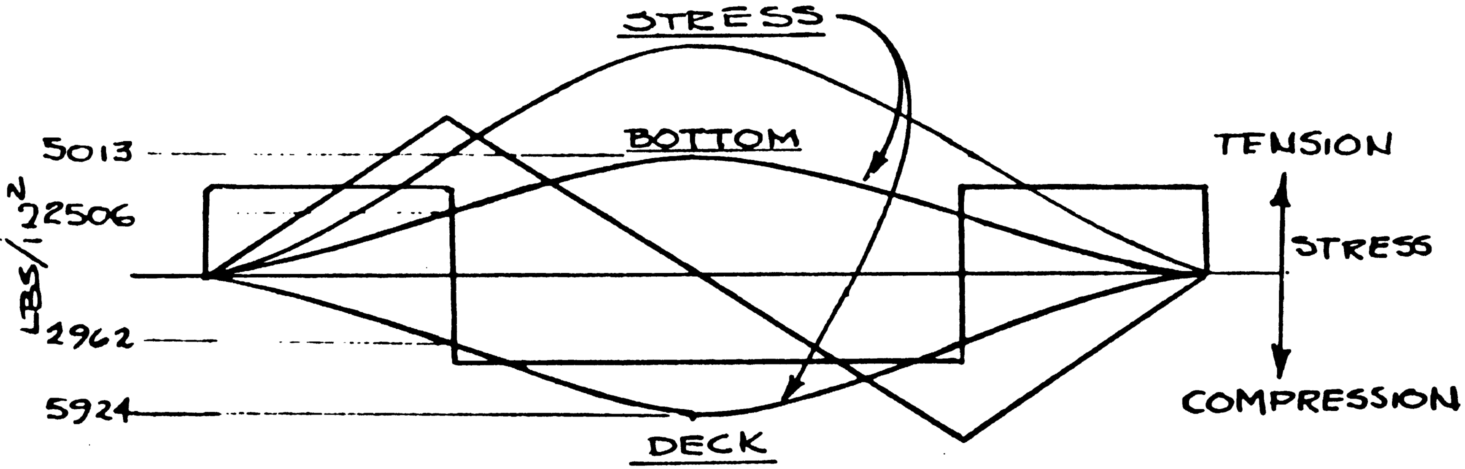
$$\sigma_{DK} = \frac{+195.3}{147.7} \frac{\text{FT-TONS}}{\text{IN}^2\text{-FT}} \times \frac{2240 \text{ LBS}}{1 \text{ TON}} = 2{,}962 \frac{\text{LBS}}{\text{IN}^2} \text{ (C)}$$

$$\sigma_{BOT} = \frac{+195.3}{174.55} \frac{\text{FT-TONS}}{\text{IN}^2\text{-FT}} \times \frac{2240 \text{ LBS}}{1 \text{ TON}} = 2{,}506 \frac{\text{LBS}}{\text{IN}^2} \text{ (T)}$$

THE STRENGTH AND STRUCTURE OF SHIPS

RECTANGULAR BARGE EXAMPLE (CON'T)

STEP 10. PLOT THE STRESSES IN THE DECK AND BOTTOM.

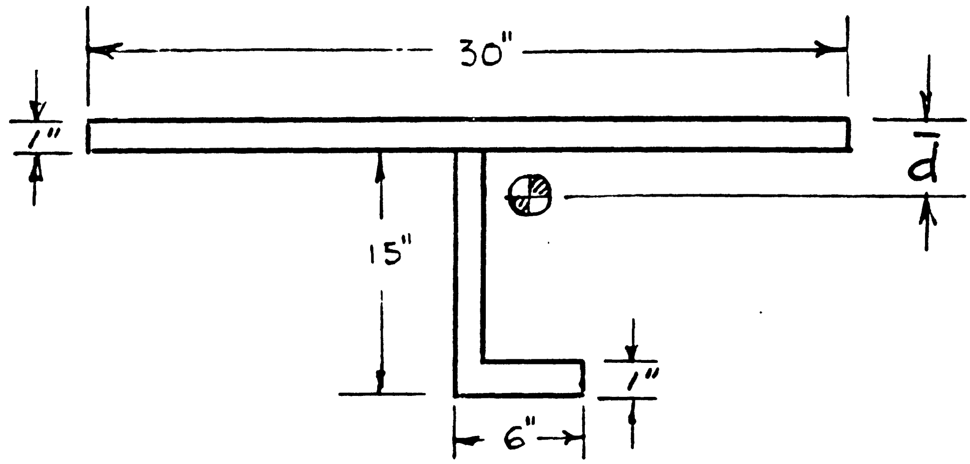


Problem 62

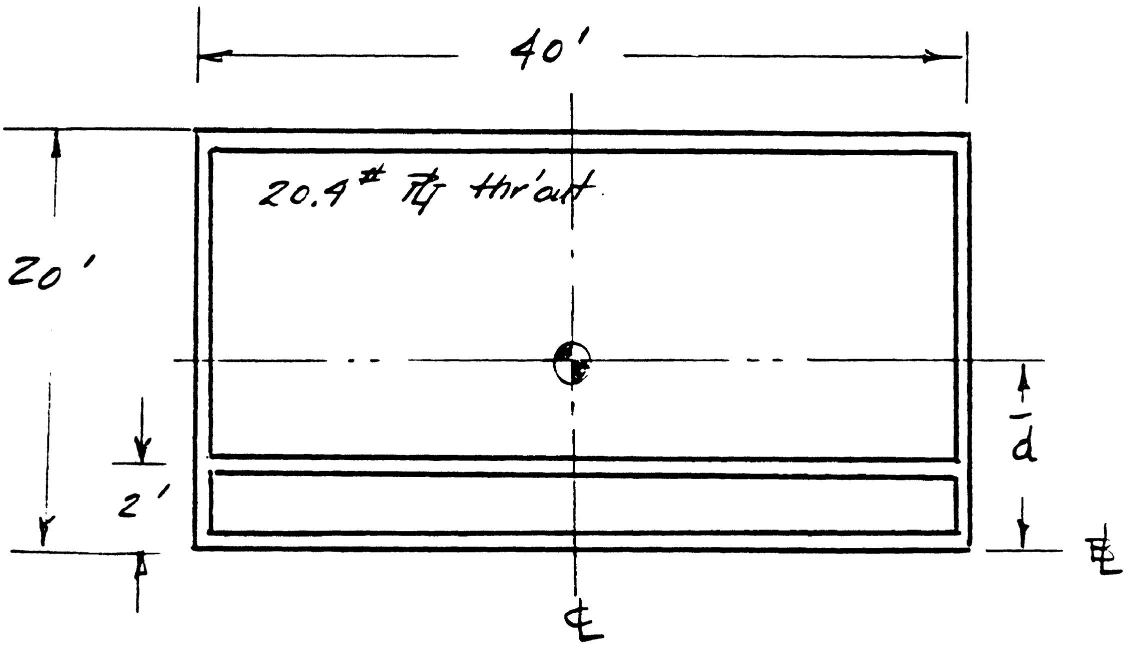
Problem Level: Intermediate

Compute the area centroid, and moment of inertia of the plane areas shown below. Use the units indicated for each problem.

(a) Panel of stiffened steel plate. (Area = in^2 centroid = in, I = in^4)



(b) Midship section of double bottom barge.
(Area = in^2, centroid = ft, I = $in^2 ft^2$)



Problem 63

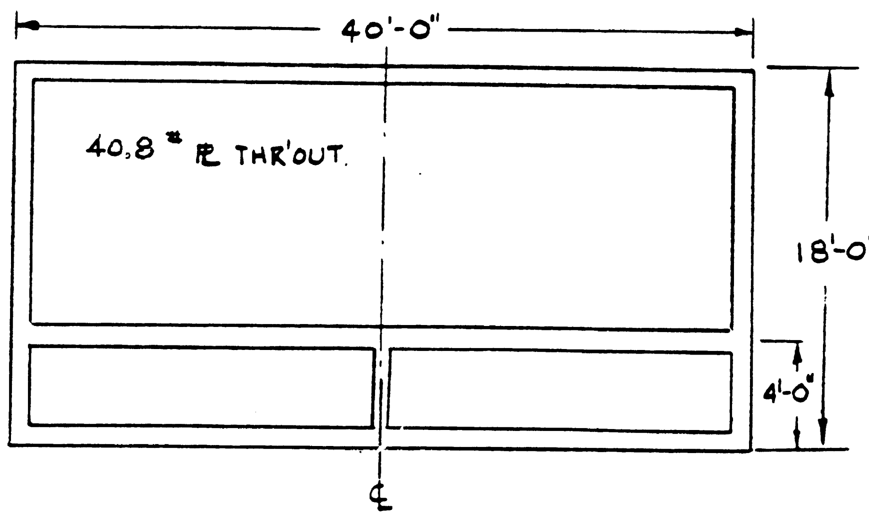
Problem Level: Intermediate

The effective continuous longitudinal structure at the midship section of a vessel is shown below. The maximum design bending moments at this location are:

Maximum hogging moment: 80,000 ton-ft

Maximum sagging moment: 60,000 ton-ft

Calculate the Section Modulus of the vessel at this location and the bending stresses which the above bending moments will produce. Use a tabular format for the calculation.



Problem 64

Problem Level: Basic

An analysis has been made of the bending moments of a 528'-0" cargo vessel on a L/20 wave:

Maximum hogging moment = 360,000 ft-tons

Maximum sagging moment = 60,000 ft-tons

The Moment of Inertia and location of the Neutral Axis have been calculated to be:

I_{na} = 1,080,000 in^2-ft^2

C_{dk} = 24.44 ft

C_{bot} = 20.23 ft

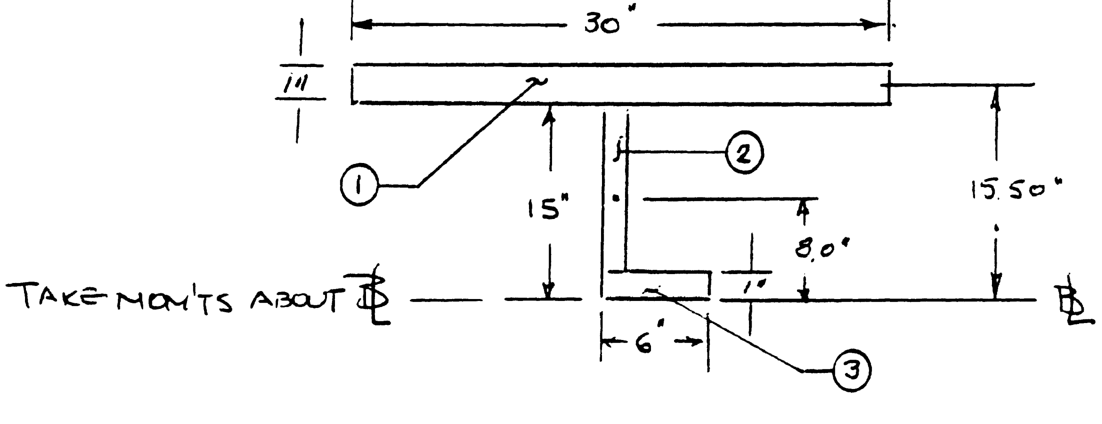
D = 44.63 ft

Find: (a) Section Modulus, $\frac{I}{C}$, for both top and bottom (Units: in^2-ft)

(b) Maximum stress in hogging and sagging condition in the deck and in the bottom (4 conditions). State whether the stress is tensile or compressive. (Units for stress = lbs/in^2)

Be careful about units in this problem.

(a) FIND: VERTICAL CENTROID AND INERTIA (ABOUT CENTROID)



ITEM	SCANTLING IN × IN	AREA A IN^2	LVR $\bar{y}$ IN	MOMT $A\bar{y}$ IN^3	TRANSFER $A\bar{y}^2$ IN^4	INERTIA i_o IN^4
TOP FLANGE, ①	30.0×1.0	30.0	15.50	465.0	7208	3 *
WEB, ②	1.0×14.0	14.0	8.00	112.0	896	229
BOTTOM FLG ③	6.0×1.0	6.0	0.50	3.0	2	1 *
		50.0	11.60 ⟵	580	8106	233
					233	
				$I_{℄}$	8339 IN^4	

THE CENTROID HAS BEEN FOUND TO BE 11.60" ABOVE THE ℄. TRANSFER INERTIA TO THE CENTROID = $(50\,IN^2)(11.60\,IN)^2 = 6728\ IN^4$

TRANSFER TERM IS ALWAYS SUBTRACTED SINCE INERTIA IS LEAST ABOUT ITS OWN CENTROID. $I_{na} = I_o = 1611\ IN^4$

THE CENTROID, $\bar{y} = 11.60"$ @ ℄
$A = 50.00\ IN^2$
$I_o = 1611\ IN^4$

NOTES:

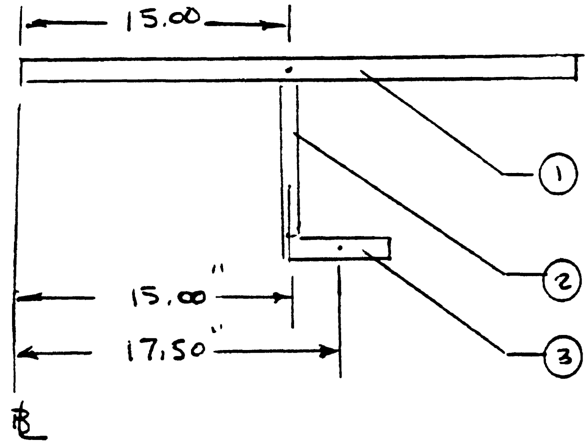
1. SELECTION OF THE LOCATION OF ℄ IS ARBITRARY, BUT BEING CONSISTENT LESSENS CHANCE FOR ERRORS
2. TRANSFER OF AXIS THM, $I_{℄} = i_o + A\bar{y}^2$. COMPUTE INERTIA ABOUT COMMON AXIS (℄) THEN TRANFER BACK TO CENTROID
3. * $i_o = bh^3/12$. FOR THIN MEMBERS PARALLEL TO ℄ THIS IS USUALLY NEGLIGIBLE
4. DROP A DECIMAL PLACE WITH EACH SUCCESSIVE MULTIPLICATION.

THE PROBLEM DOES NOT CLEARLY REQUIRE THE HORIZONTAL LOCATION OF THE CENTROID AND MOM'T OF INERTIA, BUT THE CALCULATION IS SHOWN BELOW.

DIM'N AS SHOWN IN PREV. FIG.

RELOCATE ℄ TO LEFT END (y-AXIS)

TAKE MOM'TS ABOUT ℄



ITEM	SCANTLING	AREA IN^2	LVR IN	MOM'T IN^3	TRANSFER IN^4	INERTIA IN^4
TOP FLG ①	1.0 x 30.0	30.0	15.00	450	6750	2250
WEB, ②	14.0 x 1.0	14.0	15.00	210	3150	1
BOT. FLG ③	1.0 x 6.0	6.0	17.50	105	1838	18
		50.0	15.30	765	11738	2269

2269

$I_{℄} = 14,007 \text{ IN}^4$

TRANSFER TO CENTROID $= (50.0\,IN^2)(15.30\,IN)^2 = 11,705 \text{ IN}^4$

$I_{na} = I_o = 2302 \text{ IN}^4$

NOTES: A BETTER CHOICE FOR THE AXIS, ℄, WOULD HAVE BEEN THROUGH THE CENTER OF THE WEB OF THE STIFFENER WHICH WOULD HAVE ELIMINATED MOM'T AND TRANSFER TERMS FOR ① AND ②. SAME ANSWER.

ON EACH CALCULATION THE CHOICE OF THE MOM'T AXIS SHOULD BE SPECIFIED

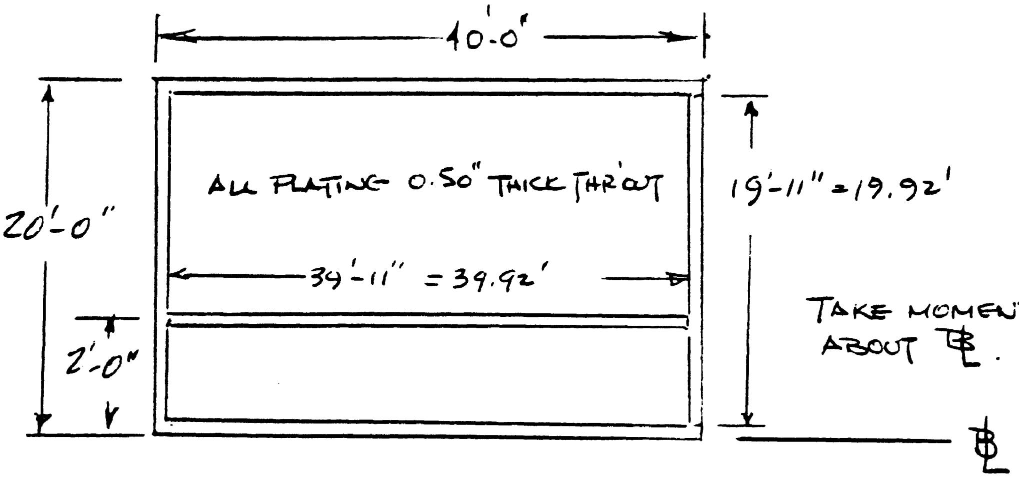
NOTE THE DIFFERENCE IN I_o TERMS BETWEEN HORIZ AND VERT CALC'NS

$\bar{x} = 15.30"$
$A = 50.00 \text{ IN}^2$
$I_o = 2302 \text{ IN}^4$

(b) MIDSHIP SECTION OF DOUBLE-BOTTOM BARGE

FIND: AREA, CENTROID (NEUTRAL AXIS) AND MOMENT OF INERTIA

NOTE CHANGE IN UNITS FOR SHIP PROBLEMS!



ITEM	SCANTLING	AREA A IN^2	LVR $\bar{y}$ FT	MOM'T $A\bar{y}$ IN^2-FT	TRANSFER $A\bar{y}^2$ IN^2-FT^2	INERTIA i_o IN^2-FT^2
DECK PL	40.0×12×.50	240.0	19.96	4790.4	95,616	– *
I.B. PL	39.92×12×.50	239.5	2.00	479.0	958	– *
BOTTOM PL	40.0×12×.50	240.0	0.02	4.8	–	– *
SIDE PL.	19.92×12×.50 ×2 (BOTH SIDES)	239.0	10.00	2390.0	23,900	7904 ** (BOTH SIDES)
		958.5	8.00	7664.2	120,474	7904
					7,904	

$C_{top} = 12.00$

$C_{bot} = 8.00$

$I_{BL} = 128,378$ IN^2-FT^2

TRANSFER INERTIA TO CENTROID (N.A.) $= (958.5\ IN^2)(8.00\ FT)^2$

TRANSFER $= 61,344$ IN^2-FT^2

$I_{na} = I_o = 67034$ IN^2-FT^2

NOTES: * NEGLECT i_o OF HORIZONTAL PLATING

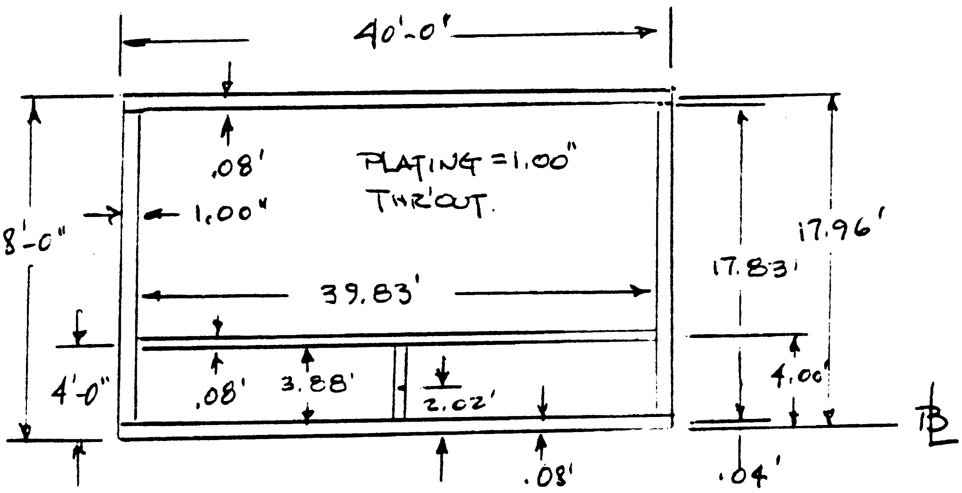
** FOR VERTICAL PLATING

$i_o = \frac{t(12h)^3}{12}\ IN^4$ t IN IN, h IN FT

$= \frac{t(12h)^3}{12} \times \frac{FT^2}{144\ IN}\ IN^2-FT^2$

$i_o = t h^3\ IN^2-FT^2$

> AREA = 958.5 IN^2
> CENTROID = 8.00 FT a BL
> I_{na} = 67,034 IN^2-FT^2



TAKE MOM'TS ABOUT THE BL

ITEM	SCANTLING	AREA A IN^2	LVR $\bar{y}$ FT	MOM'T $A\bar{y}$ IN^2-FT	TRANSFER $A\bar{y}^2$ IN^2-FT^2	INERTIA i_o IN^2-FT^2
MN. DK.	40.0'×12×1.0"	480.0	17.96	8620.8	154,830	–
INNER BOT.	39.83×12×1.0"	478.0	4.00	1912.0	7,648	–
BOTTOM	40.0'×12×1.0"	480.0	.04	19.2	1	–
CVK.	3.88'×12×1.0"	46.6	2.02	94.1	190	117 } BOTH
SIDES	17.83×12×1.0 × 2 SIDES	428.0	9.00	3852.0	34,668	11,343 } SIDES!
		1912.6	7.58	14,498.1	197,337	11,460
					11,460	

$C_{top} = 10.42$ FT

$C_{bot} = 7.58$ FT

$I_{BL} = 208,797$ IN^2-FT^2

TRANSFER INERTIA FROM BL TO N.A. $= (1912.6\ IN^2)(7.58\ FT)^2$

TRANS $= 109,891$ IN^2-FT^2

$I_{na} = 98,906$ IN^2-FT^2

SECTION MODULUS, TOP $= S_{TOP} = \dfrac{I_{na}}{C_{top}} = 9492$ IN^2-FT

SECTION MODULUS, BOTTOM $= S_{BOT} = \dfrac{I_{na}}{C_{bot}} = 13048$ IN^2-FT

} NOTE UNITS!

33

THE SAGGING MOMENT WILL CREATE COMPRESSIVE STRESSES IN THE DECK AND TENSILE STRESSES IN THE BOTTOM.

THE HOGGING MOMENT WILL CREATE TENSILE STRESSES IN THE DECK AND COMPRESSIVE STRESSES IN THE BOTTOM.

THE STRESS IS GIVEN BY THE FLEXURE FORMULA

$$\sigma = \frac{M}{I/c} = \frac{M}{S}$$

LOOK OUT FOR UNITS! MOMENTS ARE ALWAYS GIVEN IN FT-TONS, BUT MUST BE CONVERTED TO FT-LBS TO USE WITH M IN IN^2-FT^2 AND C IN FT.

HOGGING MOMENT = 80,000 FT-TONS (OR TON-FT)

$$M_H = 80{,}000 \text{ FT-TONS} \times \frac{2240 \text{ LBS}}{1 \text{ LT}}$$

$$M_H = 80 \times 10^3 \text{ FT-TONS} \times 2.24 \times 10^3 \frac{\text{LBS}}{\text{TON}}$$

$$M_H = 179.2 \times 10^6 \text{ FT-LBS} = 179{,}200{,}000 \text{ FT-LBS}$$

DECK: $$\sigma_{DK_H} = \frac{M_H}{S'_{TOP}} = \frac{179.2 \times 10^6 \text{ FT-LBS}}{9.492 \times 10^3 \text{ IN}^2\text{-FT}} = 18.879 \times 10^3 \frac{\text{LBS}}{\text{IN}^2}$$

$$\sigma_{DK_H} = 18{,}879 \text{ LBS/IN}^2 \text{ (TENSION)}$$

BOTTOM: $$\sigma_{BOT_H} = \frac{M_H}{S_{BOT}} = \frac{179.2 \times 10^6 \text{ FT-LBS}}{13.048 \times 10^3 \text{ IN}^2\text{-FT}} = 13.734 \times 10^3 \frac{\text{LBS}}{\text{IN}^2}$$

$$\sigma_{BOT_H} = 13{,}734 \text{ LBS/IN}^2 \text{ (COMPRESSION)}$$

SAGGING MOMENT: $= 60{,}000$ TON-FT $= 134.4 \times 10^6$ FT-LBS

DECK: $$\sigma_{DK_S} = \frac{M_S}{S'_{TOP}} = \frac{134.4 \times 10^6 \text{ FT-LBS}}{9.492 \times 10^3 \text{ IN}^2\text{-FT}} = 14.159 \times 10^3 \frac{\text{LBS}}{\text{IN}^2}$$

$$\sigma_{DK_S} = 14{,}159 \text{ LBS/IN}^2 \text{ (COMPRESSION)}$$

BOTTOM: $$\sigma_{BOT_S} = \frac{M_S}{S'_{BOT}} = \frac{134.4 \times 10^6 \text{ FT-LBS}}{13.048 \times 10^3 \text{ IN}^2\text{-FT}} = 10.30 \times 10^3 \frac{\text{LBS}}{\text{IN}^2}$$

$$\sigma_{BOT_S} = 10{,}300 \text{ LBS/IN}^2 \text{ (TENSION)}$$

RECAP

SECTION PROPERTIES:

AREA = 1912.6 IN^2

C_{top} = 10.42 FT

C_{bot} = 7.58 FT

NEUTRAL AXIS = 7.58 FT @ ℄

S_{top} = 9492 IN^2-FT

S_{bot} = 13,048 IN^2-FT

STRESSES:

	HOGGING	SAGGING
DECK	18,879 $\frac{LBS}{IN^2}$ (TENSION)	14,159 $\frac{LBS}{IN^2}$ (COMP)
BOTTOM	13,734 $\frac{LBS}{IN^2}$ (COMP)	10,300 $\frac{LBS}{IN^2}$ (TENSION)

GIVEN:

$M_{HOG_{MAX}} = 360,000$ FT-TONS

$M_{SAG_{MAX}} = 60,000$ FT-TONS

$I_{na} = 1,080,000$ IN^2-FT^2

$c_{dk} = 24.44$ FT

$c_{bot} = 20.23$ FT

$D = 44.63$ FT

FIND:

I/c, top & BOTTOM

σ HOG & SAG, DK & BOTTOM.

(a)

$$I/c_{dk} = \frac{1,080,000 \text{ IN}^2\text{-FT}^2}{24.44 \text{ FT}}$$

$$\underline{\underline{I/c_{dk} = 44,190 \text{ IN}^2\text{-FT}}}$$

$$I/c_{bot} = \frac{1,080,000 \text{ IN}^2\text{-FT}^2}{20.23 \text{ FT}}$$

$$\underline{\underline{I/c_{bot} = 53,386 \text{ IN}^2\text{-FT}}}$$

(b)

$$\sigma = \frac{M}{I/c}$$

$$\sigma_{dk_{HOG}} = \frac{360,000 \text{ FT-TONS} \times 2240 \text{ LBS/TON}}{44,190 \text{ IN}^2\text{-FT}}$$

$$\underline{\underline{\sigma_{dk_{HOG}} = 18,248 \text{ LBS/IN}^2 \text{ (TENSION)}}}$$

$$\sigma_{dk_{SAG}} = \frac{60,000 \text{ FT-TONS} \times 2240 \text{ LBS/TON}}{44,190 \text{ IN}^2\text{-FT}}$$

$$\underline{\underline{\sigma_{dk_{SAG}} = 3,041 \text{ LBS/IN}^2 \text{ (COMPRESSION)}}}$$

$$\sigma_{bot_{HOG}} = \frac{360,000 \text{ FT-TONS} \times 2240 \text{ LBS/TON}}{53,386 \text{ IN}^2\text{-FT}}$$

$$\sigma_{bot_{HOG}} = 15,105 \text{ LBS/IN}^2 \text{ (COMPRESSION)}$$

$$\sigma_{bot_{SAG}} = \frac{60,000 \text{ FT-TONS} \times 2240 \text{ LBS/TON}}{53,386 \text{ IN}^2\text{-FT}}$$

$$\sigma_{bot_{SAG}} = 2,518 \text{ LBS/IN}^2 \text{ (TENSION)}$$

NOTES: SECTION PROPERTIES HAVE BEEN TAKEN FROM THE MARINER EXAMPLE (SLIGHTLY MODIFIED OF PNA, PP 183.

FOR THE ASSUMED HOGGING AND SAGGING MOMENTS THE WORST CASE IS THE TENSILE STRESS IN THE DECK IN THE HOGGING CONDITION.

BASIC NAVAL ARCHITECTURE

Unit Number: 34

Title: The strength and structure of ships - 5

Tape Running Time: $34^M\ 0^S$

Reading Assignment: MSD, pp 212-216

Additional References: INA, pp 92-96

PNA, pp 172-191

Scope:

In this unit treatment of strength curves progresses from the example of the barge in still water of the last unit to ships in standard waves. Example curves taken from PNA are presented. Classification societies are discussed further and ABS longitudinal hull girder strength requirements are outlined. A method of estimating design bending moments is given. Difference between strength and stiffness is defined.

Key Points to Emphasize:

1. Suggest making transparencies of key figures in PNA, pp 172-191. Stress Figs. 6, 9, 10, 11, 14, 15, 16 and 19 (important). Cover as much as time will permit.

2. To spend time on ABS Rules at this stage would be nice if the time were available -- but it's not. Better simply to emphasize that the rules are there and that anyone involved in structural design should be intimately involved with them.

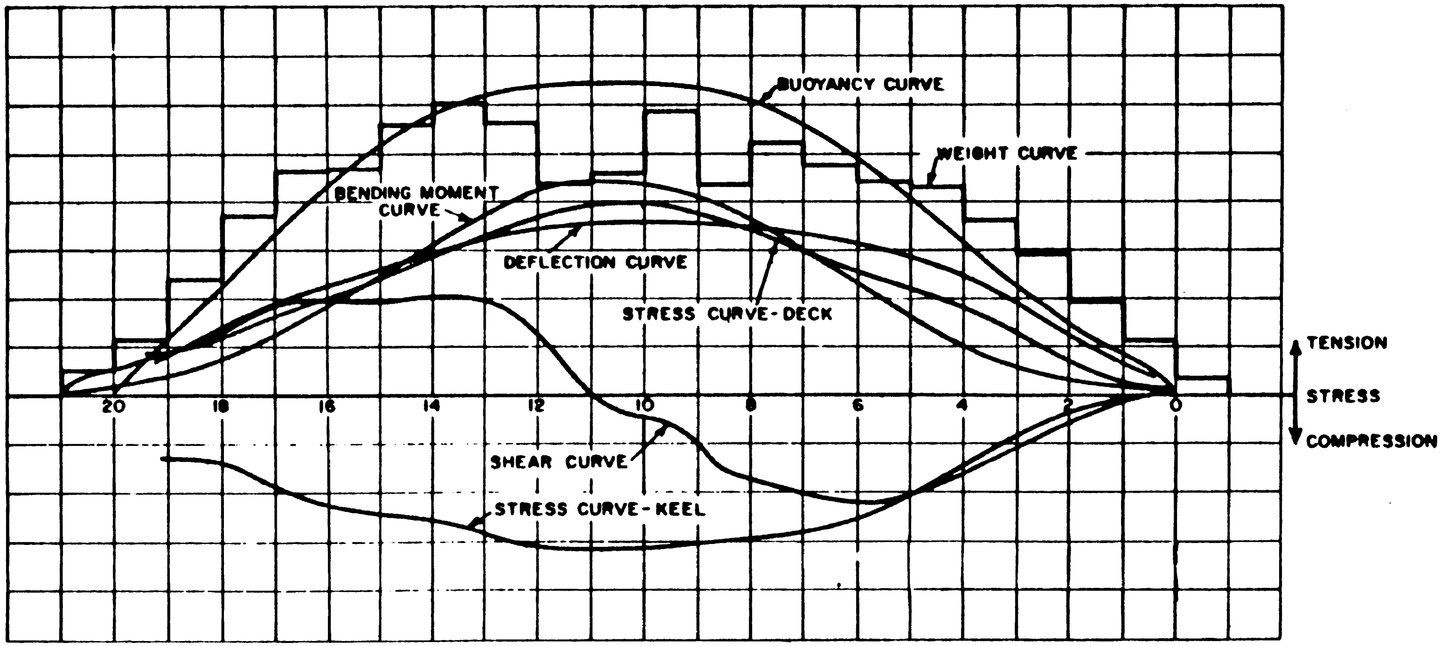
3. Emphasize difference between strength and stiffness.

Suggested Problem Assignment: 65

THE STRENGTH AND STRUCTURE OF SHIPS

LONGITUDINAL BENDING MOMENT IN STILL WATER

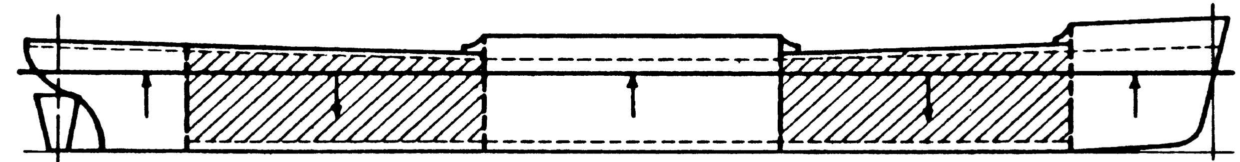
ACTUAL SHIP CURVES IN STILL WATER



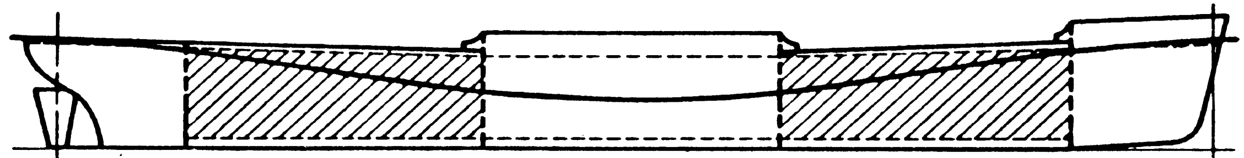
THE STRENGTH AND STRUCTURE OF SHIPS

LONGITUDINAL BENDING MOMENT IN WAVES

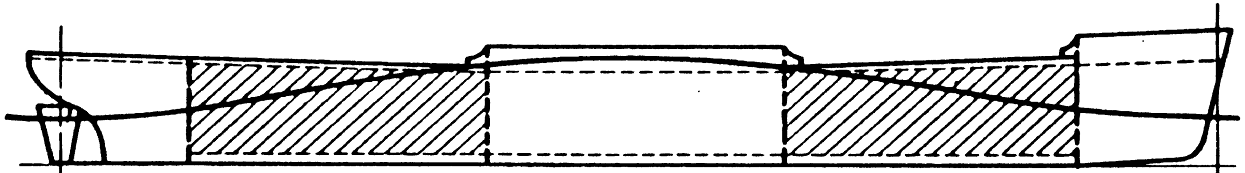
SAGGING AND HOGGING CONDITIONS



(a) VESSEL IN STILL WATER



(b) VESSEL IN SAGGING CONDITION



(c) VESSEL IN HOGGING CONDITION

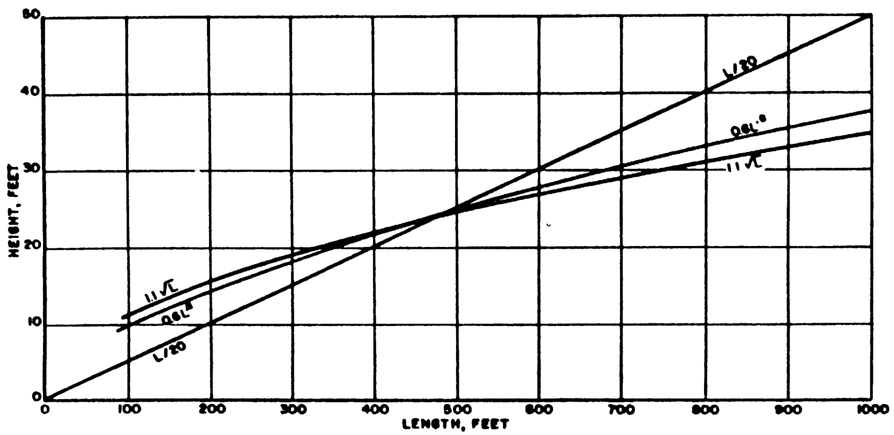
THE STRENGTH AND STRUCTURE OF SHIPS

LONGITUDINAL BENDING MOMENT IN WAVES

WAVE CONDITIONS

1. WAVE LENGTH = SHIP LENGTH
   - HOGGING (CREST AMIDSHIPS)
   - SAGGING (CRESTS BOW AND STERN)

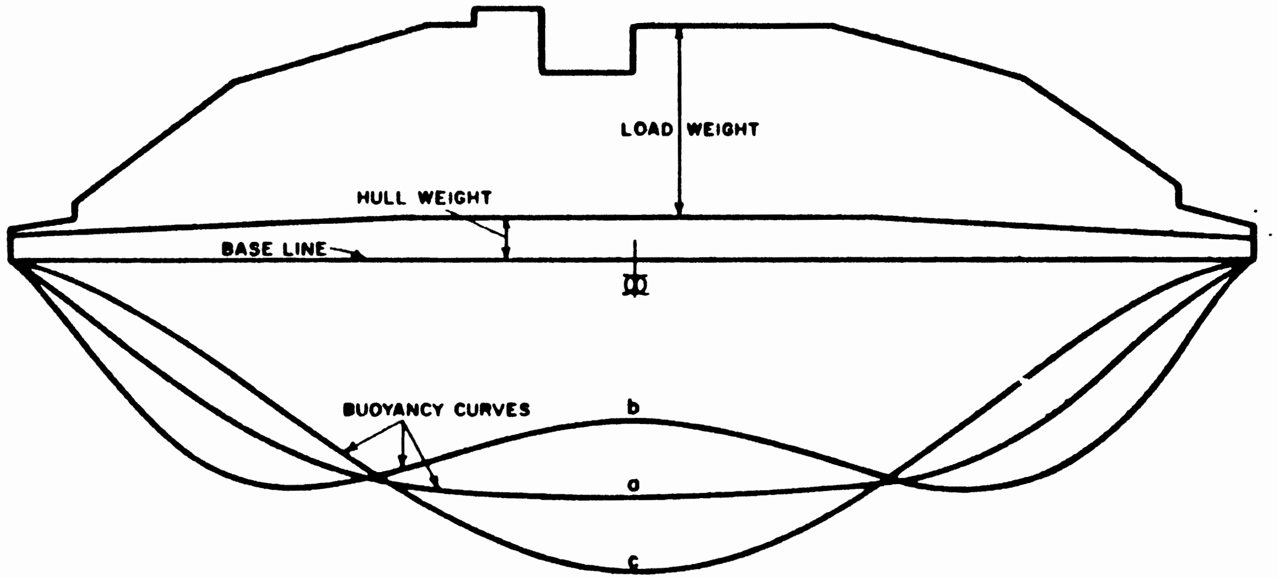
2. WAVE HEIGHT
   - ORIGINALLY, $H_W = L/20$
   - MORE COMMON TODAY, $H_W = 1.1\sqrt{L}$



THE STRENGTH AND STRUCTURE OF SHIPS

LONGITUDINAL BENDING MOMENT IN WAVES

TYPICAL WEIGHT AND BUOYANCY CURVES

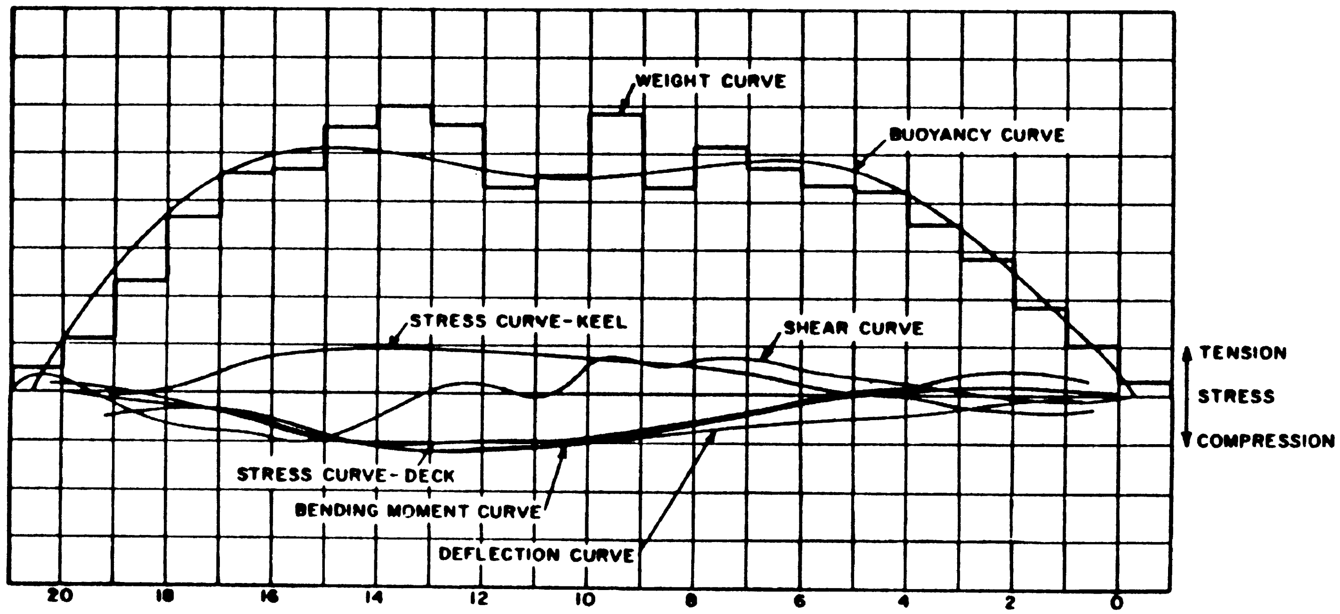


a = STILL-WATER CONDITION
b = SAGGING CONDITION
c = HOGGING CONDITION

THE STRENGTH AND STRUCTURE OF SHIPS

LONGITUDINAL BENDING MOMENT IN STILL WATER

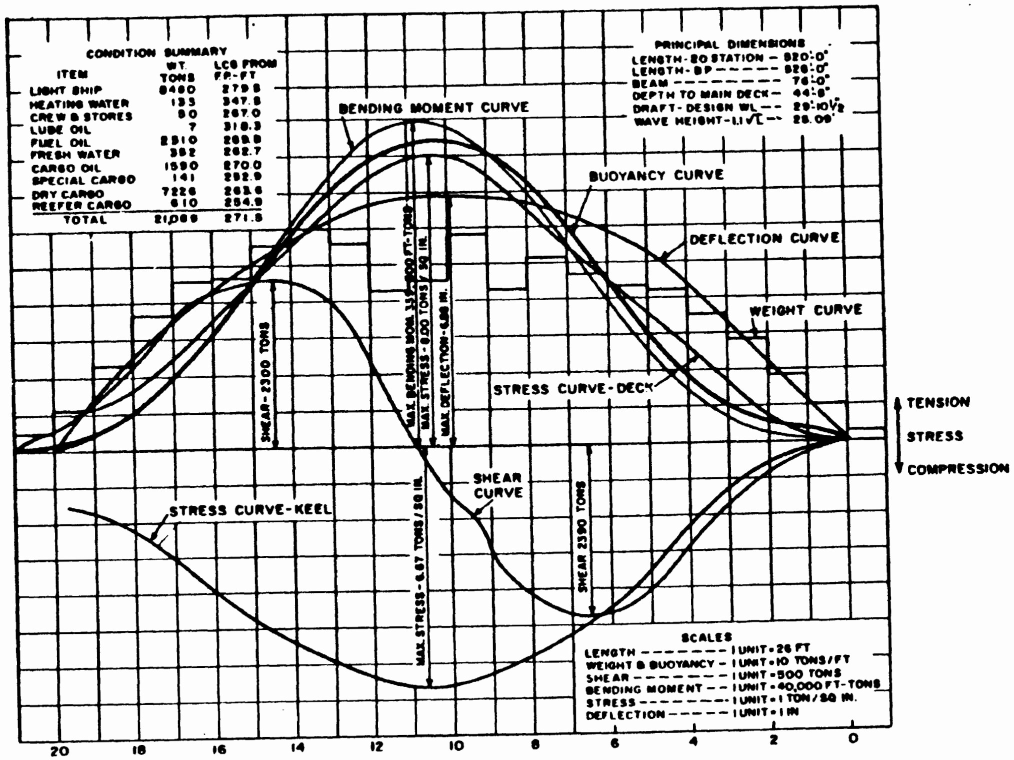
SHIP CURVES - SAGGING CONDITION



THE STRENGTH AND STRUCTURE OF SHIPS

LONGITUDINAL BENDING MOMENT IN WAVES

SHIP CURVES - HOGGING CONDITION



THE STRENGTH AND STRUCTURE OF SHIPS

MESSAGES

1. LONGITUDINAL BENDING IN WAVES IS THE PRIMARY LOADING SYSTEM.
2. STRESS AND DEFLECTION ARE CALCULATED USING SIMPLE BEAM FORMULAE.
3. HOGGING BENDING MOMENTS ARE USUALLY GREATER THAN SAGGING BENDING MOMENTS.
4. LARGEST BENDING STRESSES OCCUR IN THE MIDSHIPS REGION IN THE DECK AND IN THE BOTTOM.
5. LARGEST SHEAR STRESSES OCCUR IN THE REGION OF THE QUARTER POINTS AND AT THE NEUTRAL AXIS.

THE STRENGTH AND STRUCTURE OF SHIPS

THEORY VERSUS EXPERIENCE

- SHIP STRUCTURES ARE COMPLEX AND OFTEN INDETERMINANT STRUCTURES. A HUNDRED YEARS AGO ONLY SIMPLE METHODS OF ANALYSIS USING THE ANALOG OF A SHIP'S HULL TO A "BOX GIRDER" WERE AVAILABLE.

- IN THE PAST TWENTY FIVE YEARS THE ADVENT OF THE COMPUTER AND THE AVAILABILITY OF FINITE ELEMENT COMPUTER PROGRAMS HAVE VASTLY IMPROVED OUR ABILITY TO ANALYZE THESE COMPLEX STRUCTURES.

- STILL, EXPERIENCE AS MANIFESTED IN CLASSIFICATION SOCIETY AND NAVY DESIGN RULES PLAY AN IMPORTANT ROLE IN SHIP STRUCTURAL DESIGN.

THE STRENGTH AND STRUCTURE OF SHIPS

CLASSIFICATION SOCIETIES

CLASSIFICATION SOCIETIES PUBLISH RULES WHICH INCLUDE RULES GOVERNING THE STRUCTURAL DESIGN OF THE SHIP.

THE MAJOR CLASSIFICATION SOCIETIES ARE:

- AMERICAN BUREAU OF SHIPPING (U.S.)
- LLOYD'S REGISTER OF SHIPPING (GREAT BRITAIN)
- DET NORSKE VERITAS (NORWAY)
- BUREAU VERITAS (FRANCE)
- GERMANISCHER LLOYD (WEST GERMANY)
- REGISTRO ITALIANO NAVALE (ITALY)
- NIPPON KYOKAI (JAPAN)

THE STRENGTH AND STRUCTURE OF SHIPS

ABS REQUIREMENT-LONGITUDINAL HULL GIRDER

STILL WATER BM, $M_s = (C_{st})(L^{2.5} \cdot B)(C_b + .5)$

C_{st} = LENGTH-DEPENDENT COEFFICIENT

L, B = LENGTH, BEAM

C_b = BLOCK COEFFICIENT

WAVE INDUCED MOMENT, $M_w = (C_2)(L^2 \cdot B)(H)(K_b)$

C_2 = BLOCK-DEPENDENT COEFFICIENT

H = WAVE HEIGHT PARAMETER DEPENDENT ON SHIP LENGTH

K_b = ANOTHER BLOCK-DEPENDENT COEFFICIENT

ABS REQUIREMENTS - LONGITUDINAL HULL GIRDER

$SM = M_t / f_p$

SM = SECTION MODULUS

M_t = TOTAL BENDING MOMENT

$M_t = M_{sw} + M_w$

M_{sw} = STILL WATER BENDING MOMENT

M_w = WAVE-INDUCED BENDING MOMENT

f_p = PERMISSIBLE STRESS

$$f_p = 10.56 - \frac{790-L}{845} \text{ TONS/IN}^2 \qquad (200 \le L \le 790)$$

THE STRENGTH AND STRUCTURE OF SHIPS

BENDING MOMENT ESTIMATES

MAXIMUM BENDING MOMENTS MAY BE ESTIMATED FROM SIMILAR SHIP DATA.

USE: $B.M. = K \cdot L \cdot \Delta$

$K_{HOG} = 33 \text{ TO } 45$

$K_{SAG} = 20 \text{ TO } 30$

HOGGING MOMENT IS USUALLY LARGER THAN SAGGING MOMENT, BUT NOT ALWAYS!

DETERMINE K FROM SHIPS OF SIMILAR FUNCTION, ARRANGEMENT AND BLOCK COEFFICIENT.

IF YOU DON'T HAVE A GOOD MODEL TO USE AS A BASE DON'T BOTHER!

THE STRENGTH AND STRUCTURE OF SHIPS

STRENGTH AND STIFFNESS

- THE STRENGTH OF A STRUCTURE IS ITS ABILITY TO WITHSTAND THE LOADS IMPOSED ON IT.

- THE STIFFNESS OF A STRUCTURE IS ITS RESISTANCE TO DEFLECTIONS WITHIN THE ELASTIC LIMIT OF THE MATERIAL.

BASIC NAVAL ARCHITECTURE

Problem 65

Problem Level: Advanced

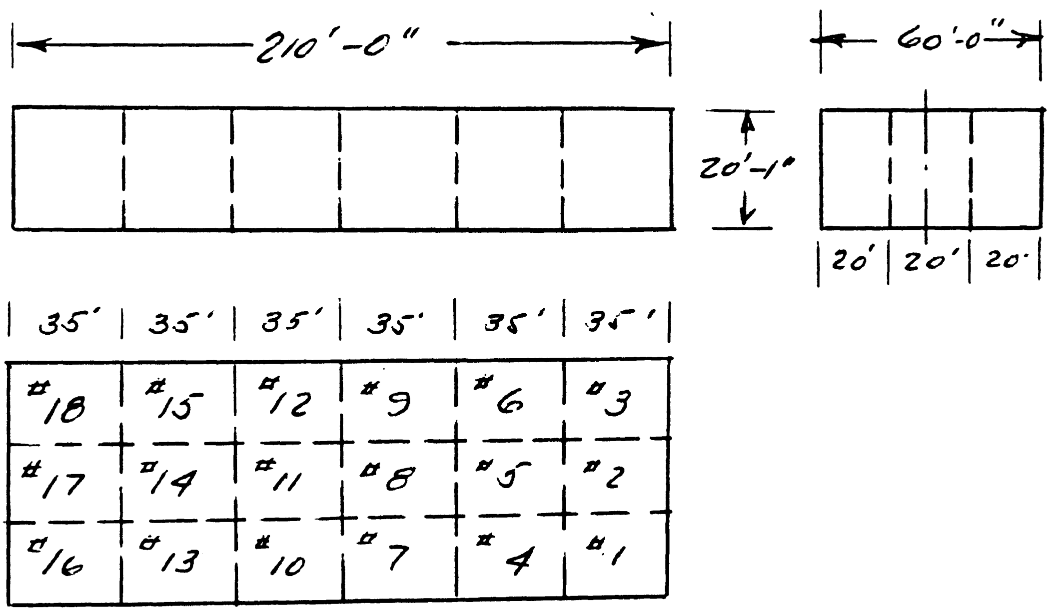
Part A: A rectangular barge has the following dimensions:

L_{pp} = 210'-0"

B = 60'-0"

D = 20'-1"

The barge is divided into 18 holds by two longitudinal bulkheads at 20-ft spacings and five transverse bulkheads at 35-ft spacings.



With no cargo on board (light ship) the barge floats in salt water at a draft of 2'-0" fore and aft. Holds 1 through 6 and 13 through 18 are now filled to the top with petroleum products at 40 ft^3/ton. Holds 7 through 12 are left void. Note that the molded depth of the tanks is 20.00'.

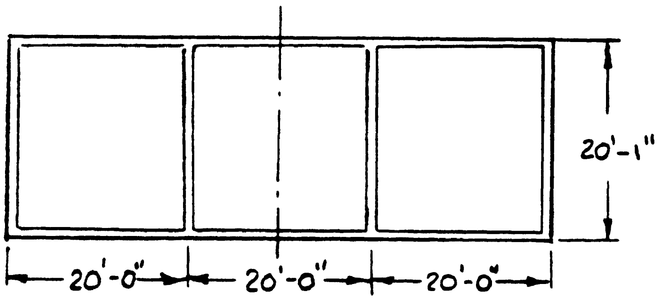
Assuming the structural weight of the barge is uniformly distributed plot the load, shear force, and bending moment curves. Take buoyancy, shear force up, and sagging moments as positive. Use 10 x 10 to the 1/2-inch graph paper and plot the curves using instruments (French curve and straight edge) to the following scales:

Problem 65 (continued)

Problem Level: Advanced

Length	=	1" = 35'
Weight and Buoyancy	=	1" = 10.00 tons/ft
Shear Force	=	1" = 500 tons
Bending Moment	=	1" = 10,000 ft-tons

Part B: A simplified midship section drawing of the barge is shown below.



1) The barge is constructed of 20.4# steel plate throughout. Find the height of the neutral axis above the base line (in feet and decimals) and the section modulus of the deck and bottom (in in^2-ft). Use standard tabular format for the calculation.

2) Under extreme loading conditions and in an L/20 trochoidal wave it is calculated that the barge would experience the following bending moments:

   Hogging: 80,000 ft-tons
   Sagging: 60,000 ft-tons

   Find the stresses in the deck and bottom for each case and specify whether they are tensile or compressive.

3) A strength analysis indicates the barge will fail in tension at a critical stress of 12 tons/in^2 and would fail in compression by buckling at a critical stress of 9 tons/in^2. Determine whether or not failure will occur in any mode. Find the factor of safety against failure in each mode.

GIVEN: DIMENSIONS AND LOADING OF BARGE

FIND: WEIGHT, BUOYANCY, LOAD, SHEAR FORCE, BENDING MOMENT CURVES

FIRST, FIND LIGHT SHIP WEIGHT AND WEIGHT DISTRIBUTION OF BARGE.

$$\Delta_{LS} = \frac{L \times B \times T_{LS}}{35} = \frac{\cancel{210.0}^{6} \times 60.0 \times 2.0}{\cancel{35.0}} \frac{FT^3}{FT^3/TON}$$

$$\Delta_{LS} = 720 \text{ LT SW.}$$

ASSUMING THE LIGHT SHIP WEIGHT IS UNIFORMLY DISTRIBUTED, THEN,

$$(WT/FT)_{LS} = \frac{720 \text{ LT}}{210.0 \text{ FT}} = 3.43 \text{ TONS/FT.}$$

NEXT, EXAMINE THE GIVEN LOADING CONDITION.

$$\text{WEIGHT OF LOAD, CARGO TKS 1-6} = \frac{70.0 \times \cancel{60.0}^{30} \times \cancel{20.0}}{\cancel{40.0}} \frac{FT^3}{FT^3/TON} = 2100 \text{ LT}$$

$$\text{WT PER FOOT, CARGO ONLY, TKS 1-6, 13-18} = \frac{2100 \text{ LT}}{70.0 \text{ FT}} = 30.0 \text{ TONS/FT}$$ (ADD L.S. WT)

WT OF CARGO, TK 1-6 = 2100 LT.
WT OF CARGO, TK 13-18 = 2100 LT
LIGHT SHIP WEIGHT = 720 LT

DISPL FOR THIS LOAD, Δ_L = 4920 LT.

$$\text{DRAFT AT THIS LOAD, } T_L = \frac{4920 \text{ LT} \times 35 \text{ FT}^3/\text{TON}}{210.0 \text{ FT} \times 60.0 \text{ FT}} = 13.67 \text{ FT}$$

BUOYANCY PER FOOT WILL BE UNIFORMLY DISTRIBUTED, AND, SINCE TOTAL BUOYANT FORCE = TOTAL WEIGHT FORCE,

$$\text{BUOYANCY/FT} = \frac{4920 \text{ LT}}{210.0 \text{ FT}} = 23.43 \text{ TONS/FT}$$

<u>RECAP</u>

WEIGHT/FT,	0 TO 70.0'	=	33.43 TONS/FT
	70' TO 140.0'	=	3.43 TONS/FT
	140.0' TO 210.0'	=	33.43 TONS/FT
BUOY/FT,	0 TO 210.0'	=	23.43 TONS/FT

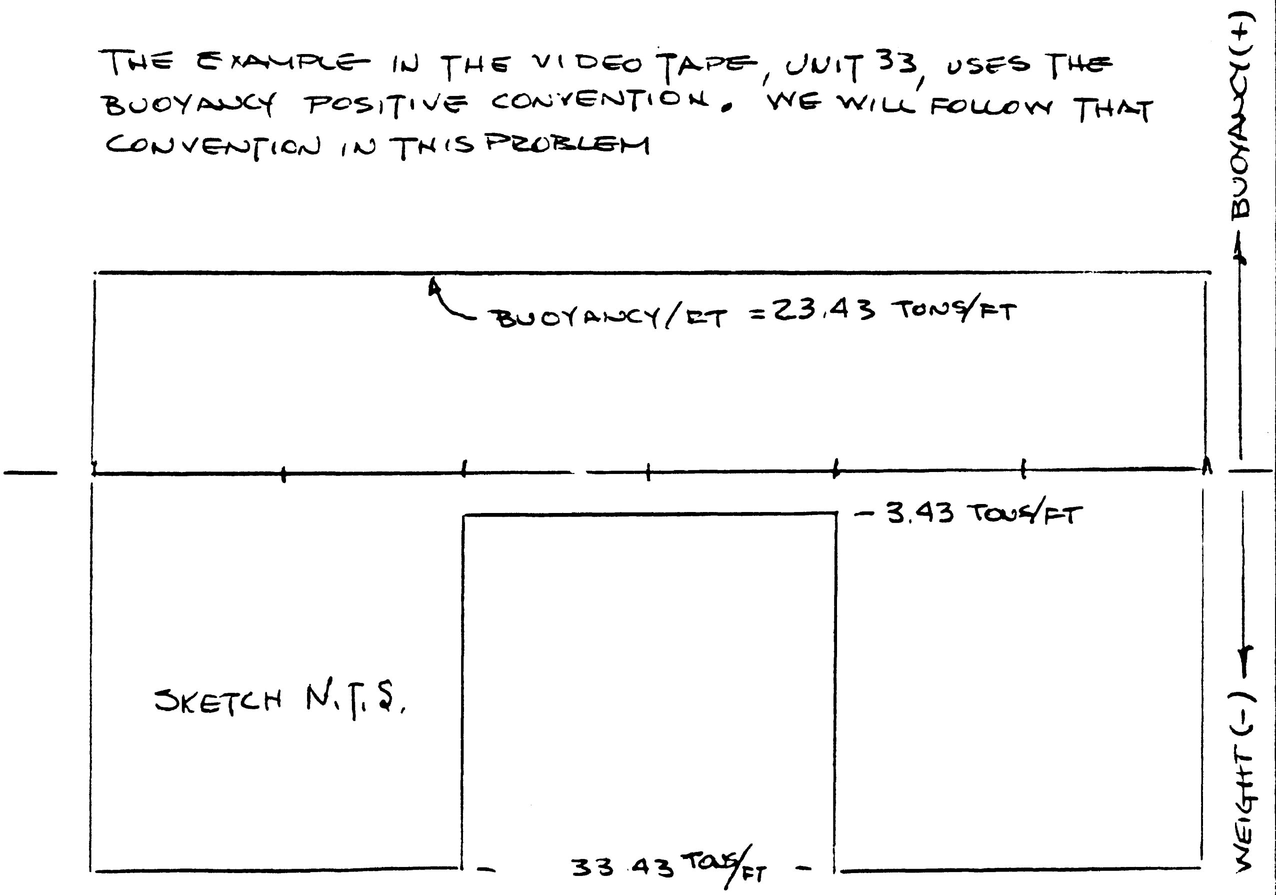
NOTE ON SIGN CONVENTIONS: TO BE CONSISTENT WITH CONVENTIONS USED IN MOST STRENGTH OF MATERIALS TEXTS x IS TAKEN AS POSITIVE UP AND y AS POSITIVE TO THE RIGHT.

THEN UPWARD FORCES WILL BE POSITIVE, DOWNWARD FORCES NEGATIVE. THUS BUOYANCY IS POSITIVE, WEIGHT IS NEGATIVE, SHEAR FORCE UP IS POSITIVE, AND SAGGING BENDING MOMENTS ARE POSITIVE.

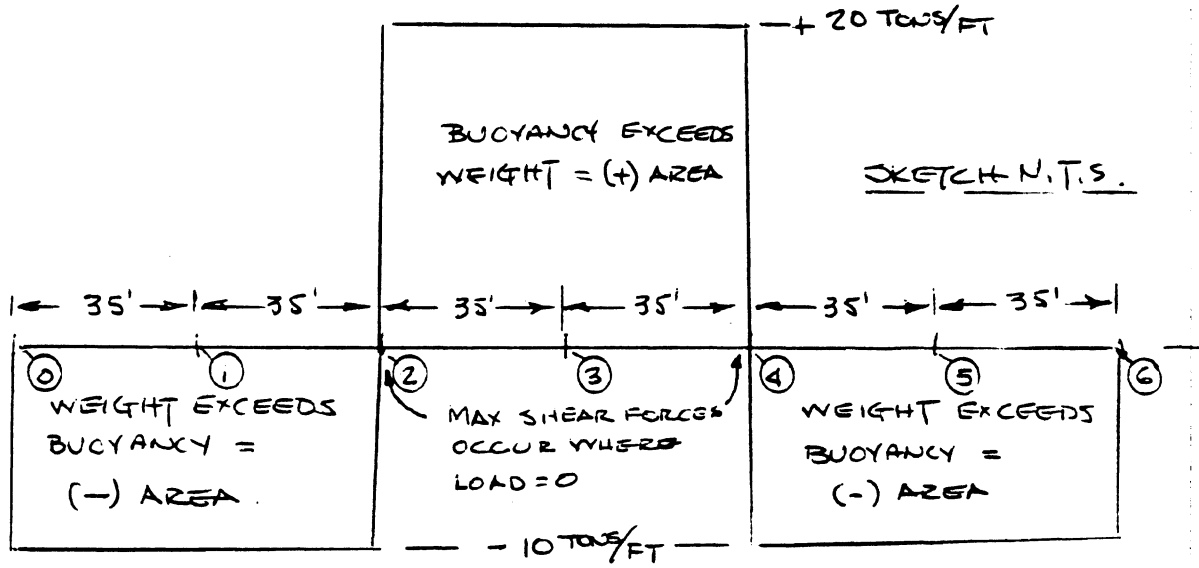
IN THE EXAMPLE IN GILLMER pp 210-212 WEIGHT IS TAKEN AS POSITIVE, BUOYANCY NEGATIVE, SHEAR FORCE UP AS NEGATIVE AND SAGGING MOMENTS POSITIVE. NOW, TO BE CONSISTENT, BENDING MOMENT ORDINATE = (−) AREA UNDER SHEAR FORCE CURVE

BOTH CONVENTIONS ARE FOUND IN PRACTICE, BUT IT IS IMPORTANT TO LABEL BENDING MOMENTS AS HOGGING OR SAGGING AND STRESSES AS TENSILE OR COMPRESSIVE.

THE EXAMPLE IN THE VIDEO TAPE, UNIT 33, USES THE BUOYANCY POSITIVE CONVENTION. WE WILL FOLLOW THAT CONVENTION IN THIS PROBLEM



LOAD DIAGRAM : GILLMER'S FIGURES 11-4 AND 11-5 DISPLAY THE IDEA THAT LOAD IS THE DIFFERENCE BETWEEN WEIGHT AND BUOYANCY BUT ARE INCONSISTENT IN SIGN CONVENTION.



NOTE THAT TOTAL AREA OF DIAGRAM = 0, A REQUIREMENT FOR EQUILIBRIUM OF VERTICAL FORCES

SHEAR FORCE DIAGRAM, THE ORDINATE OF THE SHEAR FORCE DIAGRAM = AREA UNDER LOAD DIAGRAM.

AREAS: FROM

SET ORIGIN AT LEFT END AND WORK FROM LEFT END

(0) TO (1) = $-10.0\ T/FT \times 35\ FT = -350$ TONS

(0) TO (2) = $-10.0\ T/FT \times 70\ FT = -700$ TONS

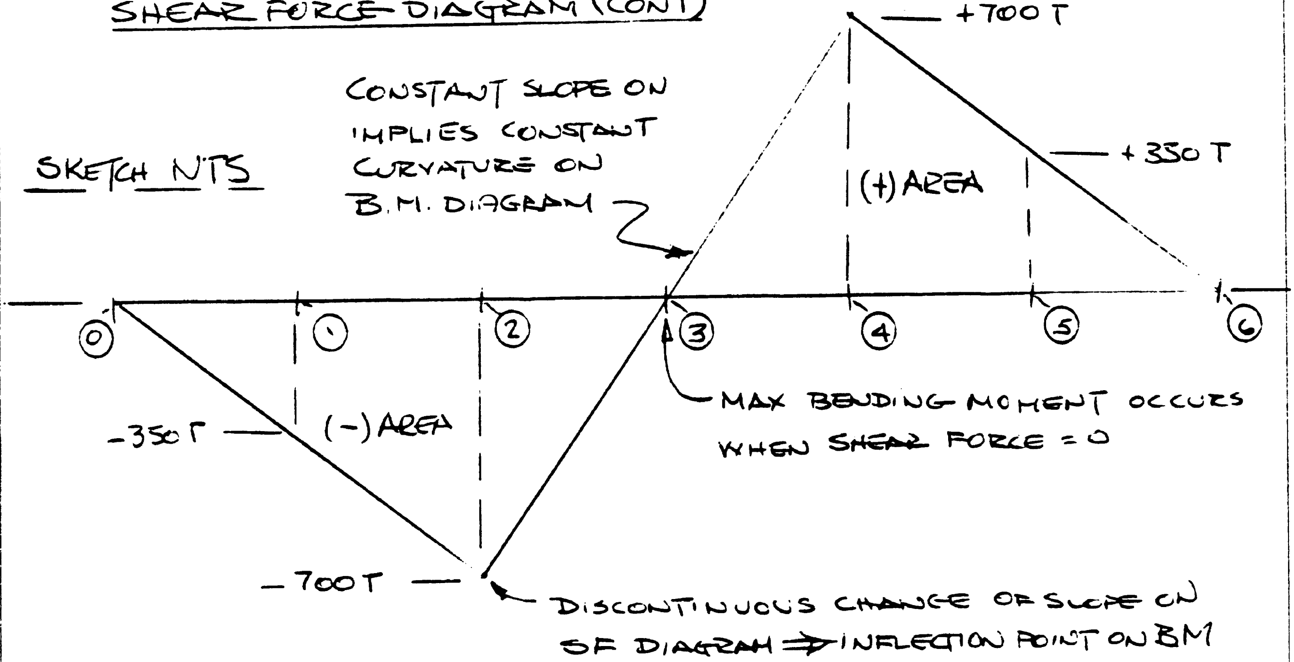
(0) TO (3) = $-10.0\ T/FT \times 70\ FT + 20.0\ T/FT \times 35\ FT = 0.0$ TONS

(0) TO (4) = $-10.0\ T/FT \times 70\ FT + 20.0\ T/FT \times 70\ FT = +700$ TONS/FT

(0) TO (5) = $-10.0\ T/FT \times 70\ FT + 20.0\ T/FT \times 70\ FT - 10.0\ T/FT \times 35\ FT = +350$ TONS/FT

(0) TO (6) = $-10.0\ T/FT \times 70\ FT + 20.0\ T/FT \times 70\ FT - 10.0\ T/FT \times 70\ FT = 0.0$ TONS/FT.

SHEAR FORCE DIAGRAM (CON'T)



TOTAL AREA UNDER SF DIAGRAM MUST = 0 FOR EQUILIBRIUM.

BENDING MOMENT DIAGRAM. ORDINATE OF BENDING MOMENT DIAGRAM = AREA UNDER SHEAR FORCE DIAGRAM.

AREAS: FROM ⓪ TO ① $= -\frac{1}{2} \times 350T \times 35FT = -6{,}125$ FT-TONS

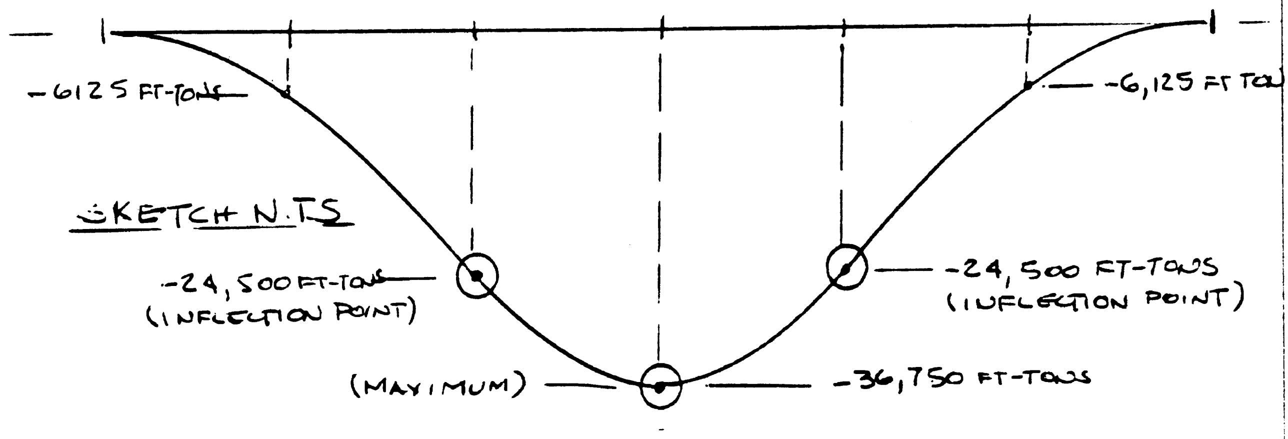
⓪ TO ② $= -\frac{1}{2} \times \quad \times 70FT = -24{,}500$ FT-TONS

⓪ TO ③ $= -\frac{1}{2} \times 700T \times 105FT = -36{,}750$ FT-TON

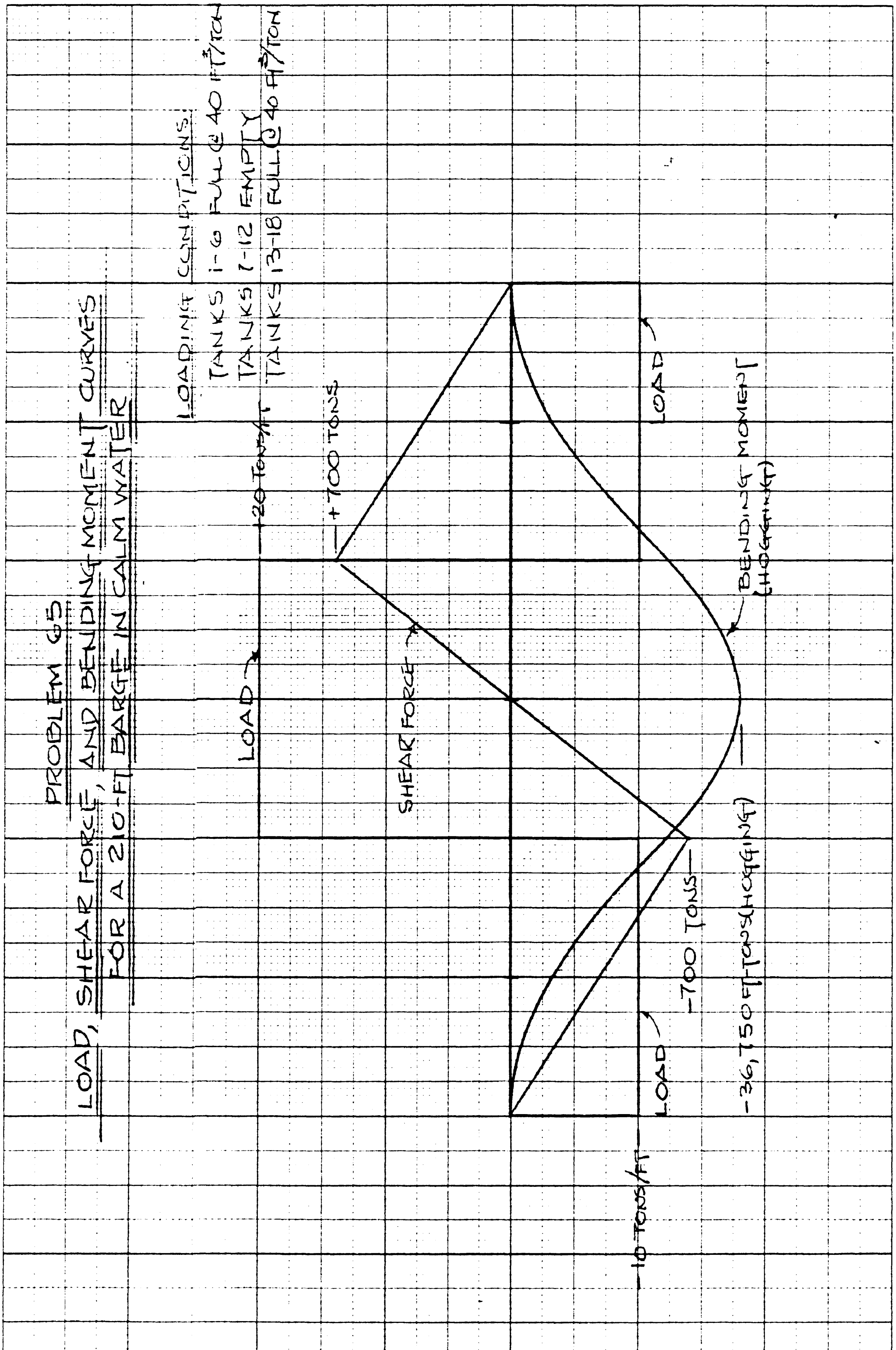
⓪ TO ④ $= -\frac{1}{2} \times 700T \times 105FT + \frac{1}{2} 700T \times 35FT = -24{,}500$ FT-TONS

⓪ TO ⑤ $= -\frac{1}{2} \times 700T \times 105FT + \frac{1}{2} \times 700T \times 35FT + \frac{1}{2}(700T + 350T) \times 35FT = -6{,}125$ FT-TONS

⓪ TO ⑥ $= -\frac{1}{2} \times 700T \times 105FT + \frac{1}{2} \times 700T \times 105FT = 0.0$ FT-TONS.



NEGATIVE BENDING MOMENTS ⇒ HOGGING CONDITION WHICH CHECKS



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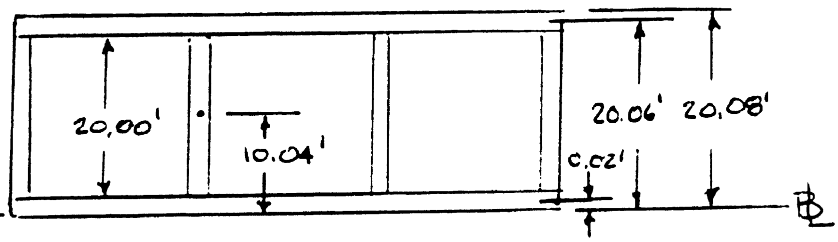
34-71

PART B

GIVEN: MIDSHIP SECTION SCANTLINGS,
M_H = 80,000 FT-TONS
M_S = 60,000 FT-TONS
σ_{CR} = TONS/IN^2 TENSION
σ_{CR} = TONS/IN^2 COMPRESSION

FIND: SECTION MODULUS, STRESSES, FAILURE MODES.

TAKE MOMENTS ABOUT ℄



ITEM	SCANTLING IN x IN	AREA A IN^2	LVR $\bar{y}$ FT	MOMENT $A\bar{y}$ IN^2-FT	TRANSFER $A\bar{y}^2$ IN^2-FT^2	INERTIA i_o IN^2-FT^2
DECK	(60'x12) x .5"	360.0	20.06	7221.6	144,865	–
BOTTOM	(60'x12) x .5"	360.0	0.02	7.2	–	–
SIDES	(20'x12) x .5" x 2 SIDES	240.0	10.04	2409.6	24,192	8,000 } BOTH SIDES & BHD'S
LONG'L BHDS	(20.0x12) x .5" x 2 BHDS	240.0	10.04	2409.6	24,192	8,000
		1200.0	10.04	12,048	193,249	16,000
					16,000	

C_{top} = 10.04
C_{bot} = 10.04

$I_{℄}$ = 209,249 IN^2-FT^2

TRANSFER INERTIA TO N.A. = $(1200\ IN^2)(10.04\ FT)^2$ = 120,962 IN^2-FT^2

I_{na} = 88,287 IN^2-FT^2

SECTION MODULUS (TOP) = $S_{top} = \dfrac{I_{na}}{C_{top}} = \dfrac{88,287\ IN^2\text{-}FT^2}{10.04\ FT}$

S_{top} = 8794 IN^2-FT

SECTION MODULUS (BOTTOM) = $S_{bot} = \dfrac{I_{na}}{C_{bot}} = \dfrac{88,287\ IN^2\text{-}FT^2}{10.04\ FT}$

S_{bot} = 8794 IN^2-FT

THE STRESSES ARE GIVEN BY THE FLEXURE FORMULA

$$\sigma = \frac{M}{I/y} = \frac{M}{S} \; ; \quad S_{top} = S_{bot} = 8794 \text{ IN}^2\text{FT}$$

HOGGING MOMENT $\quad M_H = 80{,}000 \text{ FT-TONS} = 179.2 \times 10^6 \text{ FT-LBS}$

$$\sigma_{DK} = \frac{179.2 \times 10^6 \text{ FT-LBS}}{8.794 \times 10^3 \text{ IN}^2\text{-FT}} = 20.378 \times 10^3 \frac{\text{LBS}}{\text{IN}^2}$$

$$\sigma_{DK} = 20{,}378 \text{ LBS/IN}^2 \text{ (TENSION)}$$

$$\sigma_{bot} = 20{,}378 \text{ LBS/IN}^2 \text{ (COMPRESSION)}$$

SAGGING MOMENT $\quad M_S = 60{,}000 \text{ FT-TONS} = 134.4 \times 10^6 \text{ FT-LBS}$

$$\sigma_{DK} = \frac{134.4 \times 10^6 \text{ FT-LBS}}{8.794 \times 10^3 \text{ IN}^2\text{-FT}} = 15.283 \times 10 \text{ LBS/IN}^2$$

$$\sigma_{DK} = 15{,}283 \text{ LBS/IN}^2 \text{ (COMPRESSION)}$$

$$\sigma_{bot} = 15{,}283 \text{ LBS/IN}^2 \text{ (TENSION)}$$

CRITICAL STRESSES:

TENSION, $\sigma_{CR_T} = 12 \text{ TONS/IN}^2 = 26{,}880 \text{ LBS/IN}^2$

COMPRESSION, $\sigma_{CR_C} = 9 \text{ TONS/IN}^2 = 20{,}160 \text{ LBS/IN}^2$

	HOGGING			SAGGING		
	STRESS	CRITICAL	FACTOR OF SAFETY	STRESS	CRITICAL	FACTOR OF SAFETY
DECK	20,378 T	26,880	1.32	15,283 C	20,160	1.32
BOTTOM	20,378 C	20,160	0.99	15,283 T	26,880	1.76

COMMENTS. THE ANALYSIS INDICATES THAT THE BARGE WOULD FAIL MARGINALLY BY BUCKLING IN THE BOTTOM AMIDSHIPS — IF THE BARGE EVER RAN INTO AN L/20 WAVE — AND, IF IN FACT THE CRITICAL STRESSES ARE EXACTLY CORRECT.

THE MARGINAL NATURE CERTAINLY INDICATES THAT SCANTLINGS SHOULD BE INCREASED.

BASIC NAVAL ARCHITECTURE

Unit Number: 35

Title: The strength and structure of ships - 6

Tape Running Time: 34^M 18^S

Reading Assignment: MSD, pp 216-219

Additional References: SDC, pp 339-357

INA, pp 60-74 (repeated)

Scope:

Properties of shipbuilding steels are discussed together with the tensile test and Charpy vee-notch test for measurement of properties. Other material tests are not discussed. Properties of aluminum and GRP are described briefly. Types of steel shapes are described together with derived shapes (I-T's, C-L's, built-ups, etc.)

Key Points to Emphasize:

1. With this unit we are proceeding into an area which will have more direct relevance to many students. Use SDC heavily as reference for remaining units on structure. If time permits discuss other types of material tests -- Brinell hardness, Rockwell hardness, fatigue, etc.

2. In this unit emphasize types of stiffeners -- standard, modified and built-up. Discuss plate-stiffener combinations and the trade-offs between material costs, labor costs, and weight in selecting the stiffener type.

3. The video tape makes the point that "weight is money" which in large part is true, but with exceptions, for example in a non-weight-critical ship, it may pay to oversize some stiffeners and/or plating to reduce the number of sizes ordered, reduce handling and inventory costs and improve producibility. Suggest opening this subject for active class discussion.

4. If sponsoring institution is a shipyard discuss in as much detail as time permits shipyard practices in this area.

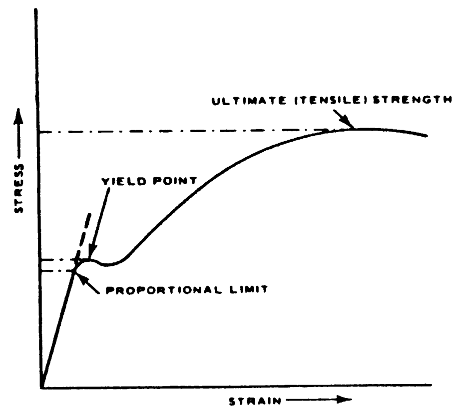
Suggested Problem Assignment: 66, 67

THE STRENGTH AND STRUCTURE OF SHIPS

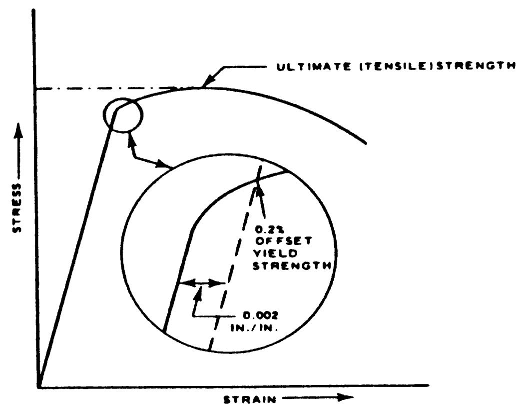
PROPERTIES OF SHIPBUILDING MATERIALS

1. YIELD STRENGTH - THE STRESS AT WHICH MILD STEEL EXHIBITS AN INCREASE IN STRAIN WITHOUT AN INCREASE IN STRESS.

   FOR HIGHER STRENGTH STEELS THE STRESS AT WHICH THE MATERIAL EXHIBITS AN OFFSET OF .002 IN/IN FROM THE STRAIGHT LINE PORTION OF THE STRESS/STRAIN DIAGRAM.



(A) STRESS-STRAIN DIAGRAM FOR ORDINARY STRENGTH



(B) STRESS-STRAIN DIAGRAM FOR HIGH STRENGTH STEEL (SHOWING AN ARBITRARILY SELECTED 0.2% OFFSET YIELD STRENGTH)

2. TENSILE STRENGTH - TENSILE STRENGTH IS THE MAXIMUM TENSILE STRESS WHICH A MATERIAL SPECIMEN CAN WITHSTAND BEFORE FAILURE.

PROPERTIES OF SHIPBUILDING MATERIALS (CONT)

3. ELONGATION - IN THE TENSILE TEST PERCENTAGE ELONGATION OF THE TEST SPECIMEN IS DEFINED AS:

$$\frac{\text{TOTAL ELONGATION OF SPECIMEN}}{\text{INITIAL LENGTH}} \times 100$$

4. REDUCTION IN AREA - THE REDUCTION IN AREA OF THE TENSILE TEST SPECIMEN, EXPRESSED AS A PERCENTAGE IS DEFINED AS:

$$\frac{\text{DECREASE IN THE SECTIONAL AREA}}{\text{ORIGINAL AREA}} \times 100$$

THE STRENGTH AND STRUCTURE OF SHIPS

SHIPBUILDING STEELS

THE DESIRABLE QUALITIES IN SHIPBUILDING STEELS ARE:

STRENGTH. THE PRINCIPAL INDICATOR OF STRENGTH IS THE YIELD STRENGTH.

TYPE STEEL	YIELD POINT
ORDINARY STRENGTH STEELS	
- ABS GRADES A,B,D,E,CS,DS	34,000 PSI
HIGHER STRENGTH STEELS	
- ABS GRADES AH32, DH32, EH32	45,500 PSI
- ABS GRADES AH36, DH36, EH36	51,000 PSI
MILITARY HIGHER STRENGTH STEELS	
- HY-80	80,000 PSI
- HY-100	100,000 PSI
- HY-130	130,000 PSI

THE STRENGTH AND STRUCTURE OF SHIPS

SHIPBUILDING STEELS

DESIRABLE QUALITIES:

DUCTILITY. DUCTILITY IS THE ABILITY OF A METAL TO DEFORM WITHOUT BREAKING. STEELS LOSE THEIR DUCTILITY AND BECOME BRITTLE AS TEMPERATURE IS LOWERED AFTER THEY PASS THROUGH A TRANSITION TEMPERATURE RANGE.

INDICATORS OF DUCTILITY ARE PERCENT ELONGATION AND PERCENT REDUCTION IN AREA IN THE TENSILE TEST.

THE STRENGTH AND STRUCTURE OF SHIPS

SHIPBUILDING STEELS

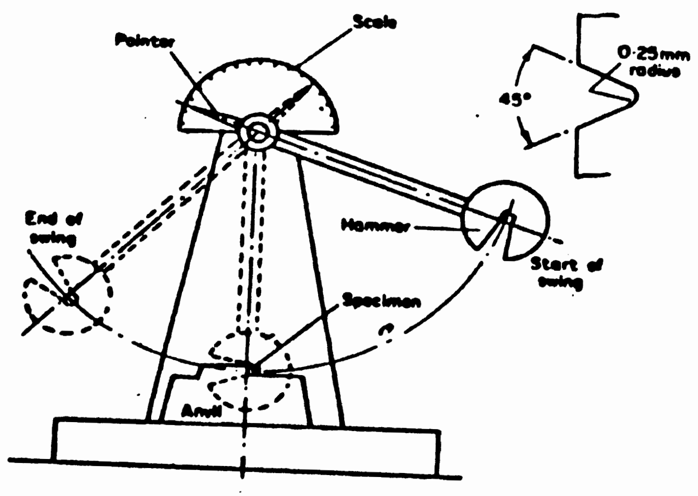
DESIRABLE QUALITIES:

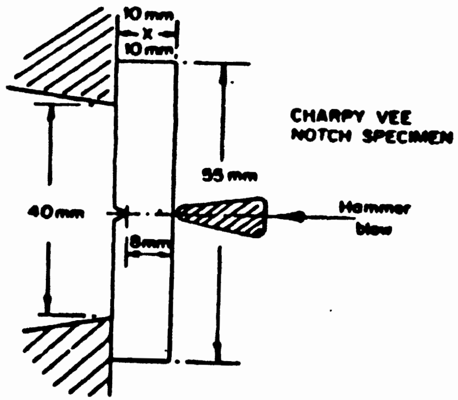
TOUGHNESS IS THE RESISTANCE OF STEEL TO NOTCH SENSITIVITY, THAT IS FAILURE OF A STEEL BY BRITTLE FRACTURE AT A NOTCH, OR DISCONTINUITY IN THE STEEL.

THERE ARE MANY TESTS THAT ARE USED TO MEASURE VARIOUS ASPECTS OF THE RESISTANCE OF A STEEL TO FRACTURE, BUT THE MOST COMMON IS THE CHARPY VEE-NOTCH TEST

CHARPY VEE NOTCH IMPACT TEST

CHARPY IMPACT TEST





THE STRENGTH AND STRUCTURE OF SHIPS

ALUMINUM

ALUMINUM IS AVAILABLE IN YIELD STRENGTHS COMPETITIVE WITH STEEL, BUT THE MODULUS OF ELASTICITY IS ONE THIRD THAT OF STEEL, WHICH MEANS THAT FOR A GIVEN LOAD IT WILL DEFLECT THREE TIMES AS MUCH AS STEEL.

FOR THE SAME STRENGTH AN ALUMINUM STRUCTURE WILL WEIGH 45-50% AS MUCH AS A STEEL STRUCTURE

ALUMINUM SUPERSTRUCTURES HAVE BEEN USED ON ALL RECENT CLASSES OF U.S. FRIGATES, DESTROYERS AND CRUISERS, BUT BECAUSE OF ITS POOR FIRE RESISTANCE ITS FUTURE USE IN NAVAL SHIPS IS IN DOUBT.

ALUMINUM IS USED EXTENSIVELY IN HIGH-SPEED SMALL SHIPS SUCH AS HYROFOIL CRAFT, GUNBOATS, SES AND ACV CRAFT.

THE STRENGTH AND STRUCTURE OF SHIPS

GLASS-REINFORCED PLASTIC (GRP)

GRP HAS BEEN USED EXTENSIVELY FOR SMALL CRAFT AND FOR SPECIAL STRUCTURES ON LARGER SHIPS.

GREAT BRITIAN, THE NETHERLANDS AND ITALY HAVE BUILT GRP MINESWEEPERS BECAUSE OF ITS NON-MAGNETIC PROPERTIES. UNITED STATES IS PRESENTLY PROCURING A GRP MINESWEEPER CLASS.

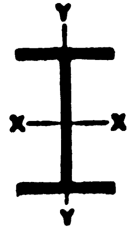
THE STRENGTH OF GRP IS IN THE FIBERS EMBEDDED IN THE PLASTIC. PROBLEMS IN PROVIDING CONTINUITY IN THESE FIBERS IN THE MIDSHIPS HALF-LENGTH LIMIT THE SIZE OF HULLS WHICH CAN BE MADE OF GRP.

NEVERTHELESS, THE FUTURE WILL SEE INCREASING USE OF GRP FOR SPECIAL STRUCTURES ON BOARD NAVAL SHIPS.

HOT ROLLED STEEL SHAPES

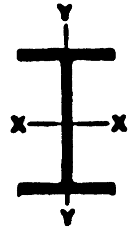
I-BEAM TYPES

W SHAPES



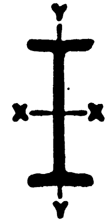
(FORMERLY WIDE FLANGE SHAPES)
(AVAILABLE 4" TO 36" DEPTH, 13-300 LBS/FT)

M SHAPES



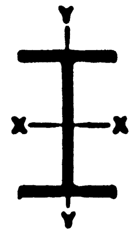
(FORMERLY MISCELLANEOUS SHAPES)
(LIGHTER THAN W SHAPES, 4" TO 14" DEPTH)

S SHAPES



(AMERICAN STANDARD I-BEAMS)
(3" TO 24" DEPTH, 5.7 TO 121 LBS/FT)

HP SHAPES



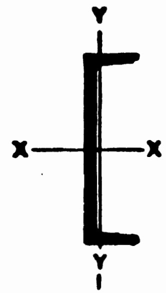
(OFTEN USED AS COLUMNS)
(8" TO 14" DEPTH, 36 TO 117 LBS/FT)

HOT ROLLED STEEL SHAPES

CHANNELS

C SHAPES

(AMERICAN STANDARD CHANNELS)
(3" TO 15" DEPTH, 4.1 TO 50 LBS/FT)



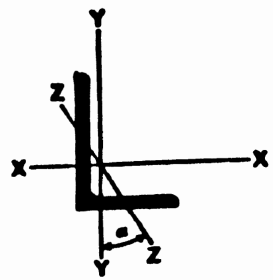
MC SHAPES

(MISCELLANEOUS CHANNELS)
(6" TO 18" DEPTH, 12 TO 58 LBS/FT)

ANGLES

L SHAPES

(ANGLES, EQUAL AND UNEQUAL LEGS)
(2" X 2" X 1.65 LBS/FT
TO 9" X 4" X 26.3 LBS/FT)



THE STRENGTH AND STRUCTURE OF SHIPS

HOT ROLLED STEEL SHAPES

TEES

- STANDARD TEES ARE MADE BY SPLITTING W, M, OR S SHAPES IN THE MIDDLE OF THE WEB
- AVAILABLE FROM 1.5" TO 18" DEPTH, 6.5 TO 150 LBS/FT
- SPLIT AT THE MILL OR IN THE SHIPYARD.

I-T

- TEES CAN ALSO BE MADE BY CUTTING THE FLANGES OFF W, M, OR S SHAPES
- USUALLY DONE AT THE SHIPYARDS.

C-L

- DEEPER ANGLE SECTIONS CAN BE MADE BY CUTTING THE FLANGE FROM A CHANNEL SHAPE.

THE STRENGTH AND STRUCTURE OF SHIPS

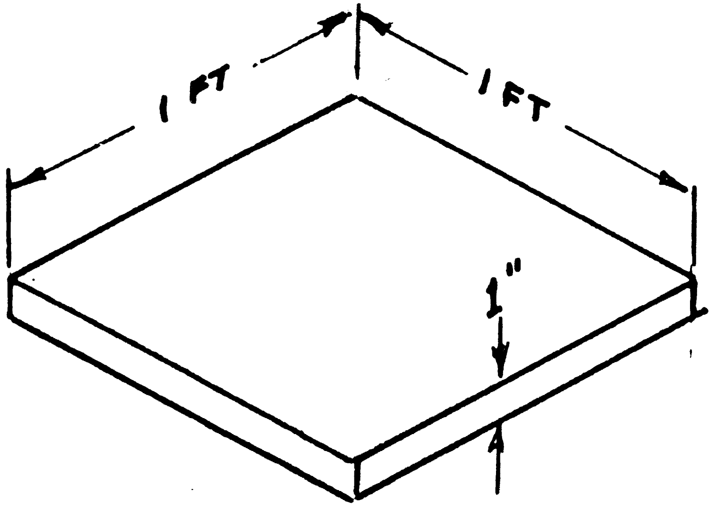
HOT ROLLED STEEL SHAPES

DESIGNATION - EXAMPLE

W 18 x 60	- W (WIDE FLANGE) SHAPE - 18" NOMINAL DEPTH - 60 LBS/FT
WT 9 x 30 (OR W-T 9 x 30)	- CUT FROM W 18 x 60 BY SPLITTING DOWN THE MIDDLE OF THE WEB - T SHAPE - 9" NOMINAL DEPTH - 30 LBS/FT
I-T 18 x 42.61	- CUT BY REMOVING FLANGES FROM W 18 x 60 - T SHAPE - 18" NOMINAL DEPTH - 42.61 LBS/FT

THE STRENGTH AND STRUCTURE OF SHIPS

WEIGHT OF STEEL PLATE



REMEMBER THIS NUMBER!!

ONE SQUARE FOOT OF STEEL ONE INCH THICK WEIGHS 40.8 LBS

THEN 1/2" = 20.4 LBS/FT²

1/4" = 10.2 LBS/FT²

7/16" = 17.85 LBS/FT² . . . ETC.

35.14

THE STRENGTH AND STRUCTURE OF SHIPS

STIFFENERS

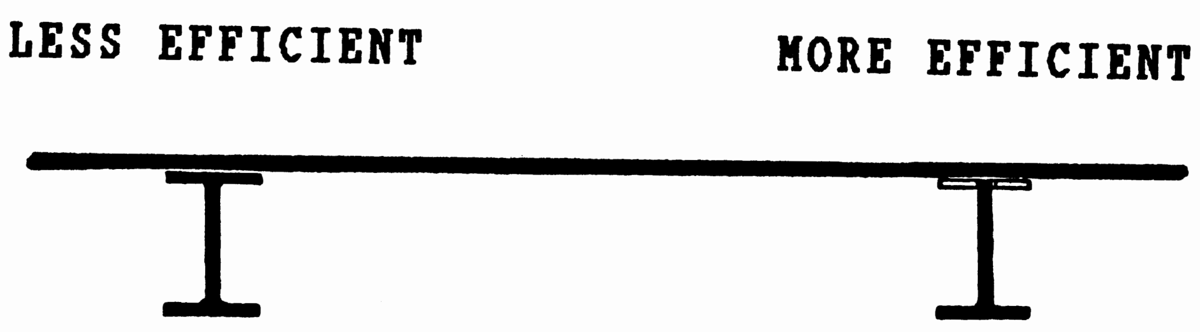
MANY SHIP STRUCTURES CONSIST OF STIFFENED PLATING.

SINCE WEIGHT IS MONEY THE OBJECTIVE IN SELECTING PLATING-STIFFENER COMBINATIONS IS TO GET THE MAXIMUM SECTION MODULUS FOR THE MINIMUM WEIGHT.

STEEL IN THE FLANGES OF A W, M, S OR C SHAPE ADJACENT TO THE PLATING HAS THE UNDESIREABLE EFFECTS OF INCREASING THE WEIGHT AND INCREASING THE STRESS IN THE OUTER FLANGE OF THE STIFFENER.

THE STRENGTH AND STRUCTURE OF SHIPS

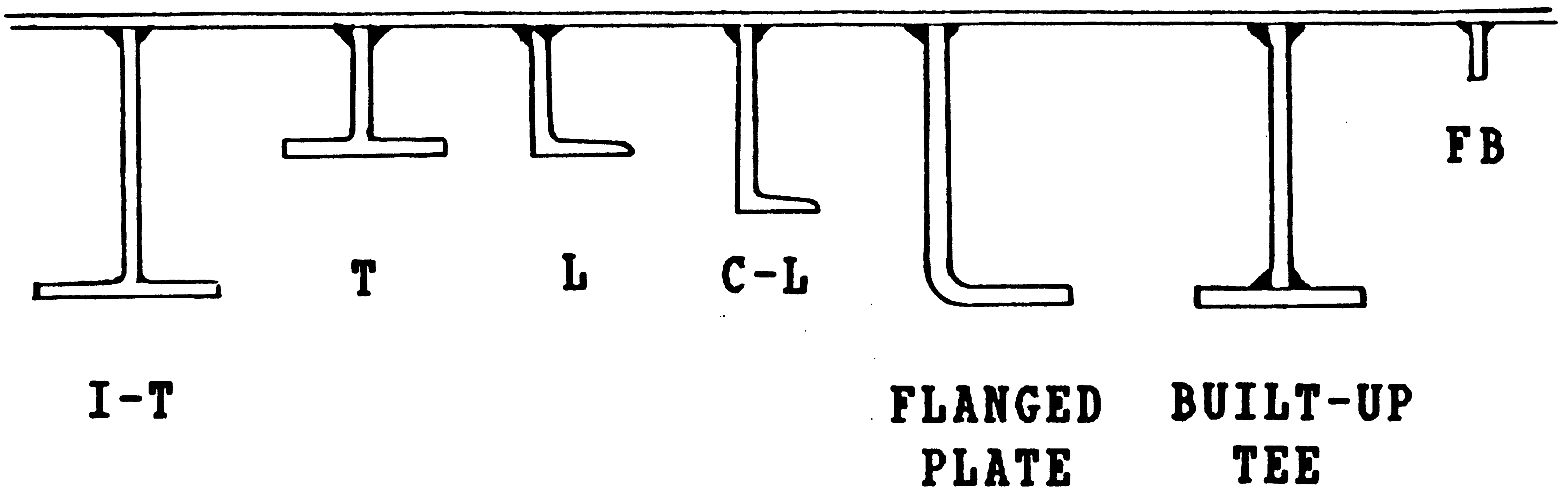
STIFFENERS



THE STRENGTH AND STRUCTURE OF SHIPS

STIFFENERS

COMMONLY USED STIFFENERS



THE STRENGTH AND STRUCTURE OF SHIPS

EFFECTIVENESS OF SECTIONS

MESSAGES:

THE MOST EFFICIENT DISTRIBUTION OF MATERIAL AS FAR AS BENDING STRESSES ARE CONCERNED IS THAT WHICH PLACES THE MATERIAL AT THE GREATEST DISTANCE FROM THE NEUTRAL AXIS.

HOWEVER, IF THE NEUTRAL AXIS IS AT SOME DISTANCE FROM THE HALF-DEPTH OF THE SECTION STRESSES IN THE FLANGE FARTHER FROM THE N.A. WILL BE SIGNIFICANTLY, GREATER.

ALSO, RECALL THAT SHEAR STRESSES ARE GREATEST AT THE NEUTRAL AXIS, MATERIAL IN THE WEB IS IMPORTANT IN RESISTING SHEAR STRESS.

BASIC NAVAL ARCHITECTURE

Problem 66

Problem Level: Intermediate

The purpose of this problem is to give the student some exposure to ABS Rules. Sections 11.5 and 11.7 of the Rules are attached to the problem and Section 11 is reproduced in the appendix.

A system of longitudinal girders and transverse deck beams support a freeboard deck. Each girder supports a 20-ft breadth of deck. The span between the pillars supporting the girders is 20'-0". Brackets are not fitted. The height, h, for the beams supported has been found from Section 10 to be 7.5 ft.

The upper flange of the girder consists of an effective breadth of 40.8 lb plate of 60 inches. The girder is to be built up as a tee with a 30.6 lb plate web and a 40.8 lb plate flange. The ratio of the depth of the girder (below the deck) to the width of the flange is to be 2.0.

Determine the depth (below the deck) and the flange width of the girder.

Comment: An analytical solution to this problem is possible, but very messy. Try a range of girder depths (below the deck) from 14 to 16 inches. Pick the depth to roughly a half-inch that satisfies the section modulus requirements determined from the Rules.

11.3.6 Bulkhead Stiffening

Bulkheads which support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders, are to be specially stiffened in such manner as to provide supports not less effective than required for stanchions or pillars.

11.3.7 Attachments

Wide-spaced tubular or solid pillars are to bear solidly at head and heel and are to be attached by welding, properly proportioned on the size of the pillar. The attachments of stanchions or pillars under bulkhead recesses, tunnel tops or deep-tank tops which may be subjected to tension loads are to be specially developed to provide sufficient welding to withstand the tension load.

11.5 Deck Girders

Girders of the sizes required by 11.7, 11.9, and 11.11 are to be fitted elsewhere as required to support the beams; in way of bulkhead recesses and the tops of tanks they are to be arranged so that the unsupported spans of the beams do not exceed 4.57 m (15 ft). Additional girders are to be fitted as required under masts, king posts, deck machinery or other heavy concentrated loads. In way of deck girders or special deep beams the deck plating is to be of sufficient thickness and suitably stiffened to provide an effective part of the girder.

11.7 Deck Girders and Transverses Clear of Tanks

11.7.1 Deck Girders Clear of Tanks

Each deck girder clear of tanks, similar to that shown in Figure 11.1, is to have a section modulus *SM* as obtained from the following equation.

$$SM = 4.74cbhl^2 \text{ cm}^3 \qquad SM = 0.0025cbhl^2 \text{ in.}^3$$

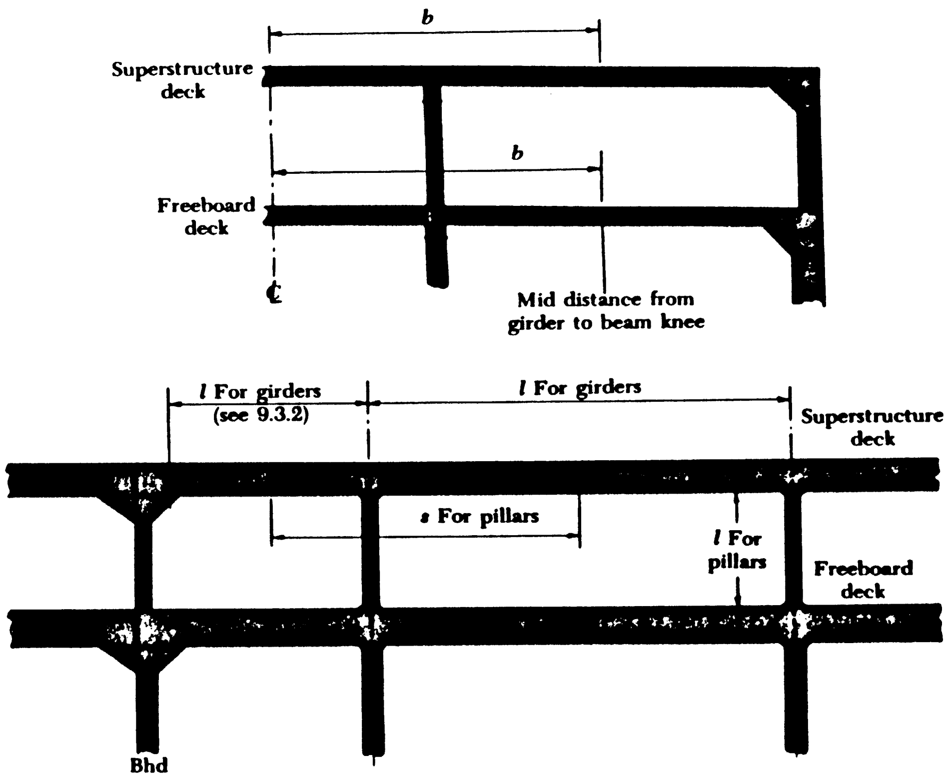
c = 1.0
b = mean breadth of the area of deck supported in m or ft
h = height as required by Section 10 for the beams supported, in m or ft
l = span between centers of supporting pillars, or between pillar and bulkhead, in m or ft. Where an effective bracket in accordance with 9.3.3 is fitted at the bulkhead, the length l may be modified.

11.7.2 Deck Transverses Clear of Tanks

Each deck transverse supporting a longitudinal deck beam is to have a section modulus *SM* as obtained from the equations in 11.7.1 where

c = 1.0
b = spacing of deck transverses in m or ft

FIGURE 11.1
Deck Girders and Pillars



h = height as required by Section 10 for the beams supported, in m or ft

l = span between supporting girders or bulkheads, or between girder and side frame, in m or ft. Where an effective bracket is fitted at the side frame, the length l may be modified. See 9.3.3.

11.7.3 Proportions

Girders are to have a depth of not less than $0.0583l$ (0.7 in. per ft of span l), the thickness is not to be less than 1 mm per 100 mm (.01 in. per in.) of depth plus 4 mm (0.16 in.), but is not to be less than 8.5 mm (0.34 in.) where the face area is 38 cm^2 (6 $in.^2$), 10 mm with 63 cm^2 (0.40 in. with 10 $in.^2$), 12.5 mm with 127 cm^2 (0.50 in. with 20 $in.^2$) and 15 mm with 190 cm^2 (0.60 in. with 30 $in.^2$).

11.7.4 Tripping Brackets

Tripping brackets arranged to support the flanges are to be fitted at every third frame where the breadth of the flanges on either side of the web exceeds 200 mm (8 in.), at every second frame where it exceeds 400 mm (16 in.) and at every frame where it exceeds 600 mm (24 in.).

11.7.5 End Attachments

End attachments of deck girders are to be effectively attached by welding.

11.9 Deck Girders and Transverses in Tanks

Deck girders and transverses in tanks are to be obtained in the same manner as given in 11.7.1 above, except the value of c is to be equal to 1.50 and the minimum depth of the girder is to be $0.0833l$ (1 in. per ft of span l). The minimum thickness and the sizes and arrangements of the stiffeners, tripping brackets and end connections are to be the same as given in 11.7.3, 11.7.4, and 11.7.5.

11.11 Hatch Side Girders

Scantlings for hatch side girders supporting athwartship shifting beams or supporting hatch covers are to be obtained in the same manner as deck girders (11.7 and 11.9). Such girders along lower deck hatches under trunks in which covers are omitted are to be increased in proportion to the extra load which may be required to be carried due to the loading up into the trunks. The structure on which the hatch covers are seated is to be effectively supported. Where deep coamings are fitted above decks, such as at weather decks, the girder below deck may be modified so as to obtain a section modulus in cm^3 or $in.^3$, when taken in conjunction with the coaming up to and including the horizontal coaming stiffener, of not less than 35% more than the required girder value as derived from 11.7.1. Where hatch side girders are not continuous under deck beyond the hatchways to the bulkheads, brackets extending for at least two frame spaces beyond the ends of the hatchways are to be fitted. Where hatch side girders are continuous beyond the hatchways, care is to be taken in proportioning their scantlings beyond the hatchway. Gusset plates are to be fitted at hatchway corners arranged so as to tie effectively the flanges of the side coamings and extension pieces or continuous girders and the hatch-end beam flanges both beyond and in the hatchway.

11.13 Hatch-end Beams

11.13.1 Hatch-end Beam Supports

Each hatch-end beam, similar to that shown in Figure 11.2, which is supported by a centerline pillar without a pillar at the corner of the hatchway, is to have a section modulus SM not less than obtained from the following equations.

a ***Where Deck Hatch-side Girders are Fitted Fore and Aft Beyond the Hatchways***

$$SM = K(AB + CD)hl \text{ cm}^2 \qquad SM = 0.000527K(AB + CD)hl \text{ cm}^3$$

b ***Where Girders are not Fitted on the Line of the Hatch Side Beyond the Hatchway***

$$SM = KABhl \text{ cm}^3 \qquad SM = 0.000527KABhl \text{ in.}^3$$

A = length of the hatchway, in m or ft

B = distance from the centerline to the midpoint between the hatch side and the line of the toes of the beam knees, in m or ft

C = distance from a point midway between the centerline and the line of the hatch side to the midpoint between the hatch side and the line of the toes of the beam knees, in m or ft; where no girder is fitted on the centerline beyond the hatchway C is equal to B

D = distance from the hatch-end beam to the adjacent hold bulkhead, in m or ft

h = height for the beams of the deck under consideration as given in Section 10, in m or ft

l = distance from the toe of the beam knee to the centerline plus 0.305 m (1 ft), in m or ft

K = $2.20 + 1.29(F/N)$ when $F/N \leq 0.6$

= $4.28 - 2.17(F/N)$ when $F/N > 0.6$

N = one-half the breadth of the vessel in way of the hatch-end beam

F = distance from the side of the vessel to the hatch side girder

35 [illegible]

Problem 67

Problem Level: Basic

The flanges of a W10 x 30 are to be cut off to form a tee of the same depth, as shown below.

Compute the following properties of the resulting section:

Area

Depth

I_{x-x}

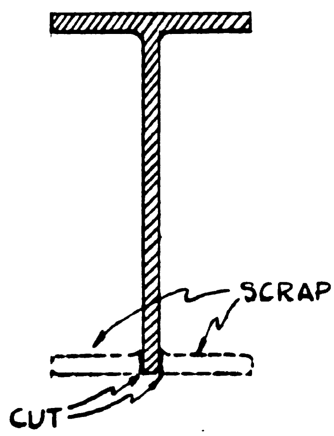
C_{top}

S_{top}

C_{bot}

S_{bot}

Neglect the effect of fillets and treat the web and flange as simple rectangles.



Comments: The purpose of this problem is to illustrate the procedure by hand calculation. In practice, it is much easier to look up the properties of W-Ts and I-Ts in the handbook cited in Problem 66. Because of the assumption, the properties you find will differ slightly from the tabulated values.

GIVEN: BREADTH, SPAN AND PARTICULARS FOR CALCULATING SCANTLINGS OF A DECK GIRDER BY ABS RULES

FIND: SCANTLINGS OF DK GIRDER

REF: ABS RULES, 1987, SECTION 11.7.1

$$SM = .0025\,c\,b\,h\,l^2 \text{ IN}^3$$

WHERE,

$c = 1.0$

b = MEAN BREADTH OF DECK SUPPORTED

$b = 20.0$ FT (GIVEN)

h = HEIGHT OF LOAD FROM SECTION 10

$h = 7.5$ FT (GIVEN)

l = SPAN BETWEEN SUPPORTING PILLARS. NO BRACKET FITTED

$l = 20.0$ FT (GIVEN)

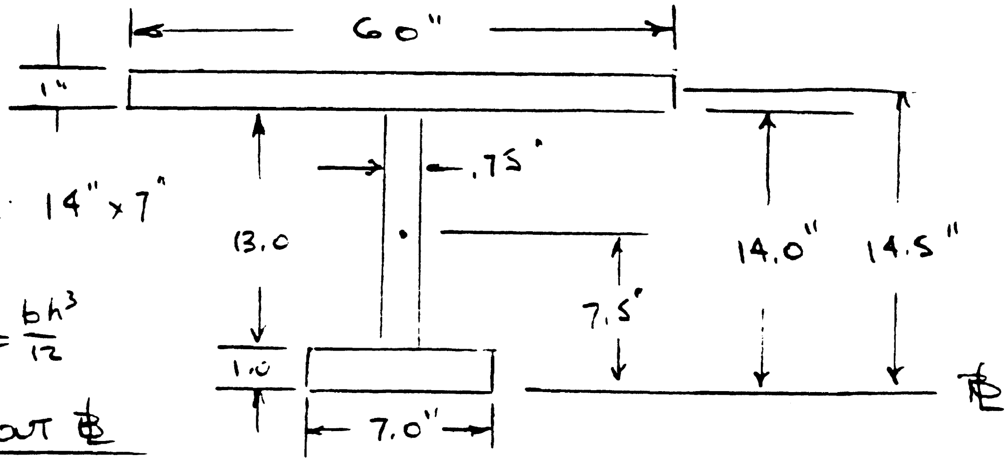
$$SM = (.0025)(1.0)(20.0 \text{ FT})(7.5 \text{ FT})(20.0 \text{ FT})^2$$

$$\underline{SM = 150 \text{ IN}^3}$$

TRY GIRDER DEPTHS OF 14", 15", 16". SELECT DEPTH IN MULTIPLES OF ½"

GIRDER WEB = 30.6# PL = .750"

GIRDER FLANGE = 40.8# PL = 1.00"



GIRDER 14" x 7"

I_o OF WEB $= \frac{bh^3}{12}$

MOM'T ABOUT ℄

ITEM	SCANTLING	AREA A IN^2	LVR $\bar{y}$ IN	MOMT $A\bar{y}$ IN^3	TRANSFER $A\bar{y}^2$ IN^4	INERTIA I_o IN^4
DECK	60.0 x 1.0	60.0	14.5	870.0	12615	—
WEB	.75 x 13	9.75	7.5	73.1	548	137
FLG	7.0 x 1.0	7.0	0.5	3.5	2	—
COMBO.		76.75	12.33	946.6	13165	137

13165
137 IN^4

$C_{FLG} = 12.33$ IN
$C_{PLT} = 2.67$ IN $I_{℄} = 13302$ IN^4

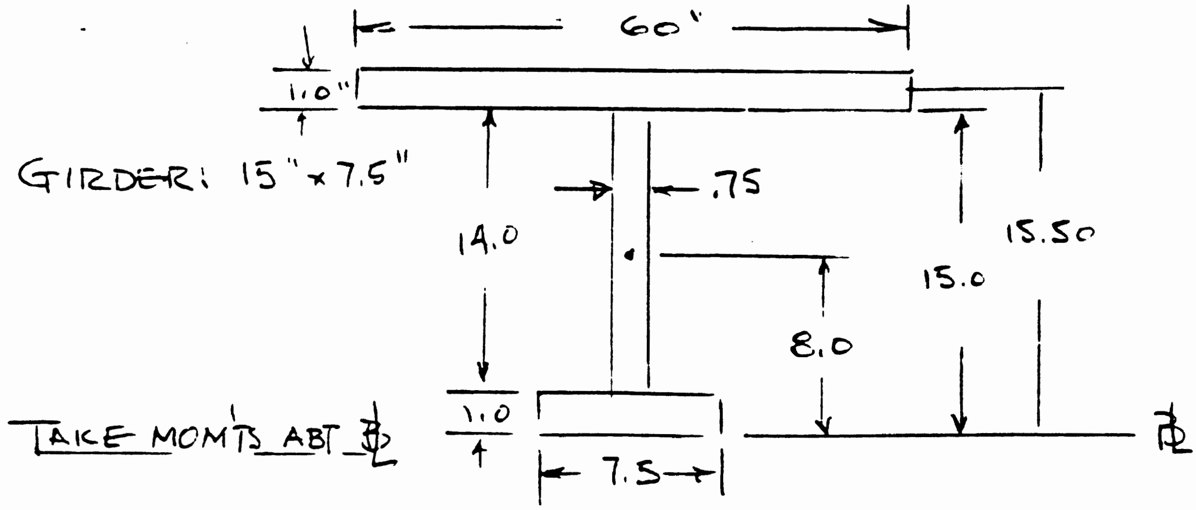
TRANSFER TO N.A $= (76.75)(12.33)^2 = 11668$ IN^4 $= I_{na}$

$I_{na} = 1634$ IN^4

SECTION MODULUS TO FLANGE $= \frac{1634\ IN^4}{12.33\ IN} = 132.5\ IN^3$

NOTE: OUR MINIMUM S HAS TO BE 150 IN^3. WE DIDN'T MAKE. THERE IS NO POINT IN FIGURING SECTION MODULUS TO THE PLATE. FOR DECK LOAD PROBLEMS, EXCEPT IN VERY UNUSUAL LOADINGS OR CONFIGURATIONS, STRESS IN THE FLANGE OF THE STIFFENER CONTROLS

DONT BOTHER FIGURING I_o OF HORIZONTAL PLATES - ITS NEGLIGIBLE. VERTICAL PLATES MUST, OF COURSE BE INCLUDED.



ITEM	SCANTLING	AREA A IN^2	LVR $\bar{y}$ IN	MOM'T $A\bar{y}$ IN^3	TRANSFER $A\bar{y}^2$ IN^4	INERTIA i_o IN^4
DECK	60" × 1.0"	60.0	15.50	930.0	14415	—
WEB	.75 × 14.0"	10.5	8.0	84.0	672	172
FLANGE	7.5 × 1.0	7.50	.50	3.8	2	—
COMBO.		78.0	13.05	1017.8	15089	172

$C_{FLG} = 13.05$

$C_{℄} = 2.95$

15089 + 172

$I_{℄} = 15261 \; IN^4$

TRANSFER TO NEUTRAL AXIS $= (78.0)(13.05)^2 = 13284 \; IN^4$

$I_{na} = 1977 \; IN^4$

SECTION MODULUS TO FLG $= \dfrac{1977 \; IN^4}{13.05 \; IN} = 151.5 \; IN^3$

WHOOPEE! GOT IT ON THE SECOND TRY! STOP! DON'T GO ANY FARTHER.

RECAP:

GIRDER DEPTH BELOW THE DECK	=	15.00 IN
WEB THICKNESS	=	0.75 IN
FLANGE WIDTH	=	7.50 IN
FLANGE THICKNESS	=	1.00 IN
AREA (BELOW DK)	=	18.00 IN^2
$\bar{y}$ (ABOVE ℄) (INCL DK)	=	13.05 IN
SECTION MOD. (INCL DK) TO FLANGE	=	151.5 IN^3

GIVEN: W 10 × 30

FIND: PROPERTIES OF W-T

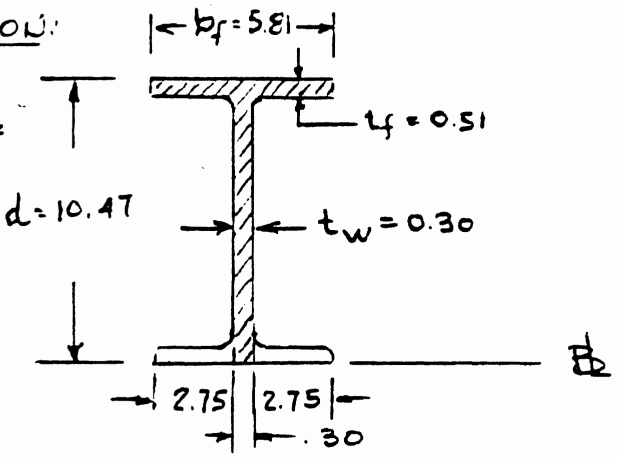
FROM MANUAL OF STEEL CONSTRUCTION:

ORIGINAL SECTION:

AREA = 8.84 IN^2

$\bar{y} = \frac{d}{2} = 5.24$

$I_o = 170\ IN^4$



TAKE MOMENTS ABOUT ℄.

ITEM	SCANTLING IN×IN×IN	AREA A IN^2	LVR $\bar{y}$ IN	MOMENT $A\bar{y}$ IN^3	TRANSFER $A\bar{y}^2$ IN^4	INERTIA I_o IN^4
ORIGINAL SECTION	10.47×5.81	8.84	5.235	46.27	242.3	170
REMOVE FLANGES	2×2.75×.51	−2.81	0.255	−0.72	−0.2	—
		6.03	7.55	45.55	242.1 IN^4	

$C_{℄} = 7.55$

$C_{FLG} = 2.92$

$I_o = 170\ IN^4$

$I_{℄} = 412.1\ IN^4$

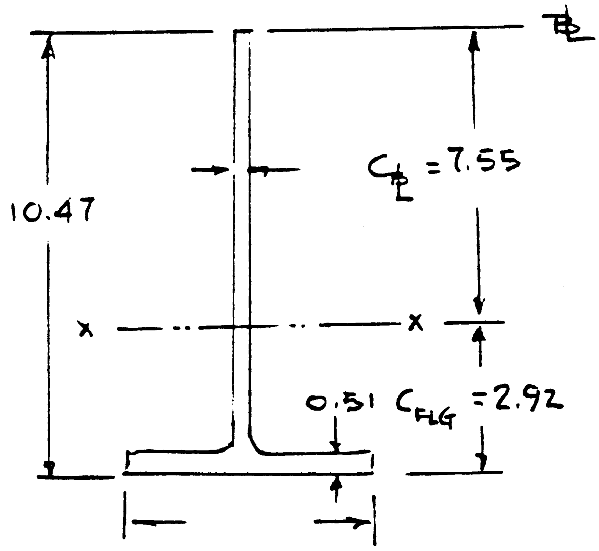
TRANSFER TO N.A. $= (6.03\ IN^2)(7.55\ IN)^2 = 343.7\ IN^4$

$I_{na} = 68.4\ IN^4$

$$\frac{I_{na}}{C_{℄}} = \frac{68.4\ IN^4}{7.55\ IN}, \quad \frac{I_{na}}{C_{℄}} = 9.06\ IN^3$$

$$\frac{I_{na}}{C_{FLG}} = \frac{68.4\ IN^4}{2.92\ IN}, \quad \frac{I_{na}}{C_{FLG}} = 23.42\ IN^3$$

RECAP (NOTE: THIS IS THE ORIENTATION IN WHICH WE WILL NORMALLY VISUALISE TEE SECTIONS



AREA = 6.03 IN^2

DEPTH = 10.47 IN

$I_{x-x} = 68.4 \ IN^4$

$C_{top} = C_{℄} = 7.55$ IN

$S'_{top} = I/C_{℄} = 9.06 \ IN^3$

$C_{bot} = I/C_{FLG} = 23.42 \ IN^3$

NOTE: THIS RESULT WILL BE USED IN PROB 68.

Unit Number: 36

Title: The strength and structure of ships - 7

Tape Running Time: 33^{M} 9^{S}

Reading Assignment: MSD, pp 219-220

Additional References: SDC, pp 275-278, 280-288

Scope:

This discusses common causes for structural failures including local plasticity, column and plate buckling, brittle fracture, fatigue cracking, stress concentrations. The importance of structural continuity is discussed. Hard spots, crack arrestors are illustrated. Causes for cracking are outlined.

Key Points to Emphasize:

1. If possible obtain photographs of structural failures, particularly buckling and cracking, to illustrate this unit.

2. Emphasize stiffened plate buckling modes with supplemental examples.

3. Discuss S-N diagrams, fatigue and fatigue cracking, influence of temperature.

4. Discuss brittle fracture, hard spots, stress concentrations. Use Liberty Ship example, or preferably, more recent examples which have been repaired in the shipyard.

5. Stress the importance of structural continuity. Try to develop in the student an intuitive feeling for load paths and stress flow.

6. Emphasize the importance of correct structural details and good workmanship in avoiding structural failures.

Suggested Problem Assignment: 68

FAILURE MODES FOR STEEL STRUCTURES

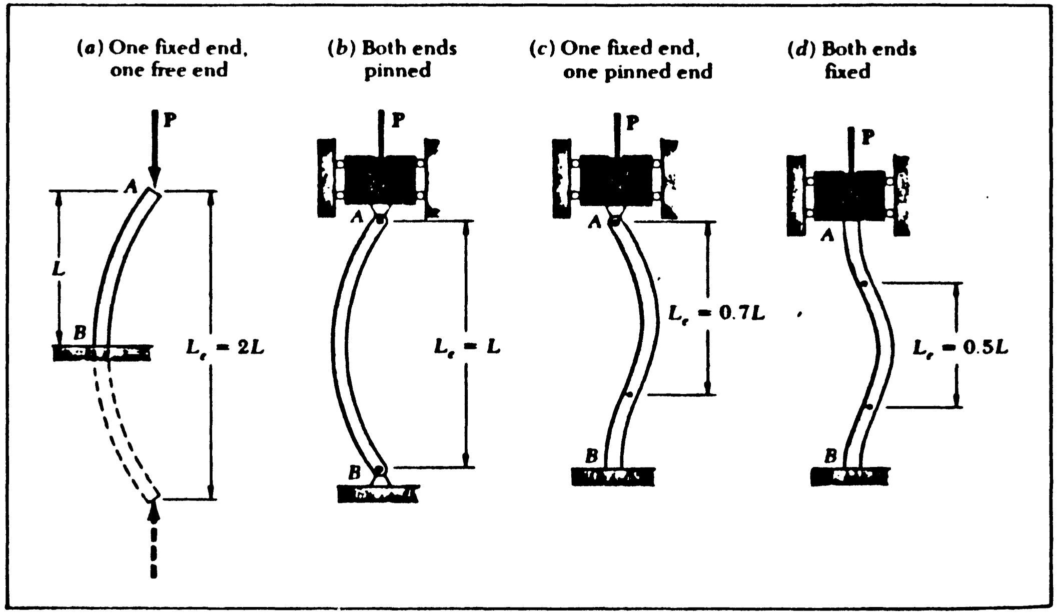
1. LARGE LOCAL PLASTICITY

IF THE STRESS AT A POINT IN A STRUCTURE EXCEEDS THE ELASTIC LIMIT THE STEEL AT THAT POINT ENTERS THE PLASTIC RANGE, THAT IS THE STEEL AT THAT POINT WILL TAKE ON A PERMANENT DEFORMATION. IF THE LOAD IS INCREASED THE REGION OF PLASTICITY WILL SPREAD UNTIL EVENTUALLY IT WILL BECOME FULLY PLASTIC AND WILL NOT BE ABLE TO SUPPORT FURTHER LOADING. FURTHER LOADING WILL SIMPLY CAUSE FURTHER DEFORMATION WITHOUT RETURN TO ITS ORIGINAL SHAPE.

FAILURE MODES (CONT)

2. BUCKLING

CONSIDER AN AXIAL COMPRESSIVE LOAD ON A COLUMN:

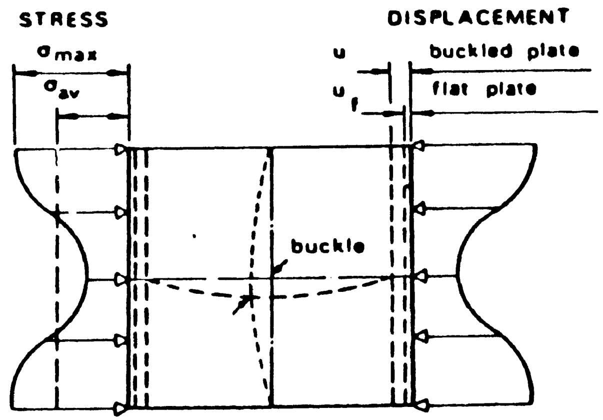


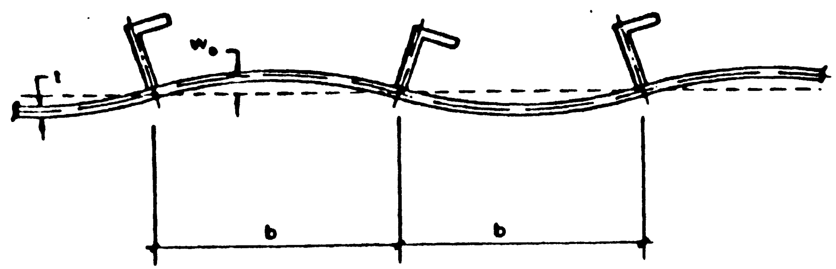
THE STRENGTH AND STRUCTURE OF SHIPS

FAILURE MODES (CONT)

2. BUCKLING

CONSIDER AN IN-PLANE COMPRESSIVE LOAD ON A PLATE:





FAILURE MODES (CONT)

3. FRACTURE

THERE ARE THREE TYPES OF FRACTURE

A. IF THE STRESS IN A STRUCTURAL COMPONENT EXCEEDS THE ULTIMATE TENSILE STRENGTH THE COMPONENT WILL FAIL BY TENSILE RUPTURE.

B. AS THE TEMPERATURE OF STEEL IS LOWERED THE DUCTILITY OF STEEL DECREASES, AND THE STEEL BECOMES MORE BRITTLE. AFTER THE TEMPERATURE PASSES THROUGH A TRANSITION RANGE THE FRACTURE MODE CHANGES FROM DUCTILE TO BRITTLE. BRITTLE FRACTURES USUALLY ORIGINATE AT A STRESS CONCENTRATION POINT AND PROPAGATE VERY RAPIDLY.

THE STRENGTH AND STRUCTURE OF SHIPS

FAILURE MODES (CONT)

3. FRACTURE (CONT)

C. WHEN A STRUCTURAL COMPONENT IS SUBJECT TO REPEATED ALTERNATING STRESS CYCLES THE STRUCTURE GRADUALLY FATIGUES AND THE STRESS AT WHICH FAILURE OCCURS DECREASES.

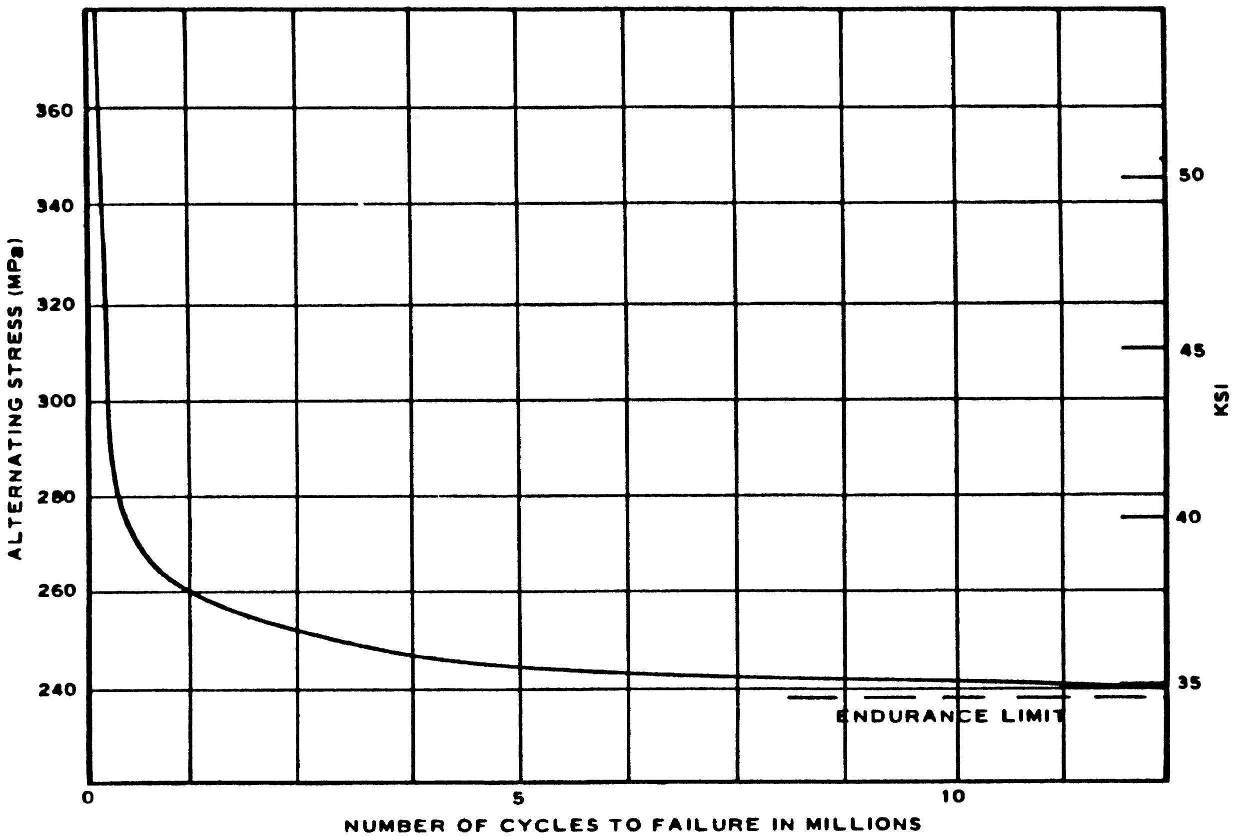
FAILURE USUALLY TAKES THE FORM OF A FATIGUE CRACK WHICH MAY START AS A VERY SMALL CRACK WHICH CONTINUES TO GROW AS THE ALTERNATING STRESS CONTINUES.

FATIGUE CRACKING MAY BE ACCELERATED IN A CORROSIVE ENVIRONMENT.

IN A NON-CORROSIVE ENVIRONMENT FATIGUE CRACKING DOES NOT OCCUR BELOW THE ENDURANCE LIMIT.

THE STRENGTH AND STRUCTURE OF SHIPS

S-N DIAGRAM AND FATIGUE



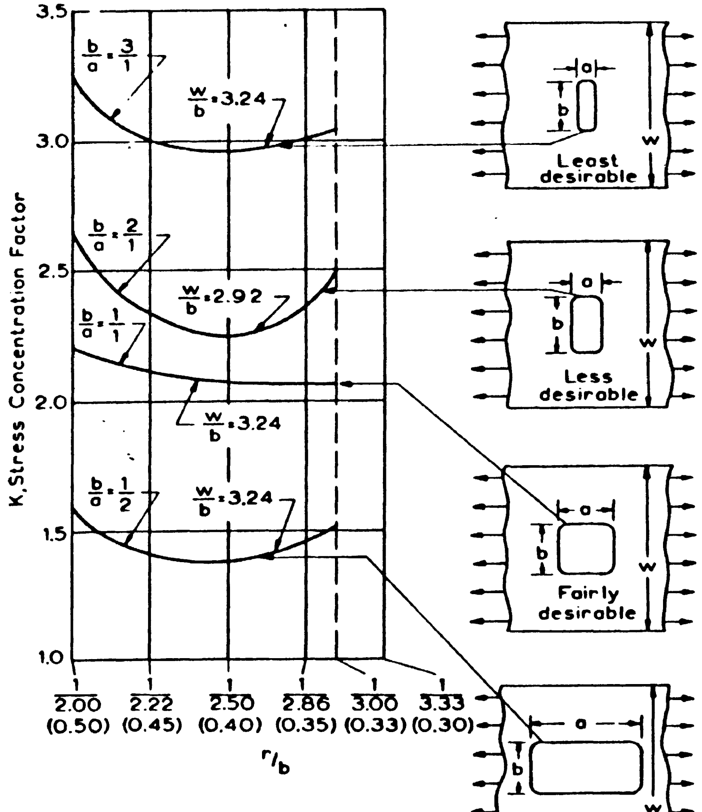
THE STRENGTH AND STRUCTURE OF SHIPS

STRESS CONCENTRATIONS

STRESS CONCENTRATION FACTOR:

$$K = \frac{\text{LOCAL STRESS AT A POINT}}{\text{AVERAGE STRESS IN MINIMUM SECTION}}$$

STRESS CONCENTRATIONS



Notes:

1) w/b = plate to opening width ratio.
2) b/a = opening width to length ratio.
3) The stress concentration factor K is the ratio of the maximum to the average stress in the minimum section.
4) r = radius of the corner.

THE STRENGTH AND STRUCTURE OF SHIPS

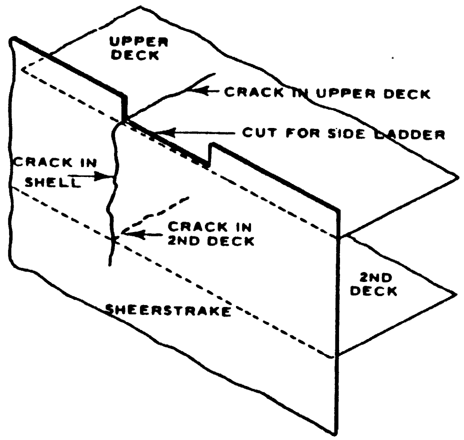
STRESS CONCENTRATIONS

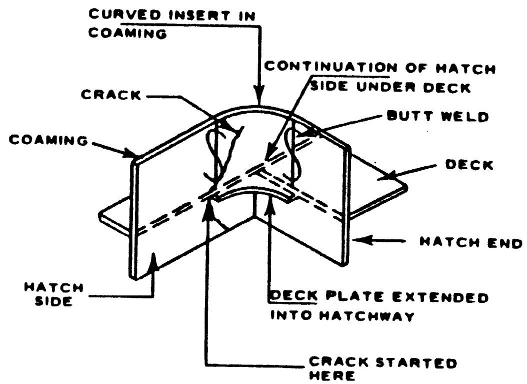
IMPORTANT MESSAGE!!!

OPENINGS OR INTERSECTIONS WITH SQUARE CUT CORNERS CAN BE BIG TROUBLE!!

21-10

BRITTLE FRACTURE CRACKS





THE STRENGTH AND STRUCTURE OF SHIPS

STRUCTURAL CONTINUITY

AN IMPORTANT OBJECTIVE IN STRUCTURAL DESIGN IS TO PROVIDE CLEAR <u>LOAD PATHS</u> FROM THE POINT OF APPLICATION OF THE LOAD TO THE SUPPORTING STRUCTURE.

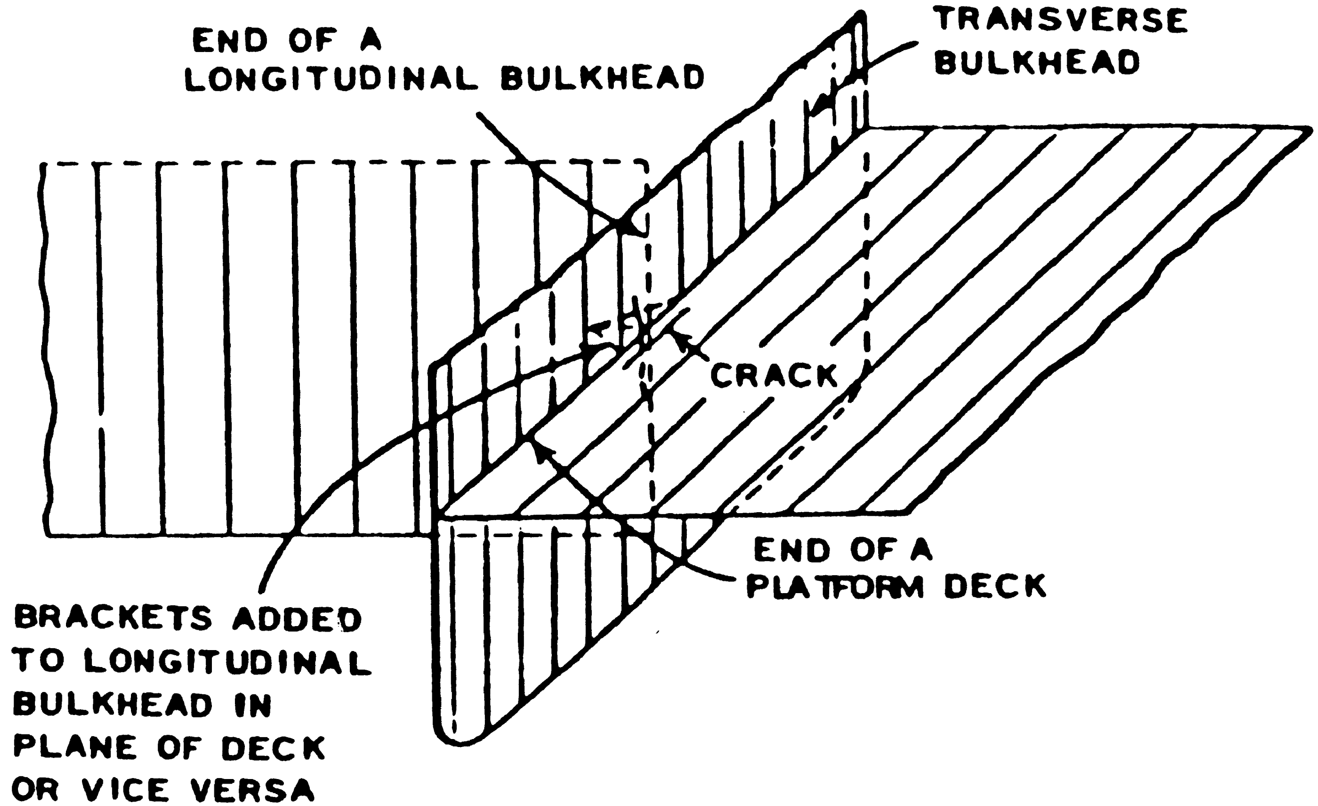
DISCONTINUITIES AND MISALIGNMENT OF STRUCTURAL MEMBERS CAN CAUSE STRESS CONCENTRATIONS THAT LEAD TO LOCAL CRACKING.

SPECIAL ATTENTION IS REQUIRED AT THE INTERSECTION OF TWO OR MORE LOAD BEARING MEMBERS. FOR EXAMPLE, THE INTERSECTION OF LONGITUDINAL AND TRANSVERSE BULKHEADS, OR THE INTERSECTION OF A TRANSVERSE BULKHEAD WITH LONGITUDINAL GIRDERS CAN CAUSE <u>HARD SPOTS</u> WHICH WILL BE A SOURCE OF STRESS CONCENTRATIONS.

THE STRENGTH AND STRUCTURE OF SHIPS

STRUCTURAL CONTINUITY

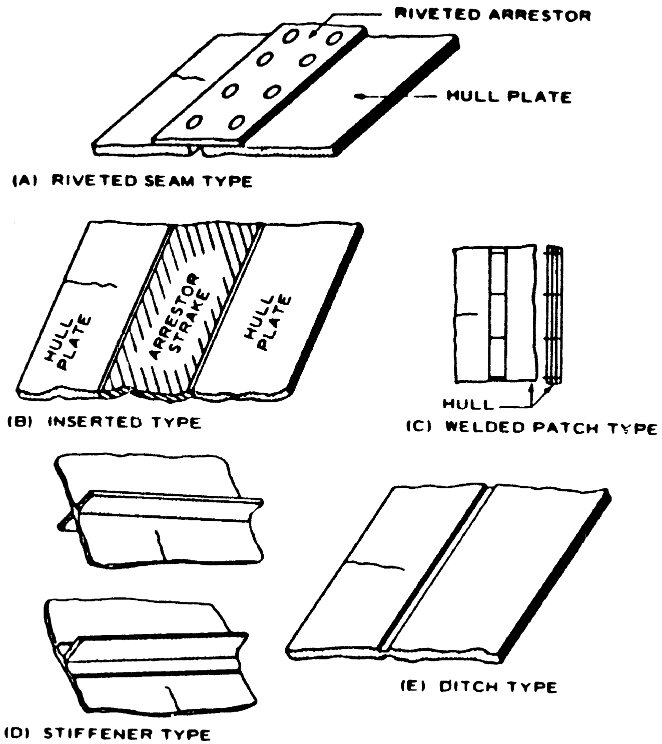
HARD SPOTS



CRACK ARRESTORS

A CRACK, ONCE STARTED, BECOMES A STRESS CONCENTRATION POINT WHICH ENCOURAGES THE PROPAGATION OF THE CRACK.

THE PURPOSE OF A CRACK ARRESTOR IS TO PROVIDE A BARRIER BEYOND WHICH THE CRACK CANNOT PROPAGATE.



THE STRENGTH AND STRUCTURE OF SHIPS

CAUSES FOR CRACKING

CURRENTLY, BRITTLE FRACTURE AND FATIGUE ARE THE MAJOR CAUSES OF CRACKING

CRACKS ARE GENERALLY INITIATED AT POINTS OF STRESS CONCENTRATION WHICH CAN BE DUE TO:

A. DESIGN DEFICIENCIES

- o CUTS IN HIGHLY STRESSED AREAS
- o ABRUPT CHANGES IN CONTINUITY

B. POOR WORKMANSHIP

- o FAULTY WELDING
- o ROUGH PLATE EDGES
- o MISALIGNMENT OF STRUCTURE

Problem 68

Problem Level: Basic

In computing the properties of a panel of stiffened plating, the plate is treated as the upper flange. The breadth of the plating is taken as the spacing between stiffeners or the "effective breadth" of the plating, whichever is less. The effective breadth is given by the following formula:

$$b_e = \sqrt{\frac{E}{Fy}}\ t$$

where b_e = effective breadth, in.

E = Modulus of Elasticity, lbs/in^2

Fy = tensile yield strength of material, lbs/in^2

t = thickness of plating, in.

For shipbuilding steels this formula yields the following standard effective breadths:

MS (mild steel)	60t
HTS	50t
HY 80	38t
HY 100	35t

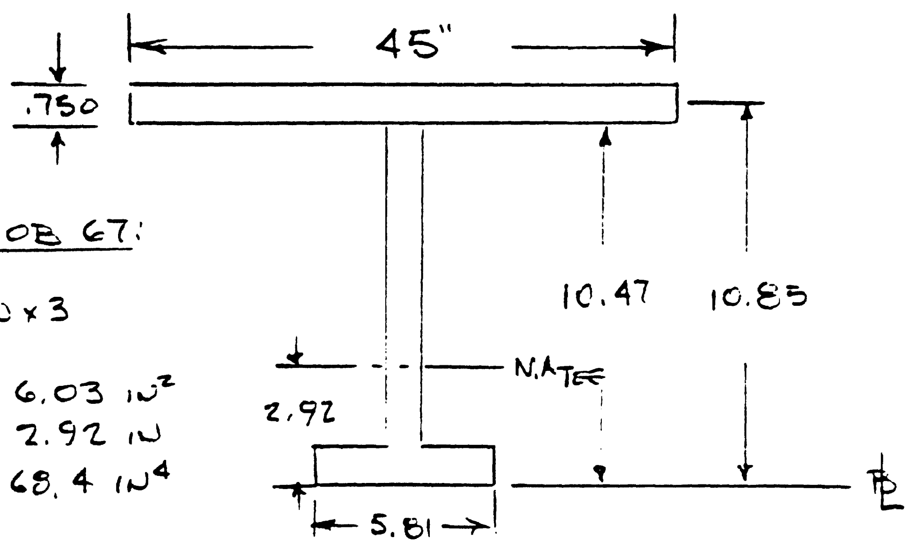
Find the properties of the plate-beam combination with an effective breadth of 30.6 lb mild steel deck plating and the W-T 10 x 30 tee stiffener of Problem 67.

GIVEN: 30.6# PL AT EFFECTIVE BREADTH WITH W-T 10x30 STIFFENER

FIND: PROPERTIES OF PLATE-BEAM COMBINATION

FOR MILD STEEL EFFECTIVE BREADTH = 60t

FOR 30.6# PL, t = .750", $b_e = 60 \times .750 = 45''$



FROM PROB 67:

W-T 10x3

AREA = 6.03 IN^2
$\bar{y}_{FLG}$ = 2.92 IN
I_o = 68.4 IN^4

TAKE MOMENTS ABOUT PL

ITEM	SCANTLING IN x IN	AREA A IN^2	LVR $\bar{y}$ IN	MOM'T $A\bar{y}$ IN^3	TRANSFER $A\bar{y}^2$ IN^4	INERTIA I_o IN^4
PLATE	45 x .75	33.75	10.85	366.18	3973.1	–
TEE	10.47 x 5.81	6.03	2.92	17.61	51.4	68.4
		39.78	9.64	383.79	4024.5 IN^4	

$C_{FLG} = 9.64$

$C_{PL} = 1.58$

$I_o = 68.4\ IN^4$

$I_{PL} = 4092.9\ IN^4$

TRANSFER TO N.A $= (39.78\ IN^2)(9.64\ IN)^2 = 3696.7\ IN^4$

$I_{na} = 396.2\ IN^4$

$\frac{I_{na}}{C_{FLG}} = \frac{396.2\ IN^4}{9.64\ IN}$, $I_{na}/C_{FLG} = 41.1\ IN^3$

$\frac{I_{na}}{C_{PL}} = \frac{396.2\ IN^4}{1.58\ IN}$, $I_{na}/C_{PL} = 250.8\ IN^3$

RECAP

PROPERTIES OF PLATE-BEAM COMBINATION:

A SQUARE FOOT OF STEEL PLATE 1" THICK WEIGHS 40.8 LB., THEREFORE 1" x 1" x 1 FT LONG WEIGHS $\frac{40.8\ LB/FT^2\text{-}IN}{12\ IN/FT}$ = 3.40 FOR 1" SQ SECTION 1-FT LONG.

AREA OF TEE = 6.03 IN^2

WT/FT OF TEE = 6.03 IN^2 x 3.40 $\frac{LBS}{IN^2\ FT}$ = 20.5 $\frac{LBS}{FT}$

AREA OF PL = 33.75 IN^2

WT/FT OF PL = 33.75 IN^2 x 3.40 $\frac{LBS}{IN^2\ FT}$ = 114.75 $\frac{LBS}{FT}$

AREA OF COMBINED SECTION = 39.78 IN^2

WT/FT OF COMBINED SECTION = 135.25 LB/FT

C_{FLG} = 9.64 IN

C_{PLT} = 1.58 IN

I_{na} = 396.2 IN^4

S_{FLG} = 41.1 IN^3

S_{PLT} = 250.8 IN^3

Unit Number: 37

Title: The strength and structure of ships - 8

Tape Running Time: 30^{M} 22^{S}

Reading Assignment: MSD, pp 221-227

Additional References: SDC, pp 289-304

Scope:

Structural terminology originally introduced in Unit 6, is reviewed and amplified. Types of framing systems, longitudinals, stringers, girders, beams, side frames, web frames, floors are described. Single and double bottom types of construction are described. Typical bow and stern construction types are illustrated.

Key Points to Emphasize:

1. Structural terminology was originally introduced in Unit 6 with emphasis on nomenclature. Some additional material is introduced in this unit. Emphasis should be on structural function.

2. The instructor should add additional material as available. Shipyard photographs showing structural components would be helpful if available.

3. Producibility considerations will be discussed in Unit 44; however this is a good time to introduce the subject by discussing labor content and cost factors for various types of construction.

Suggested Problem Assignment: 69

THE STRENGTH AND STRUCTURE OF SHIPS

FRAMING SYSTEMS

TRANSVERSE FRAMING SYSTEM

- TRANSVERSE MEMBERS INCLUDING

  FLOORS

  SIDE FRAMES

  BEAMS

  ARE CLOSELY SPACED (24" TO 36")

- LONGITUDINAL MEMBERS INCLUDING SIDE STRINGERS AND LONGITUDINAL GIRDERS IN BOTTOM AND DECKS ARE WIDELY SPACED

THE STRENGTH AND STRUCTURE OF SHIPS

FRAMING SYSTEMS

LONGITUDINAL FRAMING SYSTEM

- LONGITUDINAL MEMBERS INCLUDING

  BOTTOM LONGITUDINALS

  SIDE LONGITUDINALS

  DECK LONGITUDINALS

  ARE CLOSELY SPACED (24" TO 36")

- TRANSVERSE MEMBERS, PRINCIPALLY DEEP WEB FRAMES ARE WIDELY SPACED (8' TO 12')

THE STRENGTH AND STRUCTURE OF SHIPS

LONGITUDINAL VERSUS TRANSVERSE FRAMING

- LONGITUDINAL FRAMING IS MORE EFFICIENT STRUCTURALLY, BUT-
- FOR SHIPS WHICH CARRY BREAK-BULK, RO/RO, OR CONTAINER CARGOES THE DEEP WEBS WHICH ARE USED WITH THE LONGITUDINAL FRAMING SYSTEMS INTERFERE WITH CARGO STOWAGE.
- DEEP WEBS ARE NO PROBLEM FOR LIQUID CARGOES AND BULK CARGOES. FOR THIS REASON TANKERS AND BULK CARRIERS ARE LONGITUDINALLY FRAMED.
- COMBINATION FRAMING IS OFTEN USED, LONGITUDINAL FRAMING IN INNER BOTTOM AND DECKS - TRANSVERSE FRAMING IN SIDE SHELL.

THE STRENGTH AND STRUCTURE OF SHIPS

STRUCTURAL TERMINOLOGY

LONGITUDINALS ARE THE LONGITUDINAL STIFFENERS USED IN THE LONGITUDINAL FRAMING SYSTEM TO SUPPORT DECKS, FLATS, INNER BOTTOM, BOTTOM AND SIDE SHELL.

STRINGERS ARE LONGITUDINAL MEMBERS USED TO SUPPORT THE SIDE SHELL FRAMES AND PLATING. THE TERM IS USUALLY USED IN CONNECTION WITH TRANSVERSE SIDE FRAMING.

THE STRINGER PLATE IS THE OUTBOARD STRAKE OF PLATING ON ANY DECK.

THE MARGIN PLATE IS THE OUTBOARD STRAKE OF PLATING IN THE INNER BOTTOM.

THE STRENGTH AND STRUCTURE OF SHIPS

STRUCTURAL TERMINOLOGY

GIRDERS ARE MAIN LONGITUDINAL MEMBERS WHICH SUPPORT DECK BEAMS, DECK STRUCTURE AND BOTTOM.

HATCH-SIDE GIRDERS FORM THE LONGITUDINAL BOUNDARIES OF HATCHES.

SIDE GIRDERS RUN LONGITUDINALLY IN THE INNER BOTTOM.

THE CENTER VERTICAL KEEL (CVK) IS ALSO KNOWN AS THE CENTER GIRDER, THE BOTTOM FLANGE OF THE CVK IS OFTEN HEAVIER THAN ADJACENT BOTTOM PLATING AND IS CALLED THE FLAT PLAT KEEL (FPK)

BEAMS ARE TRANSVERSE STRUCTURAL MEMBERS WHICH SUPPORT AND STIFFEN DECK PLATING

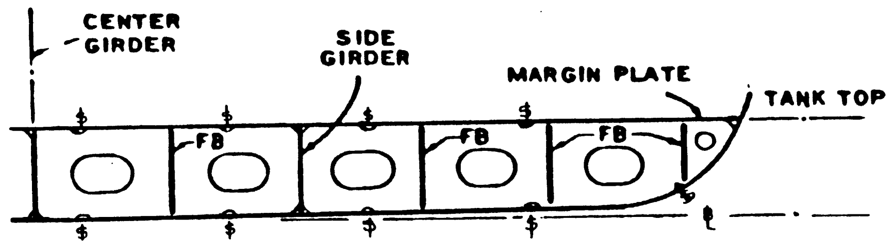
27.6

THE STRENGTH AND STRUCTURE OF SHIPS

STRUCTURAL TERMINOLOGY

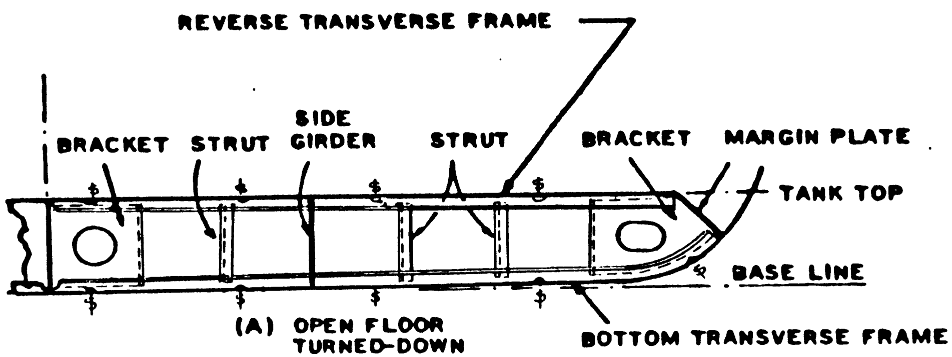
FLOORS ARE TRANSVERSE VERTICAL STRUCTURAL MEMBERS WHICH CONNECT THE BOTTOM SHELL AND THE INNER BOTTOM.

SOLID FLOORS ARE MADE UP OF VERTICAL PLATES (WHICH ARE ONLY "SOLID" IF THE FLOOR IS A WT OR AN OT BOUNDARY).



(B) SOLID FLOOR HORIZONTAL MARGIN

OPEN FLOORS UTILIZE STRUTS FOR VERTICAL MEMBERS



(A) OPEN FLOOR TURNED-DOWN MARGIN

THE STRENGTH AND STRUCTURE OF SHIPS

STRUCTURAL TERMINOLOGY

A KEELSON IS A LONGITUDINAL GIRDER IN SINGLE BOTTOM CONSTRUCTION. THE CENTER KEELSON CORRESPONDS TO THE CVK.

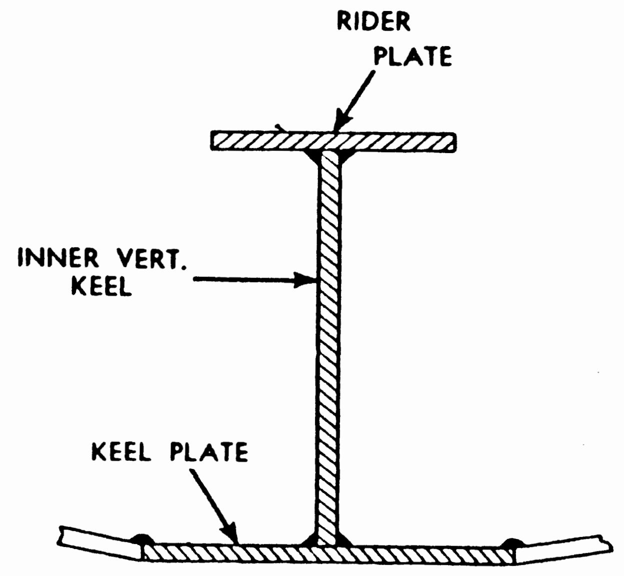
SIDE KEELSONS CORRESPOND TO SIDE GIRDERS.

A RIDER PLATE IS A CONTINUOUS FLAT PLATE ATTACHED TO THE TOP (OR BOTTOM) OF A KEELSON OR A GIRDER

THE BILGE STRAKE IS THE STRAKE OF SHELL PLATING AT THE TURN OF THE BILGE.

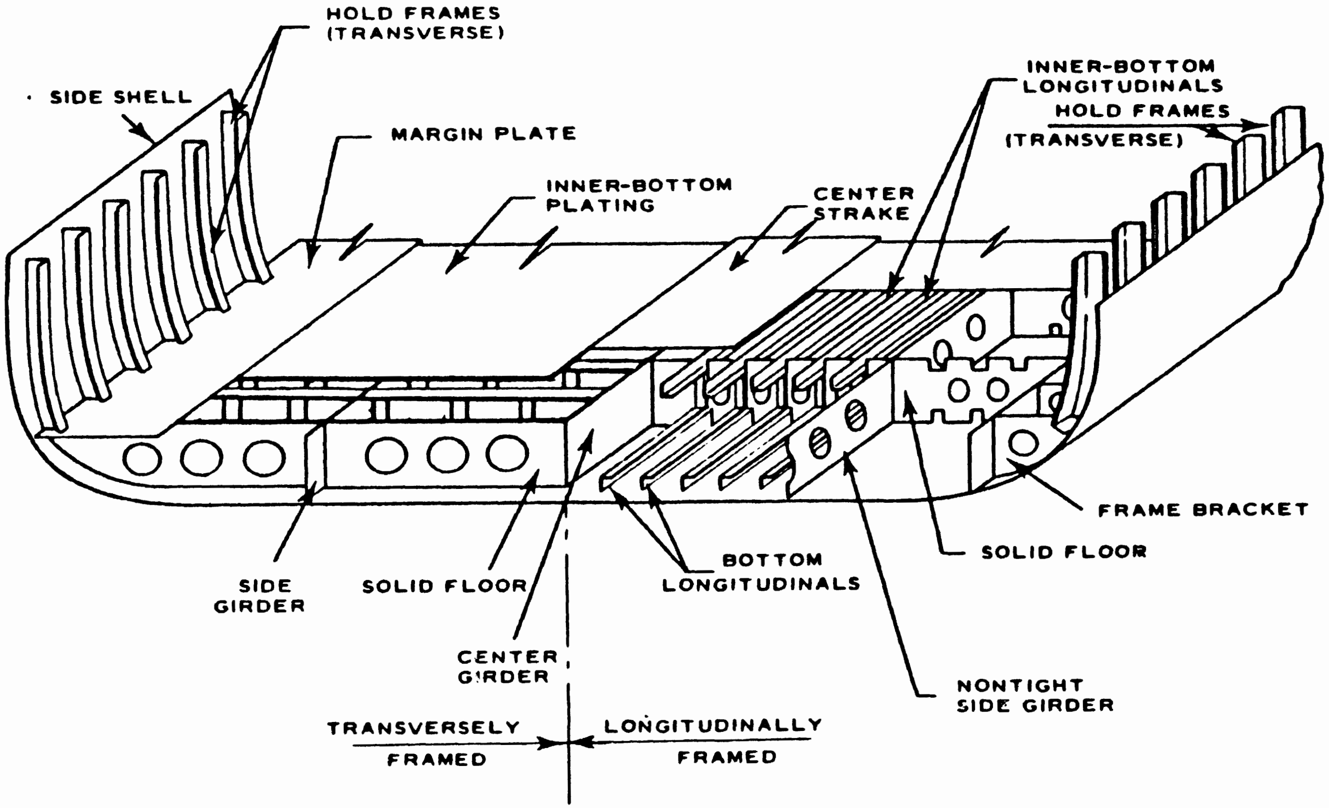
THE SHEER STRAKE IS THE STRAKE OF SHELL PLATING WHOSE UPPER EDGE RUNS AT THE STRENGTH DECK LEVEL

KEEL CONSTRUCTION



THE STRENGTH AND STRUCTURE OF SHIPS

DOUBLE BOTTOM CONSTRUCTION



THE STRENGTH AND STRUCTURE OF SHIPS

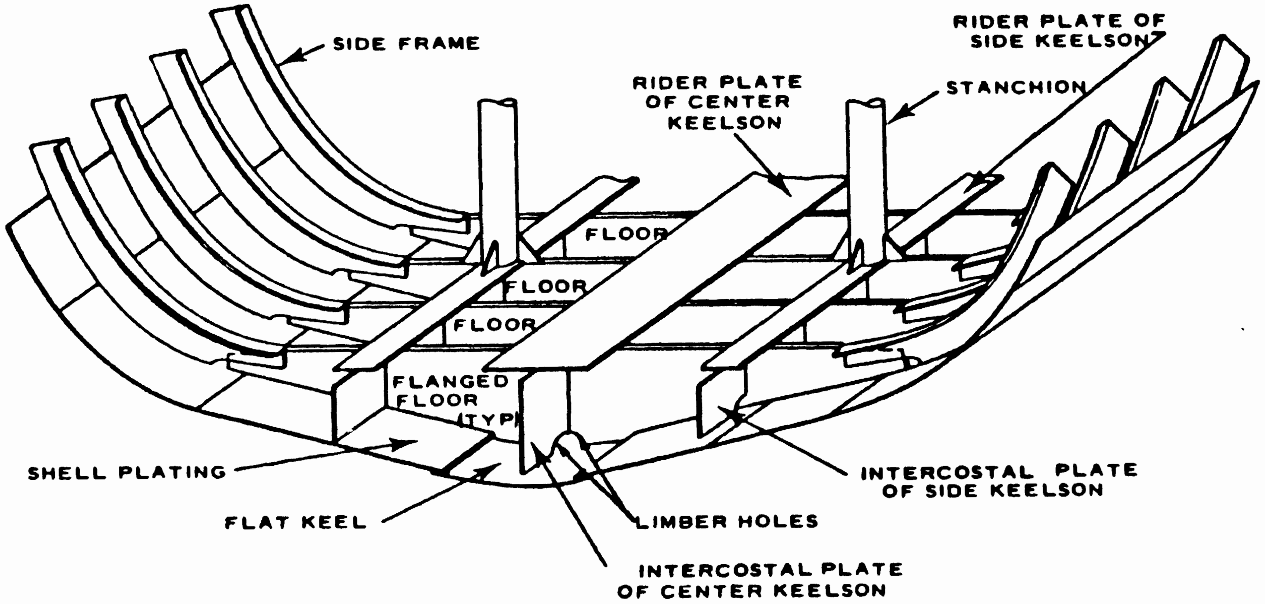
DOUBLE BOTTOM CONSTRUCTION

DOUBLE BOTTOM CONSTRUCTION OFFERS ADVANTAGES OVER SINGLE BOTTOM CONSTRUCTION:

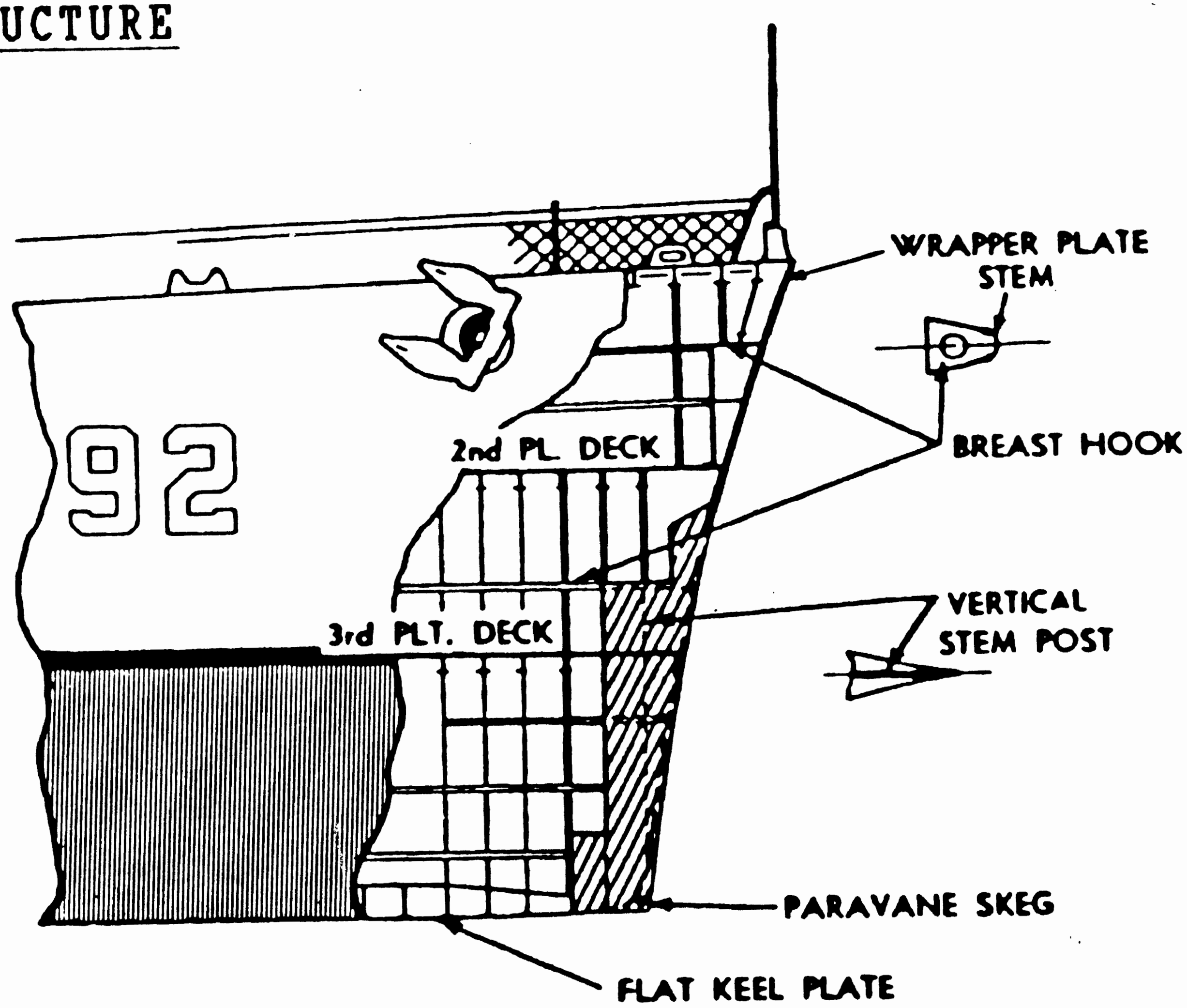
- ADDITIONAL STRENGTH TO RESIST:
  - HULL GIRDER BENDING STRESSES
  - HYDROSTATIC PRESSURES
- PROTECTION FROM FLOODING IN THE EVENT OF BOTTOM DAMAGE.
- PROVIDES TANKAGE FOR THE CARRIAGE OF LIQUIDS.
- INNER BOTTOM PROVIDES SMOOTH SURFACE FOR CARRYING CARGO.

THE STRENGTH AND STRUCTURE OF SHIPS

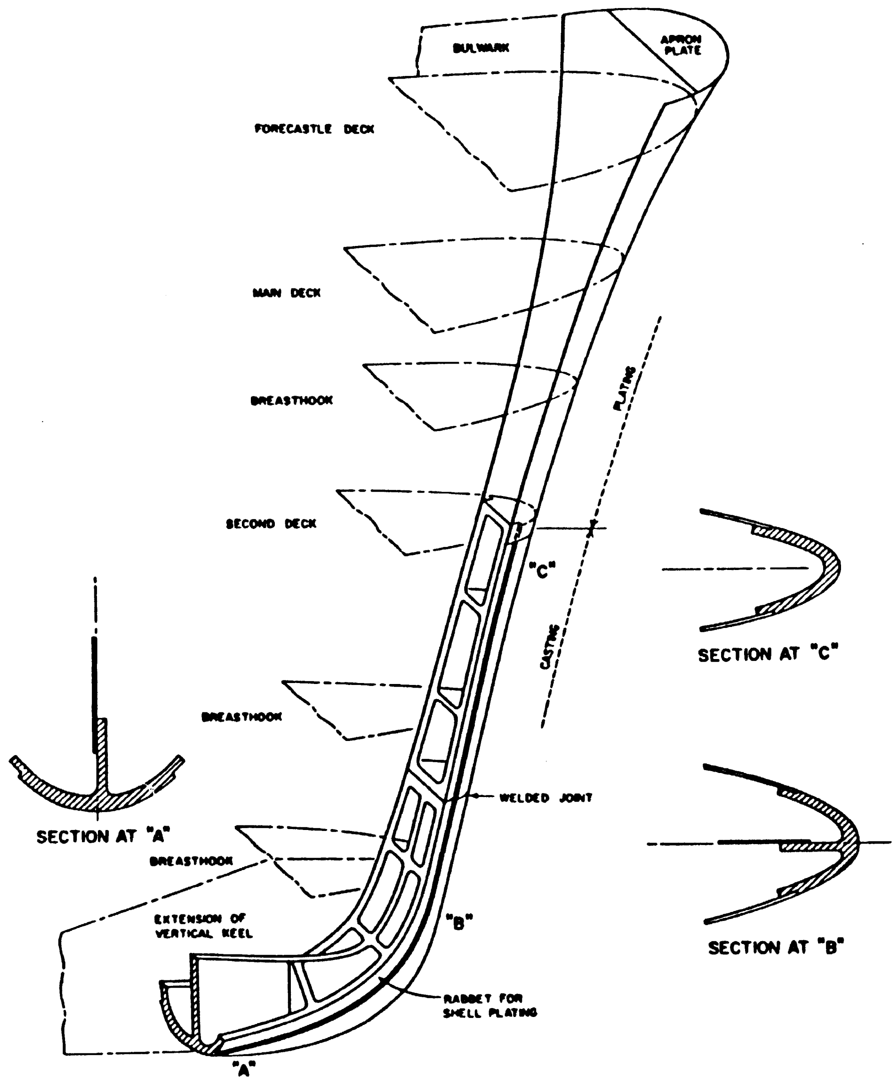
SINGLE BOTTOM CONSTRUCTION (SMALLER SHIPS)



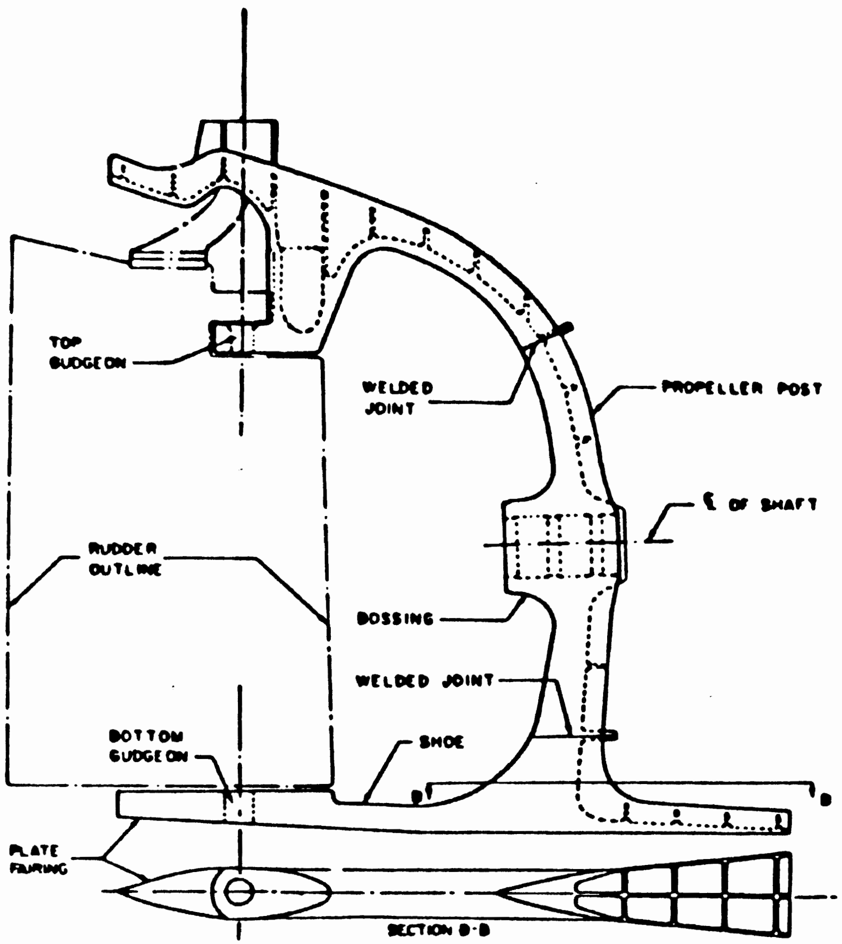
BOW STRUCTURE



BOW STRUCTURE



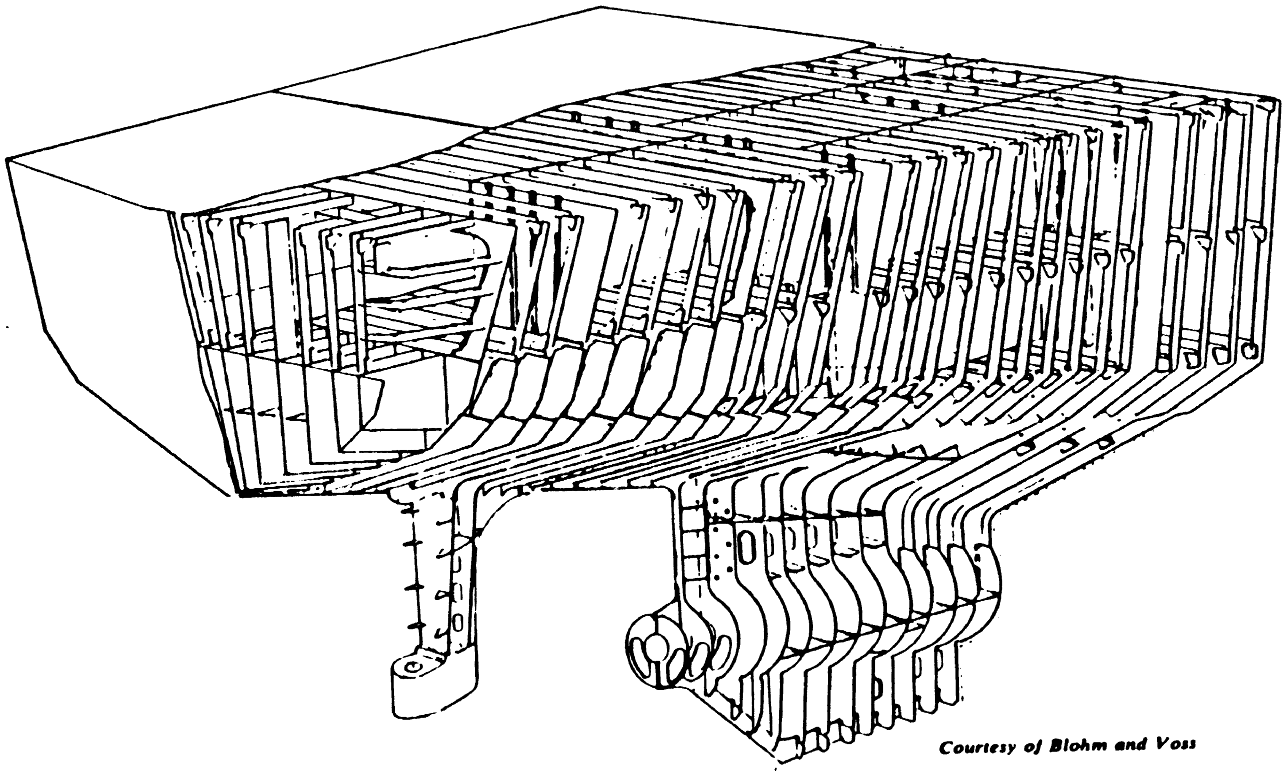
STERN CONSTRUCTION



(B) STERN FRAME FOR BALANCED STREAMLINED TWO-BEARING RUDDER

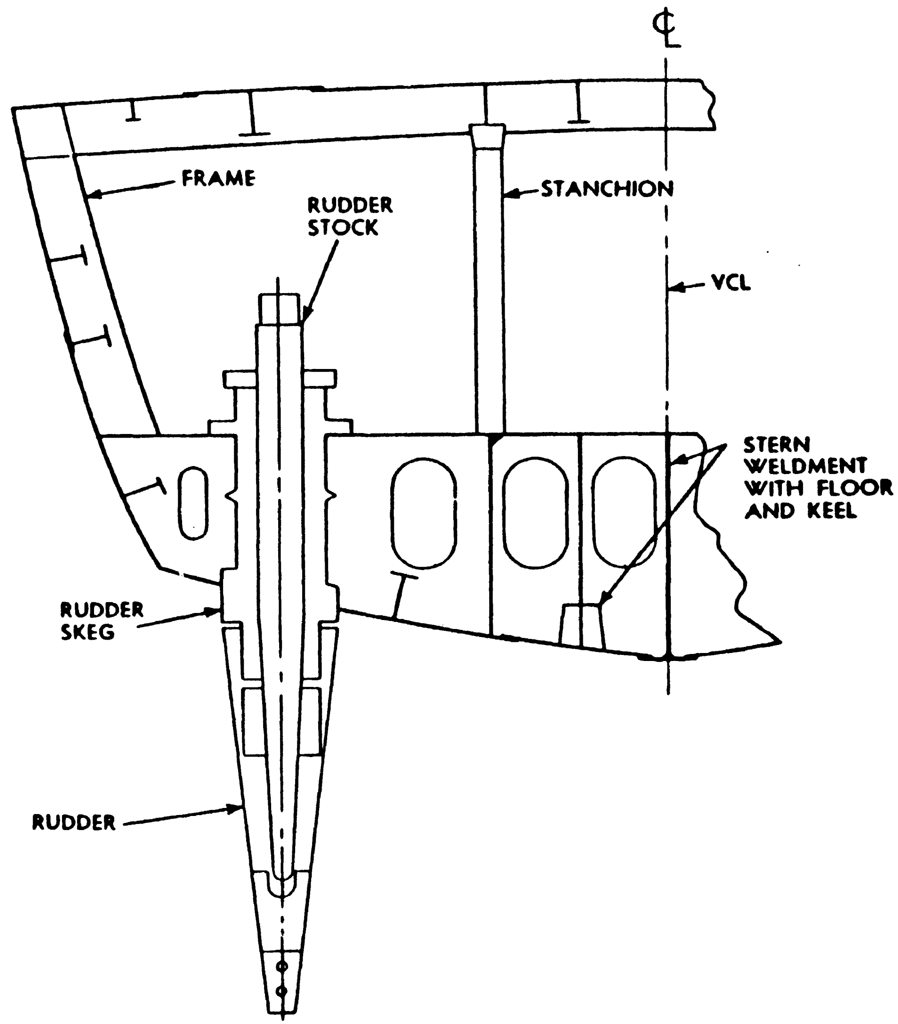
Fig 74 Stern frames of single-screw ships

STERN CONSTRUCTION

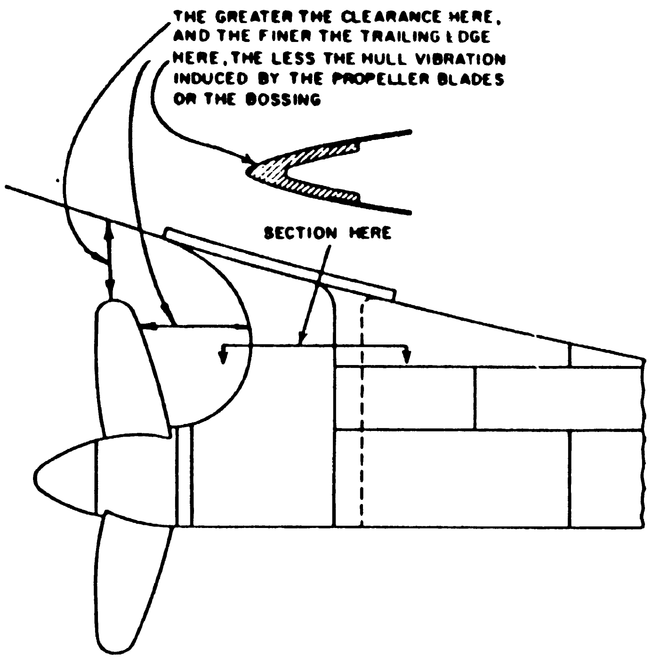


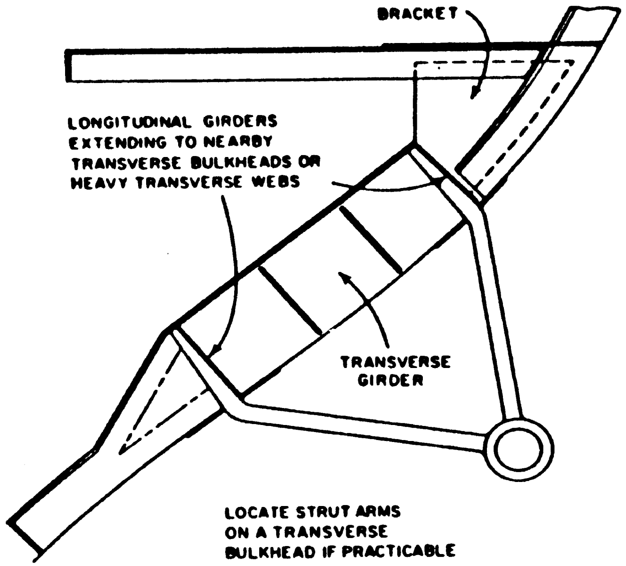
Courtesy of Blohm and Voss

STERN CONSTRUCTION



STERN CONSTRUCTION





32-16

THE STRENGTH AND STRUCTURE OF SHIPS

SHIP STRUCTURAL DETAILS

REFERENCES:

1. SHIP DESIGN AND CONSTRUCTION, SNAME, 1980 CHAPTERS VI,VII,VIII
2. REVIEW OF SHIP STRUCTURAL DETAILS, SHIP STRUCTURE COMMITTEE, 1977 (AVAILABLE THROUGH NTIS, AD- A040941).
3. A GUIDE TO SOUND SHIP STRUCTURES, A.M. ARCANGELO, CORNELL MARITIME PRESS, 1964.
4. DESIGN OF WELDED STRUCTURES, O.W. BLODGETT, LINCOLN ARC WELDING FOUNDATION, 1966.
5. PRACTICAL SHIP BUILDING, PART A, GT. DE R001J, THE TECHNICAL PUBLISHING CO. H. STAM, HAARLEM, HOLLAND.
6. RULES FOR BUILDING AND CLASSING STEEL VESSELS, AMERICAN BUREAU OF SHIPPING, 45 EISENHOWER DRIVE, PARAMUS, N.J. 07653-0910 (ISSUED ANNUALLY)
7. MANUAL OF STEEL CONSTRUCTION, EIGHTH EDITION, AMERICAN INSTITUTE OF STEEL CONSTRUCTION, INC. 400 NORTH MICHIGAN AVENUE, CHICAGO, IL. 60611

BASIC NAVAL ARCHITECTURE

Problem 69

Problem Level: Intermediate

A deck panel has 30" spacing between deck longitudinals. The span between transverse girders is 10'-0". Treating the support provided by the girders as simple supports and considering the properties of the combined plate and stiffener, find the scantlings of the least-weight longitudinal inverted angle stiffeners required to support an 8-foot head of salt water if the allowable bending stress in the flange of the stiffener is 19,000 psi and the deck is 20.4 lb plate.

Note: See appendix to problem set for properties of angles.

Comments: You should find that each of the following angles will satisfy the requirements, so you may confine your calculations to these sections:

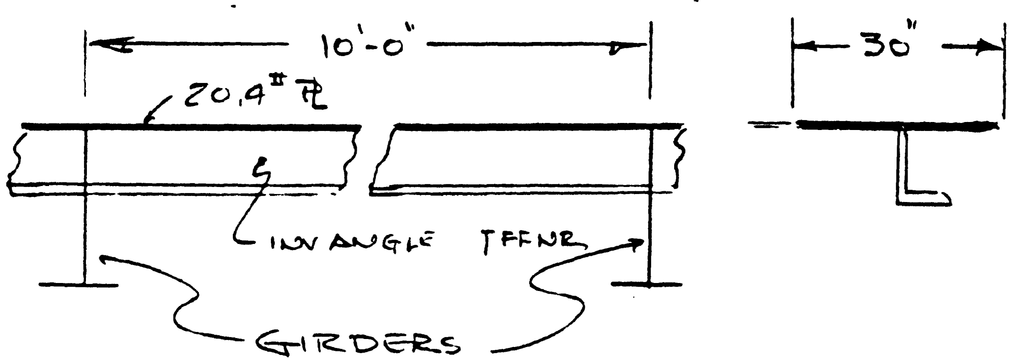
5 x 5 x 3/8

6 x 3½ x 3/8

The point of this problem is to illustrate the procedure by hand calculation; however, there is an easier way. The following publication contains tables of the characteristics of all the combined plates and beams used in shipbuilding:

> MIL-HDBK-264(SH) 30 September 1980, "Properties of Steel Shapes and Plate-Beam Combinations Used in Shipbuilding," Department of Defense, Naval Sea Systems Command.

Having determined the required Section Modules of the plate-beam combination, the candidates can be selected and the least-weight solution determined simply by inspection of the tables.



THE EFFECTIVE BREADTH OF PLATING FOR MILD STEEL IS 60t

FOR 20.4# ℔ WHICH IS 1/2" THICK, 60t = 30" WHICH IS ALSO THE STIFFENER SPACING.

FIRST, FIND THE BENDING MOMENT ACTING ON THE 10'-0" × 30" SPAN UNDER 8-FT HEAD OF SALT WATER. TREAT THE BEAM AS SIMPLY SUPPORTED. (CONSERVATIVE)

FROM BEAM DIAGRAMS IN APPENDIX, CASE NO. 1 - SIMPLE BEAM - UNIFORMLY DISTRIBUTED LOAD.

$$M_{MAX} \text{ AT CENTER} = \frac{wl^2}{8}$$

SALT WATER WEIGHS 64 LBS/FT³. THE WEIGHT PER RUNNING FOOT 2.5 FT WIDE IS:

$$w = 64 \frac{LBS}{FT^3} \times 8\,FT \times 2.5\,FT = 1280\ LBS/FT$$

THE MAXIMUM STRESS IN A STIFFENED PLATE UNDER DECK LOADING WILL ALMOST ALWAYS BE IN THE FLANGE OF THE STIFFENER. UNLESS UNUSUAL CONDITIONS PREVAIL NORMALLY IT IS NOT EVEN NECESSARY TO CALCULATE THE STRESS IN THE PLATE

$$M_{MAX} = \frac{\left(1280 \frac{LBS}{FT}\right)(10.00\,FT)^2}{8}$$

$$M_{MAX} = 16{,}000\ FT\text{-}LBS$$

THE ALLOWABLE STRESS IN THE FLANGE IS GIVEN AS $\sigma_{all} = 19{,}000 \text{ LBS/IN}^2$

SINCE $\sigma = \dfrac{M}{I/c} = \dfrac{M}{S}$, THEN $S = \dfrac{M_{MAX}}{\sigma_{all}}$

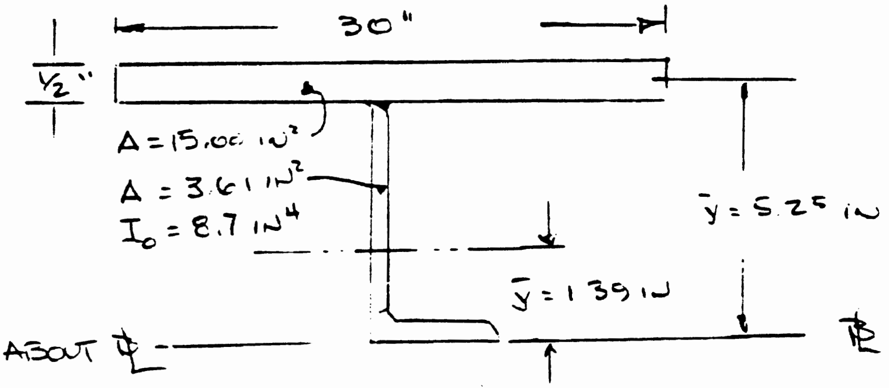
THE REQUIRED SECTION MODULUS OF THE PLATE-BEAM COMBINATION TO THE FLANGE OF THE STIFFENER WILL BE ~

$$S_{req'd} = \frac{(16{,}000 \text{ FT-LBS})(12 \frac{\text{IN}}{\text{FT}})}{19{,}000 \text{ LBS/IN}^2}$$ ← LOOK OUT!

$$S_{req'd} = 10.11 \text{ IN}^3$$

CALCULATE THE SECTION MODULUS OF THE TWO ANGLES GIVEN WHICH IS MOST ECONOMICAL

FIRST, 5×5×3/8 ANGLE. GET AREA, $\bar{y}$, I_o FROM MANUAL OF STEEL CONSTRUCTION



TAKE MOM'T ABOUT ℄

ITEM	SCANTLINE IN×IN×IN	AREA A IN²	LVR $\bar{y}$ IN	MOM'T $A\bar{y}$ IN³	TRANSFER $A\bar{y}^2$ IN⁴	INERTIA I_o IN⁴
PLATE	30 × 1/2	15.00	5.25	78.75	413.4	—
ANGLE	5 × 5 × 3/8	3.61	1.39	5.02	7.0	8.7
COMBO		18.61	4.50	83.77	420.4	8.7

$c_{FLG} = 4.50$

$I_o = 8.7$

$I_{℄} = 429.1 \text{ IN}^4$

TRANSFER TO N.A = $(18.61 \text{ IN}^2)(4.50 \text{ IN})^2$ = 376.9 IN^4

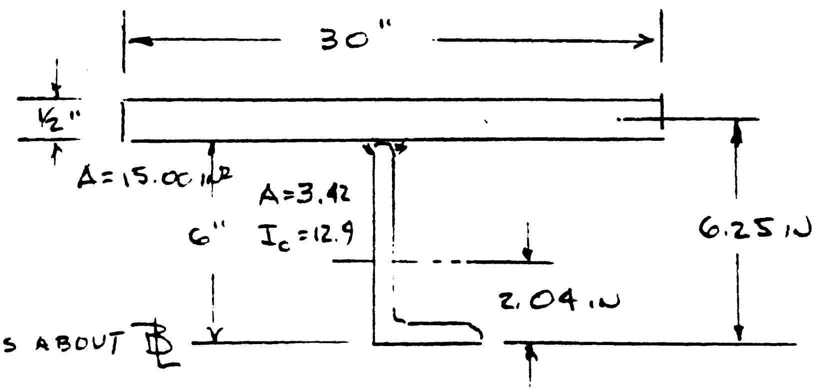
$I_{na} = 52.2 \text{ IN}^4$

$$S = \frac{I}{c_{FLG}} = \frac{52.2 \text{ IN}^4}{4.50 \text{ IN}} = 11.6 \text{ IN}^3$$

THE PLATE WEIGHS 20.4 LBS/FT², THUS THE WEIGHT OF THE PLATE PER RUNNING FOOT $= 2.5\ FT \times 20.4 \frac{LBS}{FT^2} = 51.0 \frac{LBS}{FT}$ HOWEVER THIS WILL BE THE SAME IN BOTH CASES, SO WE CAN MAKE THE COMPARISON SIMPLY ON THE WEIGHT PER FOOT AND SECTION MODULUS OF THE STIFFENER.

FROM THE MANUAL WT/FT OF THE 5×5×3/8 = 12.3 LBS/FT

NEXT THE $6 \times 3\frac{1}{2} \times \frac{3}{8}$



TAK MOM'TS ABOUT ℄

ITEM	SCANTLING IN×IN×IN	AREA A IN²	LVR $\bar{y}$ IN	MOM'T $A\bar{y}$ IN³	TRANSFER $A\bar{y}^2$ IN⁴	INERTIA I_o IN⁴
PLATE	$30 \times \frac{1}{2}$	15.00	6.25	93.75	585.9	—
ANGLE	$6 \times 3\frac{1}{2} \times \frac{3}{8}$	3.42	2.04	6.98	14.2	12.9
COMB'D		18.42	5.47	100.73	600.1	12.9

$C_{FLG} = 5.47$

$$I_{℄} = 613.0\ IN^4$$ (600.1 + 12.9)

TRANSFER TO N.A. $= (18.42\ IN^2)(5.47\ IN)^2 = 551.1\ IN^4$

$$I_{na} = 61.9\ IN^4$$

$$S = I/C_{FLG} = \frac{61.9\ IN^4}{5.47\ IN} = 11.3\ IN^3$$

WEIGHT PER FOOT OF $6 \times 3\frac{1}{2} \times \frac{3}{8}$ = 11.7 LBS/FT.

SINCE THE $6 \times 3\frac{1}{2} \times \frac{3}{8}$ INV. ANGLE STIFFENER MEETS THE REQUIRED SECTION MODULUS AND HAS A LOWER WEIGHT PER FOOT IT WILL BE THE SECTION OF CHOICE.

Unit Number: 38

Title: The strength and structure of ships - 9

Tape Running Time: 34^{M} 12^{S}

Reading Assignment: MSD, pp 228-232

Additional References: SDC, pp 304-337

A Guide to Sound Ship Structures (GSSS), 1964, A.M. Darcangelo, Cornell Maritime Press, pp 3-1 to 3-17

Review of Ship Structural Details (RSSD), 1977, Ship Structure Committee (SSC)

Scope:

Types of bulkheads, their subdivision and structural functions are described. Structural treatment of hatch corners is discussed. Various types of structural details are illustrated. Structural function of foundations is described.

Key Points to Emphasize:

1. Instructor should supplement video graphics with his own transparencies. GSSS is old but still a good source of material on structural detailing. RSSD is also a good source of material. Larger shipyards maintain their own booklets of standard details and, if available, this should be a primary source of material.

2. Presumably many of the students of this course may be very much involved with structural details, either in design or construction. This unit is particularly important for those students. If this is the case, the instructur may wish to spend an additional period on the subject, even at the expense of other material in the course.

3. Throughout, the importance of good design practice and careful workmanship in structural details should be emphasized. Labor content and cost factors of various types of details should be discussed. See RSSD.

4. If Problem 70 is to be assigned, the problem should be introduced and discussed in advance. The instructor may wish to replace the cost factors given with numbers appropriate for his shipyard.

Suggested Problem Assignment: 70

THE STRENGTH AND STRUCTURE OF SHIPS

BULKHEADS

TRANSVERSE STRENGTH BULKHEADS PROVIDE STRENGTH AGAINST TRANSVERSE LOADS FROM HYDROSTATIC PRESSURE, SEAWAY LOADS, AND LOADS FROM CARGO. THEY PROVIDE STIFFNESS TO THE HULL AND CONTRIBUTE TO MAINTAINING THE HULL SHAPE. THERE ARE BASICALLY THREE TYPES:

SUBDIVISION BULKHEADS ARE WATERTIGHT BULKHEADS WHICH LIMIT FLOODING IN THE CASE OF DAMAGE. FOR THIS TYPE OF BULKHEAD THE BULKHEAD AND STIFFENERS ARE DESIGNED IN THE PLASTIC RANGE; THAT IS IN THE EVENT OF FLOODING THE BULKHEAD WILL EXPERIENCE A PERMANENT SET BUT WILL NOT FAIL.

THE STRENGTH AND STRUCTURE OF SHIPS

BULKHEADS

TANK BOUNDARIES ARE SUBJECTED TO REPEATED LOADS AS THE TANK IS EMPTIED AND FILLED. THESE BULKHEADS ARE DESIGNED IN THE ELASTIC RANGE.

MISCELLANEOUS NON-TIGHT BULKHEADS ARE USED FOR A VARIETY OF ARRANGEMENT PURPOSES. THEY MAY BE STRUCTURAL BULKHEADS IN WHICH CASE THEY CONTRIBUTE TO THE TRANSVERSE STRENGTH OF THE SHIP, OR THEY MAY BE NON-STRUCTURAL BULKHEADS IN WHICH CASE THEY SERVE A LOCAL PURPOSE.

LONGITUDINAL BULKHEADS CONTRIBUTE TO THE LONGITUDINAL STRENGTH OF THE SHIP IF THEY ARE CONTINUOUS, EFFECTIVE, AND RUN THROUGH THE MIDSHIP HALF-LENGTH.

BULKHEADS

WATERTIGHT BULKHEADS REQUIRED BY ABS

1. A WATERTIGHT COLLISION BULKHEAD IS FITTED ON ALL VESSELS BETWEEN .05L AND .08L AFT OF THE F.P. AND FOR THE FULL DEPTH OF THE VESSEL AT THAT POINT. EXCEPT FOR PIPE PENETRATIONS NO OPENINGS ARE PERMITTED IN THIS BULKHEAD. THERE ARE SPECIAL LOCATION REQUIREMENTS FOR VESSELS OVER 656-FT, VESSELS WITH BULBOUS BOWS, AND PASSENGER VESSELS.

2. AN AFTER-PEAK BULKHEAD IS REQUIRED SO AS TO INCLUDE THE SHAFT TUBES IN A WATERTIGHT COMPARTMENT.

5-36

THE STRENGTH AND STRUCTURE OF SHIPS

BULKHEADS

WATERTIGHT BULKHEADS REQUIRED BY ABS

3. MACHINERY SPACES ARE TO BE ENCLOSED BY WATERTIGHT BULKHEADS.

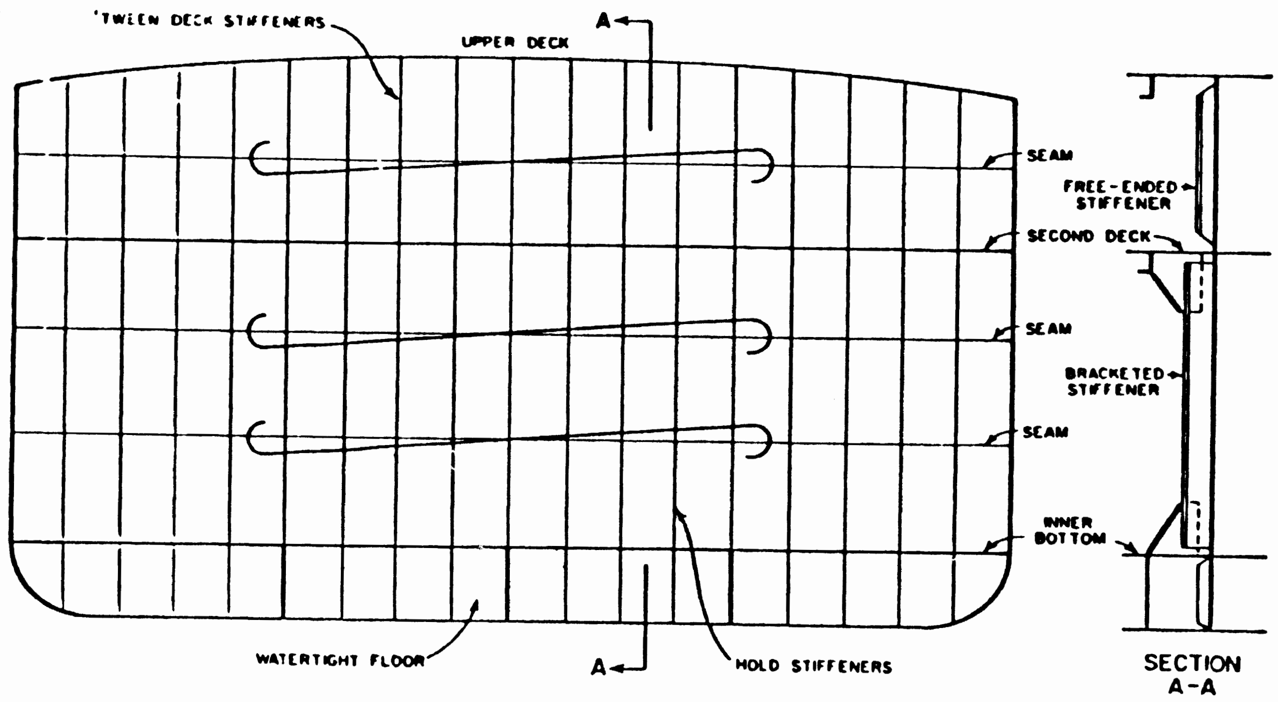
4. WATERTIGHT BULKHEADS ARE ALSO REQUIRED BETWEEN THE BULKHEADS IDENTIFIED ABOVE. THE NUMBER AND LOCATION DEPENDS ON SHIP LENGTH AND MACHINERY LOCATION.

5. A SHAFT TUNNEL IS A WATERTIGHT TUNNEL WHICH IS FITTED AROUND THE ENTIRE SHAFT BETWEEN THE ENGINE ROOM AND THE STUFFING BOX AT THE STERN. ITS PURPOSE IS TO CONTAIN FLOODING IN THE EVENT OF DAMAGE TO THE TAIL SHAFT OR THE STERN TUBE.

THE STRENGTH AND STRUCTURE OF SHIPS

BULKHEADS

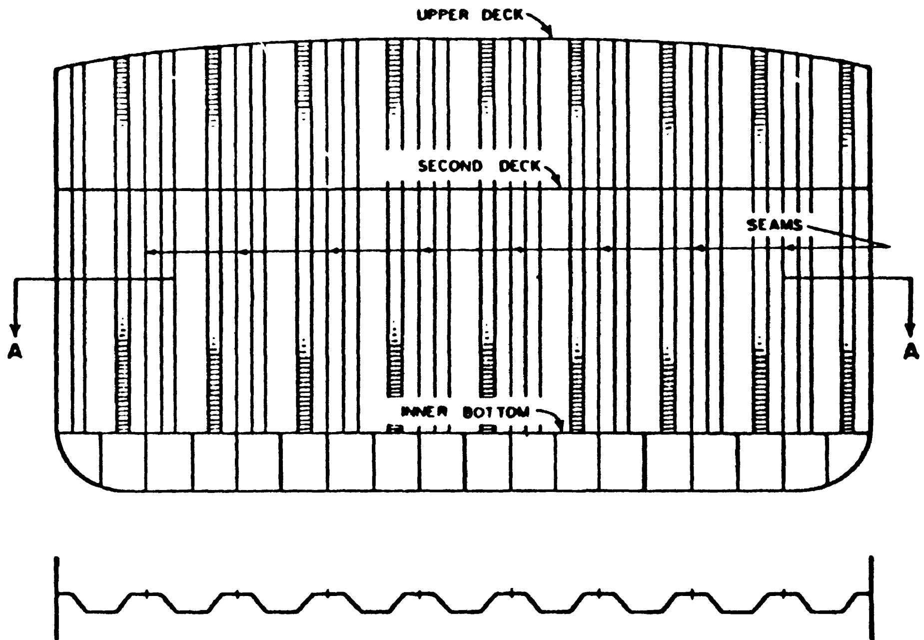
FLAT BULKHEADS WITH VERTICAL STIFFENERS



THE STRENGTH AND STRUCTURE OF SHIPS

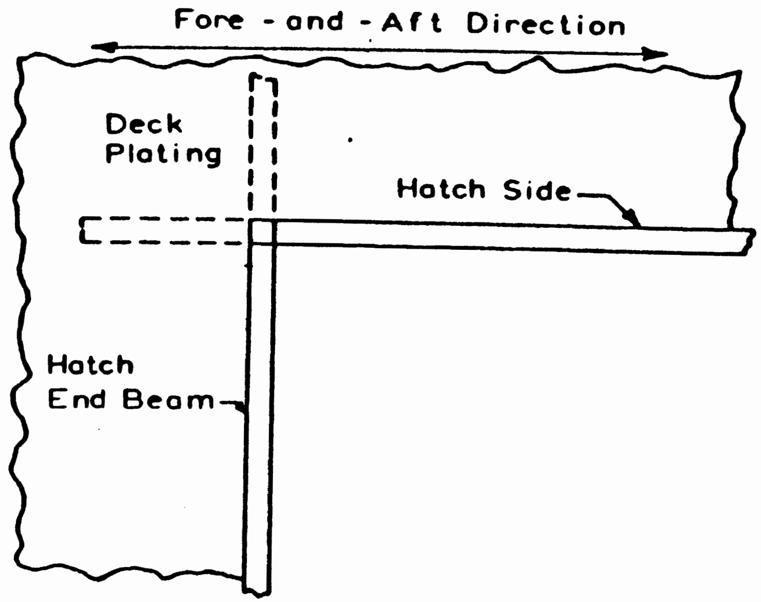
BULKHEADS

CORRUGATED BULKHEADS



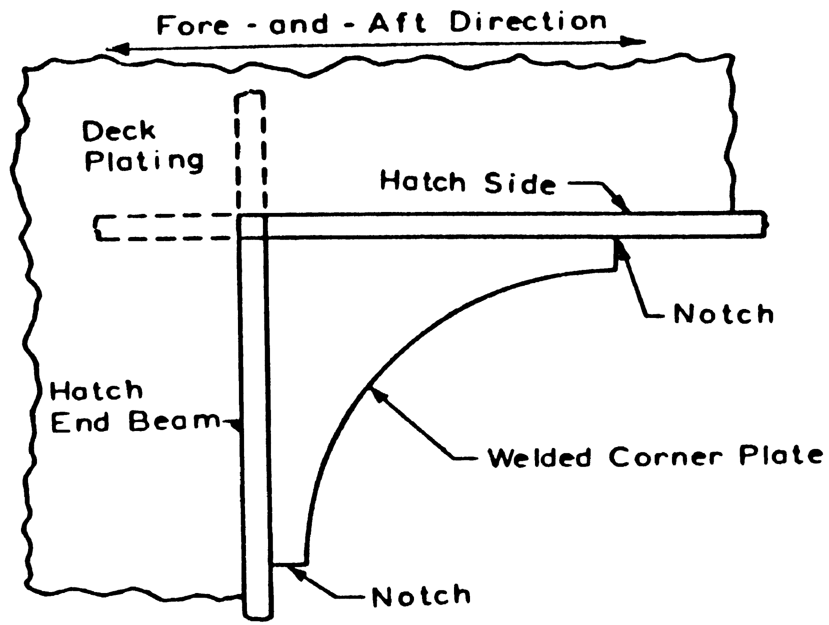
SECTION A-A

HATCH CORNERS



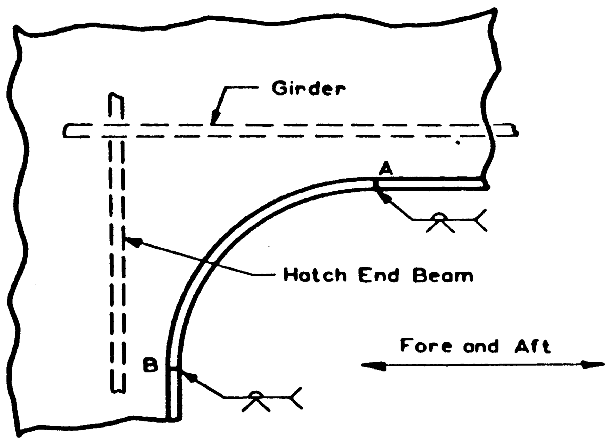
a) Very unsatisfactory welded hatch corner detail. Hatch opening with square cut corner.

HATCH CORNERS

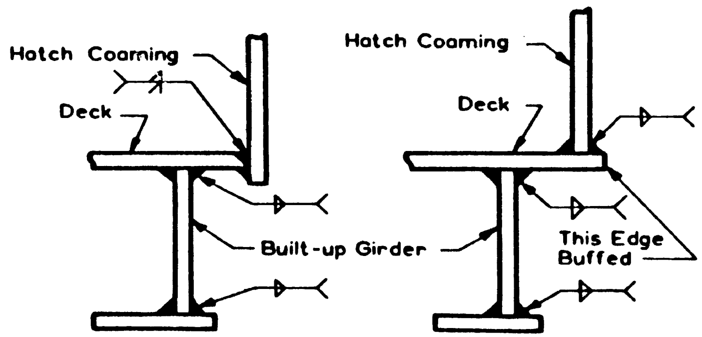


b) Unsatisfactory welded corner detail. Hatch opening with square corner and welded corner plate.

HATCH CORNERS



a) Plan view of hatch corner.



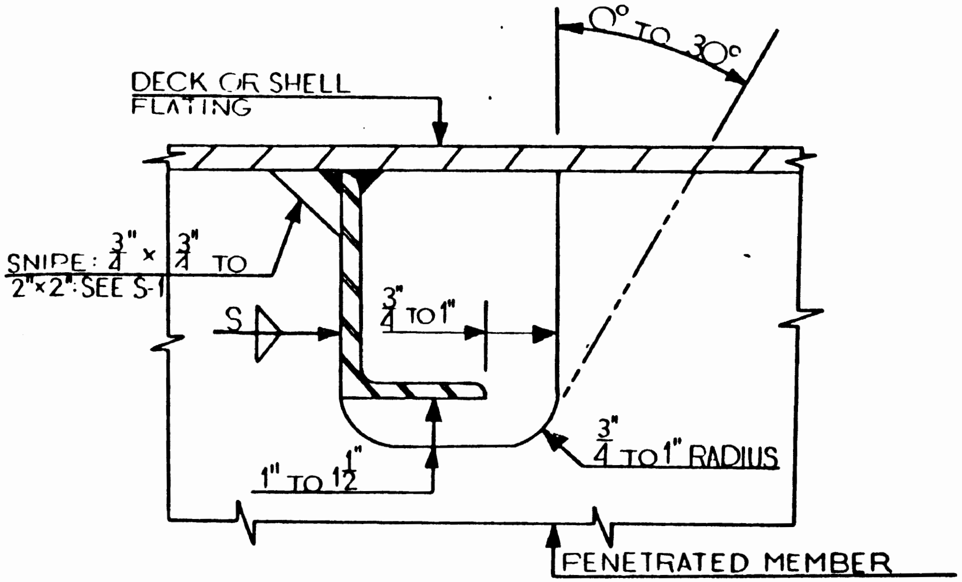
b) Typical section.   c) Alternate typical section.

THE STRENGTH AND STRUCTURE OF SHIPS

INTERSECTIONS OF LONGITUDINALS AND TRANSVERSES

CONTINUOUS LONGITUDINALS PENETRATING TRANSVERSE FLOORS, WEBS OR BULKHEADS

CLEARANCE CUT FOR LONGTITUDINAL

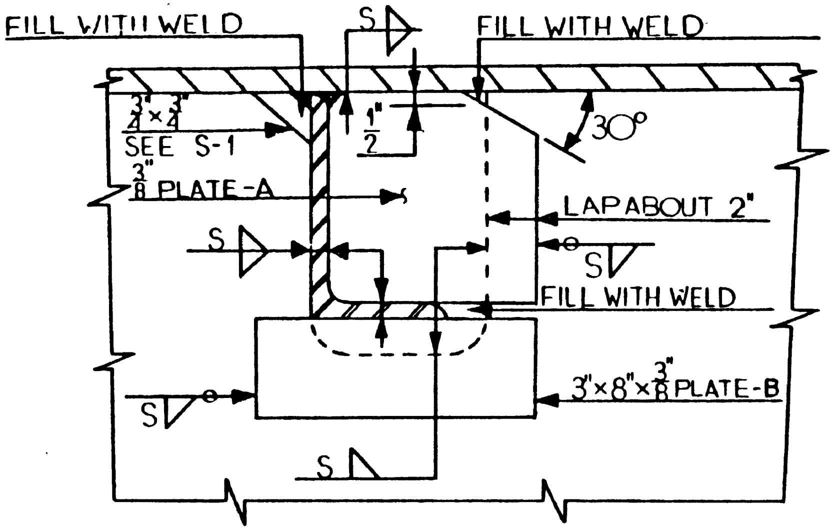


38/11

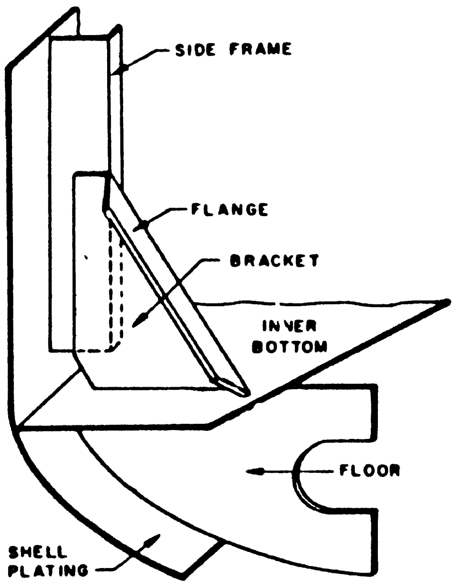
INTERSECTIONS OF LONGITUDINALS AND TRANSVERSES

CONTINUOUS LONGITUDINALS PENETRATING TRANSVERSE FLOORS, WEBS OR BULKHEADS

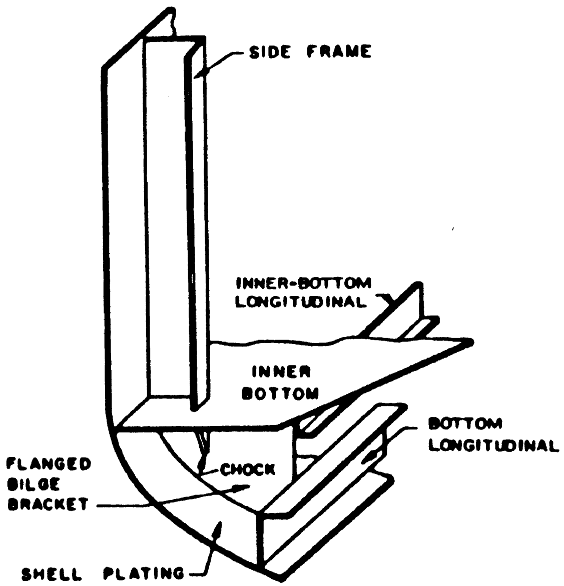
LONGITUDINAL WITH LAPPED TIGHT COLLAR



BILGE CONNECTIONS



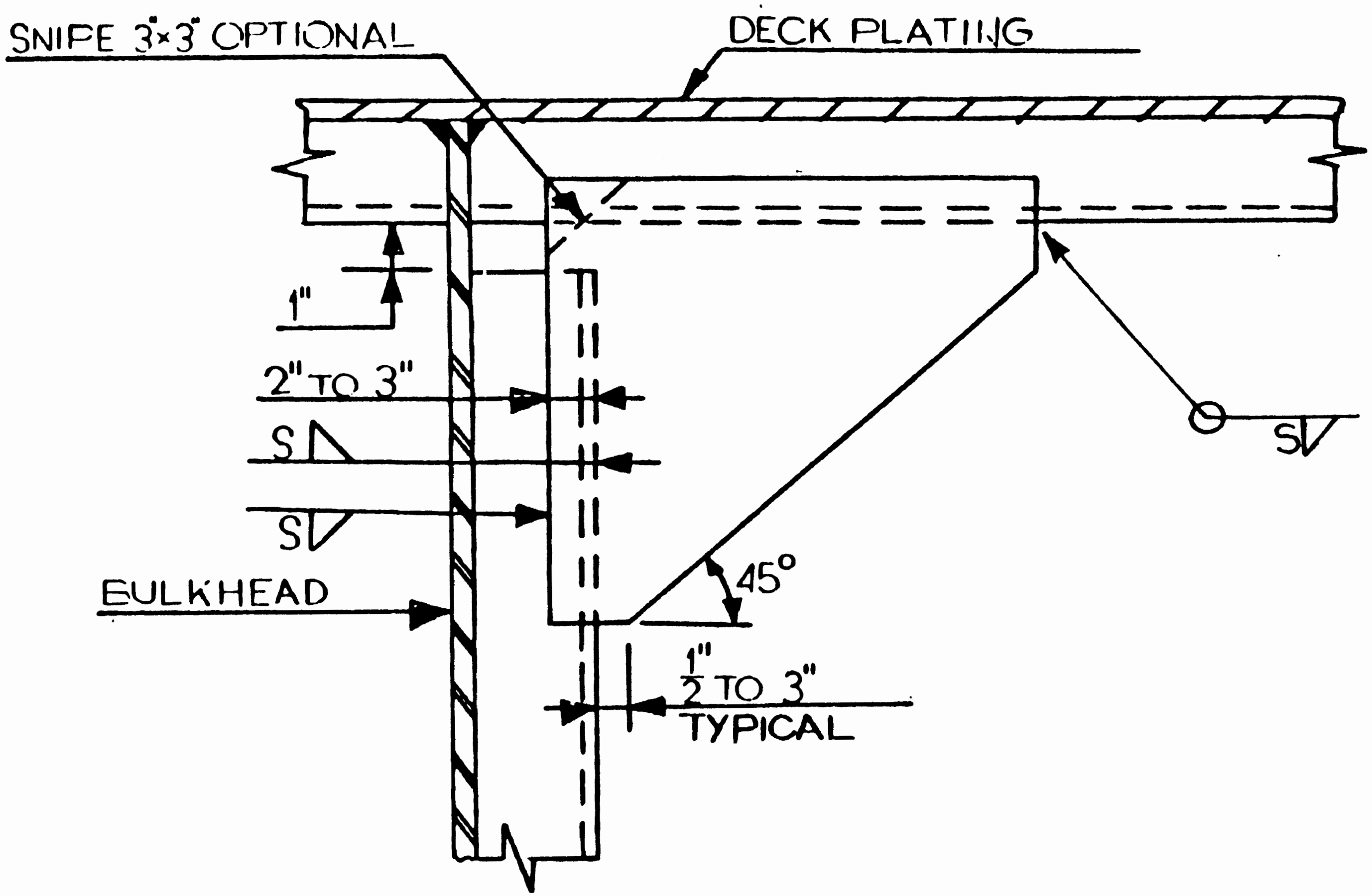
(A) HOLD FRAME BRACKET



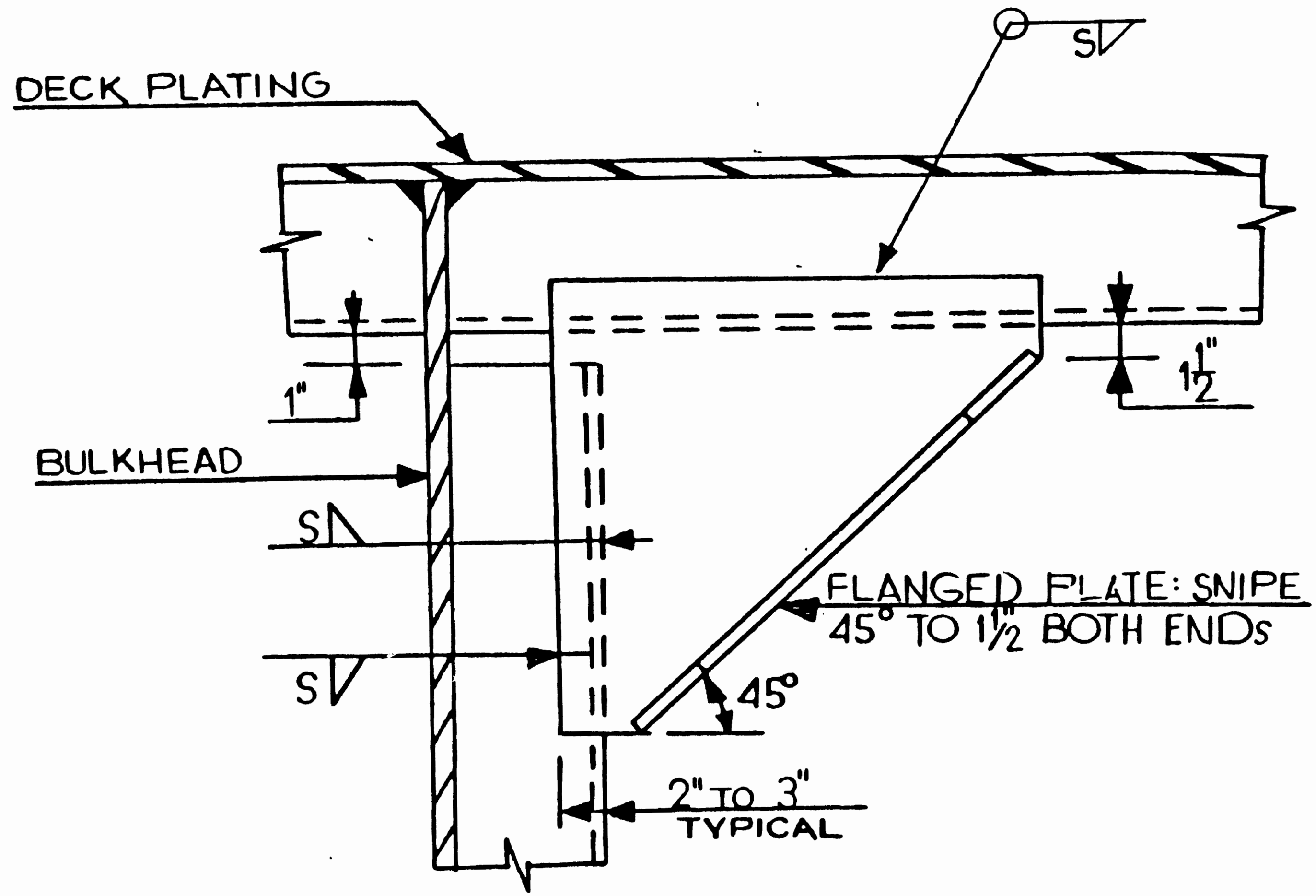
(B) BILGE BRACKET

36.13

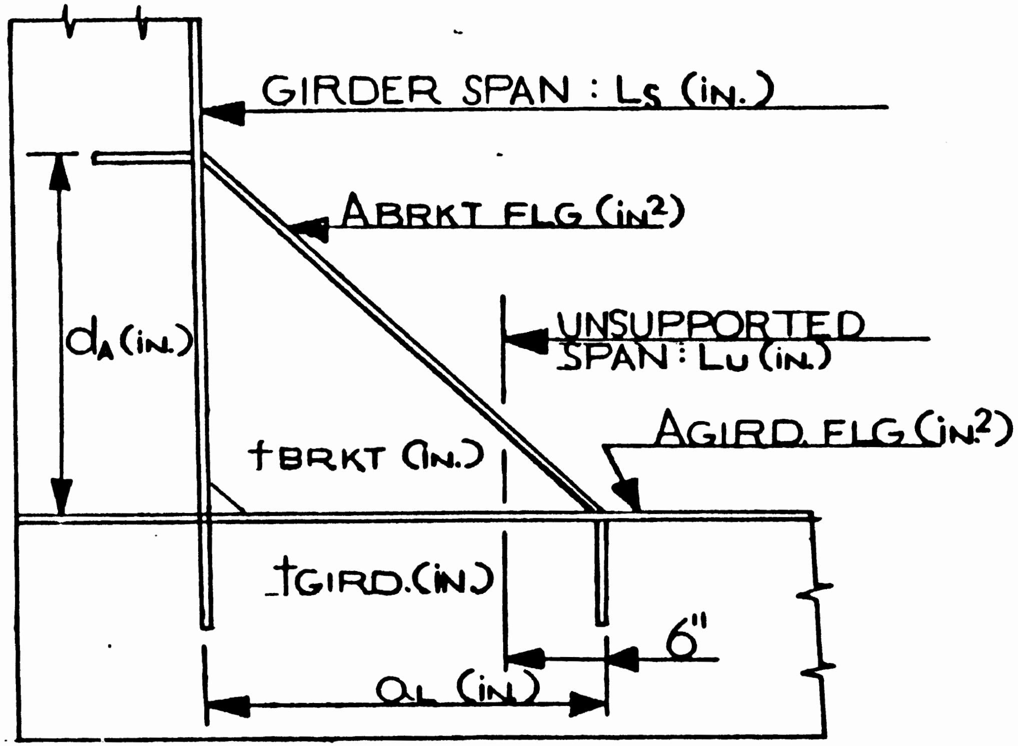
BRACKETS


SNIPE 3"×3" OPTIONAL
DECK PLATING
1"
2" TO 3"
S
S
BULKHEAD
45°
½" TO 3"
TYPICAL
S

BRACKETS


DECK PLATING
BULKHEAD
S
S
S
1"
1½"
FLANGED PLATE: SNIPE
45° TO 1½" BOTH ENDS
45°
2" TO 3"
TYPICAL

BRACKETS



$A_{BRKT\ FLG} \geqq (A_{GIRD\ FLG}) \div 2$ in^2

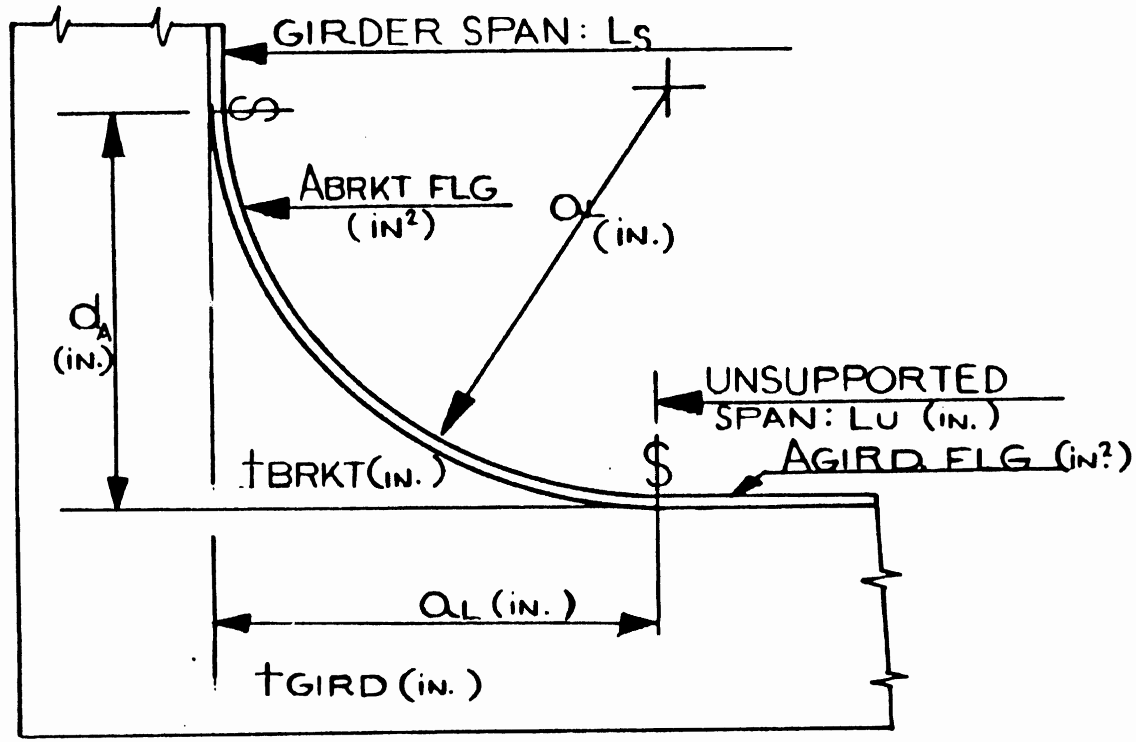
$t_{BRKT} \geqq t_{GIRD.}$ in.

$a_L \leqq 1.5\, d_A$ in.

$a_L \leqq L_S/4$ in.

$L_U = L_S - 2(6 - a_L)$ in.

BRACKETS



$A_{BRKT\,FLG} = A_{GIRD\,FLG}$ in.^{2}

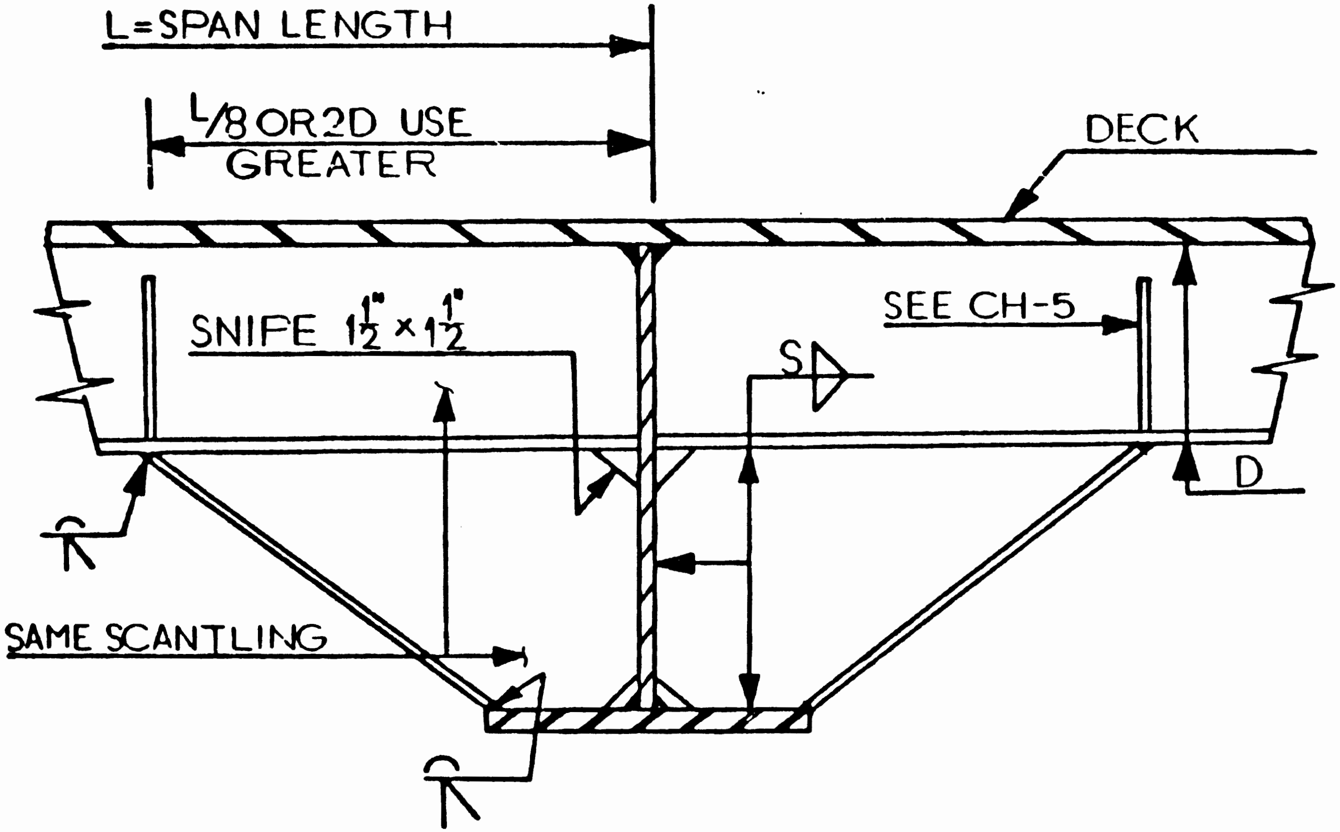
$t_{BRKT} \geqq t_{GIRD}$ in.

$a_L \leqq 1.5 d_A$ in.

$a_L \leqq L_S/4$ in.

$L_U = L_S - 2a_L$ in.

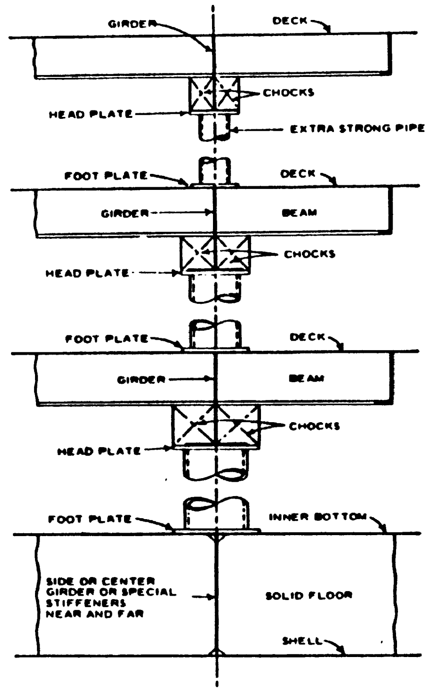
BRACKETS


L=SPAN LENGTH
L/8 OR 2D USE GREATER
DECK
SNIPE 1½" x 1½"
SEE CH-5
S
D
SAME SCANTLING

THE STRENGTH AND STRUCTURE OF SHIPS

PILLARS AND STANCHIONS

THE TERMS ARE OFTEN USED INTERCHANGEABLY, BUT GENERALLY A PILLAR IS A HEAVIER VERTICAL COLUMN SUPPORTING MAIN LONGITUDINAL GIRDERS AND DEEP TRANSVERSE BEAMS. STANCHIONS ARE LIGHTER VERTICAL COLUMNS WHICH PROVIDE LOCAL SUPPORT.



38.19

SUPERSTRUCTURES

LONG SUPERSTRUCTURES AMIDSHIPS, SAY IN EXCESS OF 10% OF THE SHIP'S LENGTH, WILL ACT AS PART OF THE HULL GIRDER IN ABSORBING HULL GIRDER BENDING.

SUCH SUPERSTRUCTURES ARE DESIGNED SO THAT THE LONGITUDINAL SCANTLINGS WILL GIVE A HULL-GIRDER SECTION MODULUS EQUAL TO THAT IN OTHER PARTS OF THE MAIN HULL GIRDER.

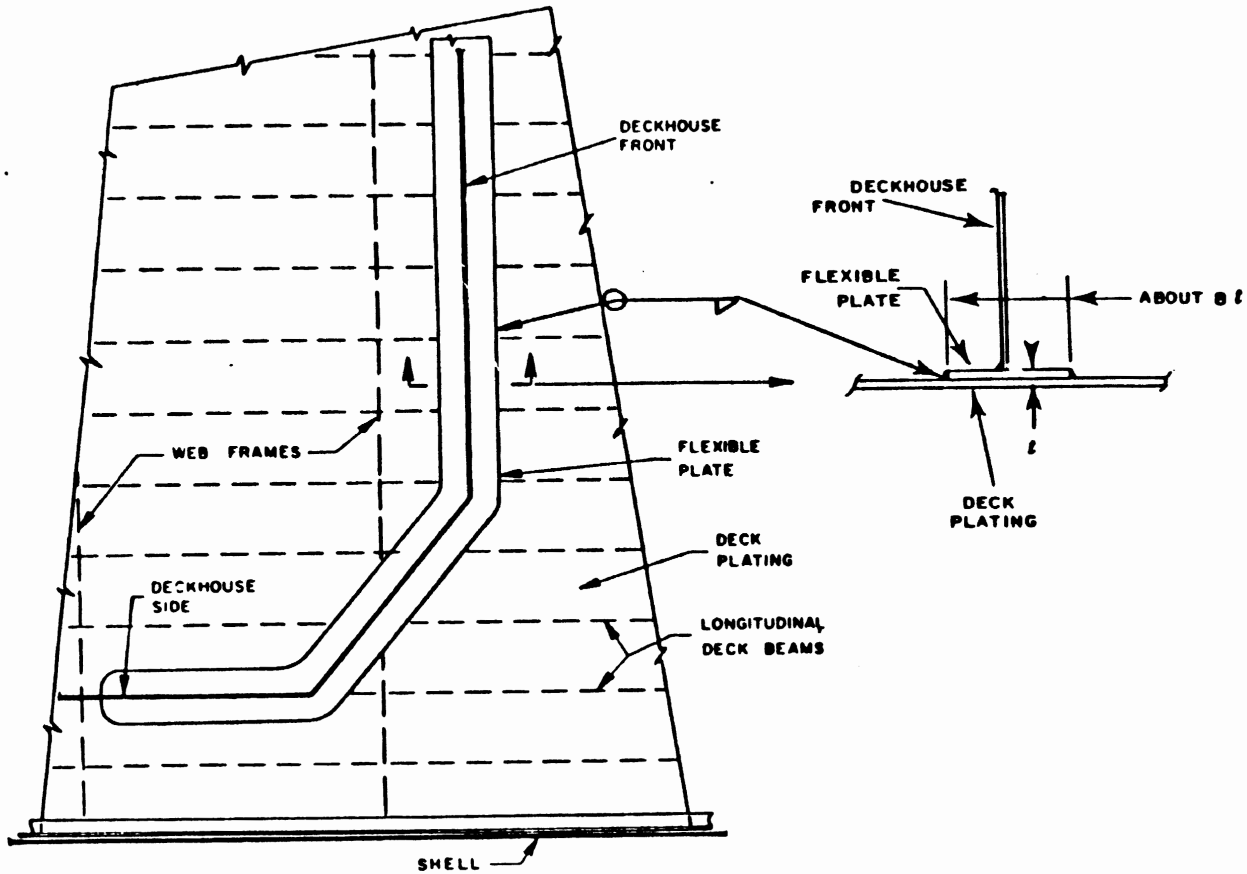
IN THE PAST EXPANSION JOINTS HAVE BEEN USED IN LONG DECKHOUSES TO RELIEVE THE HOUSE OF LONGITUDINAL HULL-GIRDER BENDING STRESS. EXPANSION JOINTS CAN ALSO BE TROUBLE SPOTS AND ARE NOT FOUND FREQUENTLY IN MODERN CONSTRUCTION.

SPECIAL CARE IS REQUIRED IN DESIGNING THE LANDINGS OF THE DECK HOUSE ON THE MAIN DECK.

32-2C

THE STRENGTH AND STRUCTURE OF SHIPS

DECKHOUSES

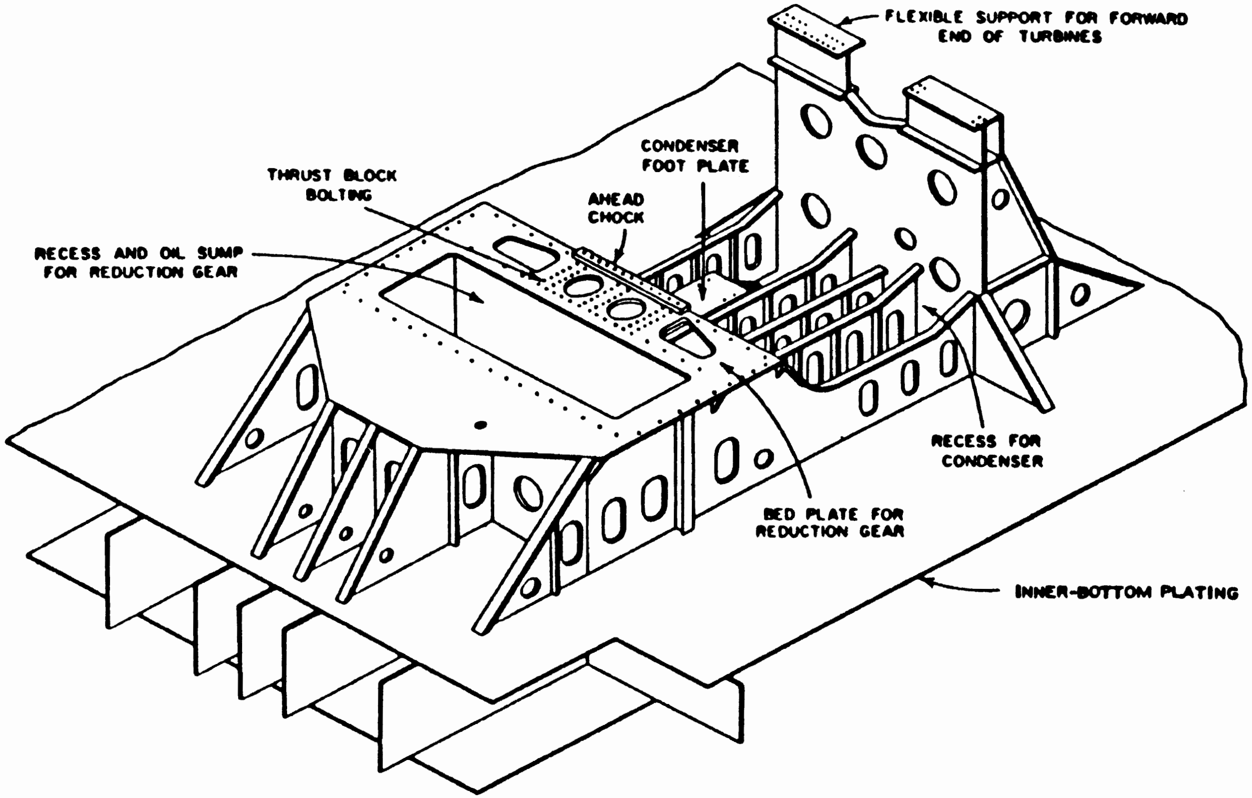


12.8.91

THE STRENGTH AND STRUCTURE OF SHIPS

FOUNDATIONS

STEAM TURBINE, CONDENSER, REDUCTION GEAR

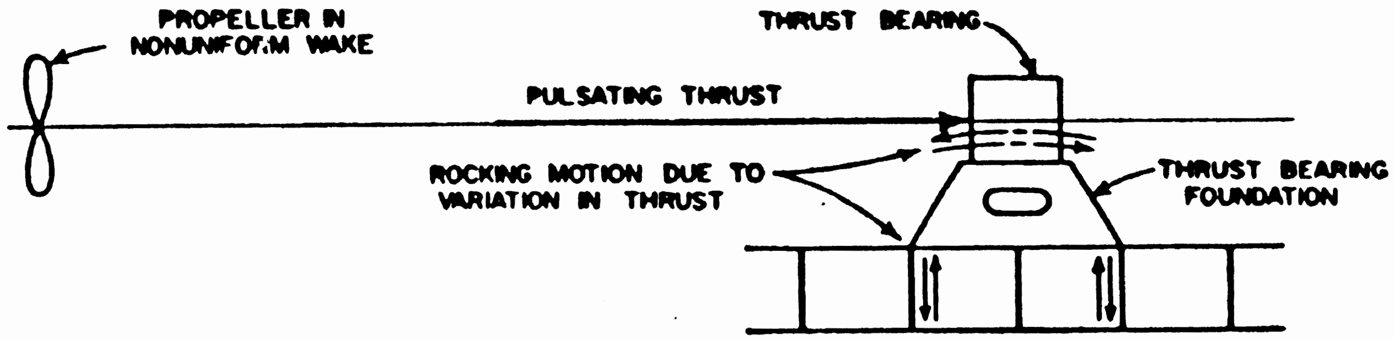


36.37

THE STRENGTH AND STRUCTURE OF SHIPS

FOUNDATIONS

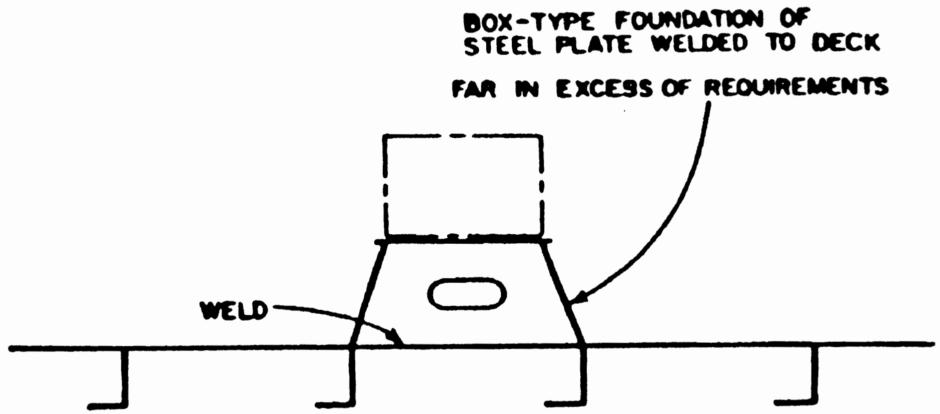
THRUST BEARING



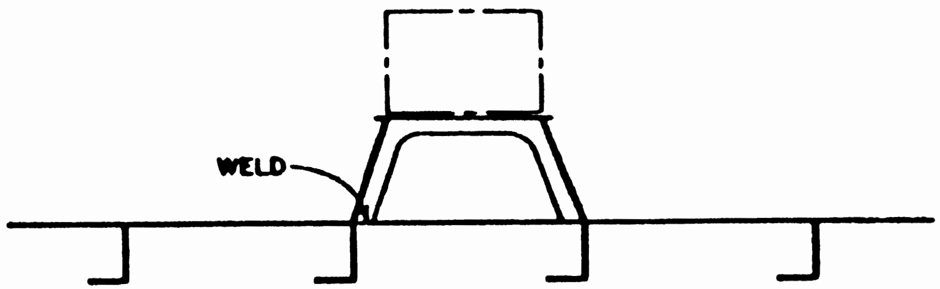
THE STRENGTH AND STRUCTURE OF SHIPS

FOUNDATIONS

SMALL EQUIPMENT



(A)



(B)

Problem 70

Problem Level: Advanced

The purpose of this problem is to compare the costs of various types of stiffeners. The student should note that cost factors used will vary from shipyard to shipyard and from year to year, but the important features to observe from this problem are the sensitivity of the results to the various factors..

A stiffened panel requires stiffeners with a minimum Section Modulus of 8.7 in^3 (stiffener only). Identify the least-weight candidates for each of the following type stiffeners:

Inverted angle

Standard tee

W-T

Flanged plate

Built-up tee

Results of previous problems may be used.

Estimate the cost per foot of each of the above sections using the following cost data:

Cost of mild steel plate	\$0.23 per lb
Cost of mild steel W and L shapes	0.26 per lb
Cost of mild steel standard tees	0.27 per lb
Credit for scrap	0.01 per lb
Cutting: plates using 4-head burner (4 simultaneous cuts) 20-ft plate, 26 min labor, overhead and equipment usage	50.00 per hr
Cutting: flange removal using 4-head burner (4 simultaneous cuts), two 20-ft W sections to be cut to T, 26 min plus 10 minutes setup, labor, overhead, and equipment usage	50.00 per hr
Bending: Bend flange on one 20-ft plate. Labor, overhead, and equipment usage.	36.00 per hr
Welding: machine welding using GMAW welder. For built-up tees weld both sides of web to flange simultaneously. Labor, overhead, and equipment usage.	50.00 per hr

Problem 70 (continued)

Use the following cost factors:

Cost of mild steel plate	$0.23 per lb
Cost of mild steel W and L shapes	0.26 per lb
Cost of mild steel standard tees	0.27 per lb
Flange removal: burning time for each cut: labor (1 man & equipment)	1.3 ft/min
Flange bending: time required for one flange on a 20-ft length of plate (2 men & equipment)	10 min
Welding: (1 man & equipment)	2.5 ft/min

SOLUTION

INVERTED ANGLE

USING A LIST OF STANDARD SHAPES AND SEARCHING FOR ANGLES WITH A SECTION MODULUS ≥ 8.7 IN^3, THE LEAST WEIGHT ANGLE IS AN 8 x 4 x 5/8

WEIGHT = 24.2 lb/FT

SM = 9.21 IN^3

COST = (24.2 lb/FT)($0.26/lb)

COST = $6.29/FT

STANDARD TEE

USING A LIST OF SHAPES AS ABOVE, THE OPTIMAL SHAPE IS AN ST9 x 27.35

WEIGHT = 27.35 lb/FT

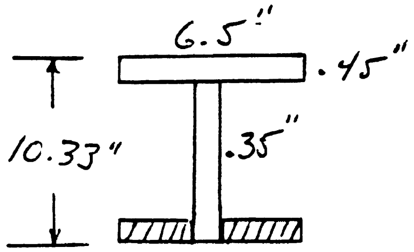
SM = 9.61 IN^3

COST = (27.35 lb/FT)($0.27/lb)

COST = $7.38/FT

W-T

THIS INVOLVES PURCHASING A W SECTION AND CUTTING IT TO A T SECTION. THE OPTIMAL SECTION FROM A LIST OF SHAPES IS A WT10.5 x 22. THE SECTION DIMENSIONS ARE AS FOLLOWS:



$$\text{VOLUME} = [(6.5'')(2)(.45'') + (10.33 - .9'')(.35'')](12'')$$
$$= 109.81 \text{ IN}^3$$

$$\text{MAT'L COSTS} = (109.81 \text{ IN}^3)(.286 \tfrac{\text{lb}}{\text{IN}^3})(\$.26/\text{lb})$$
$$\text{MAT'L COSTS} = \$8.16/\text{FT}$$

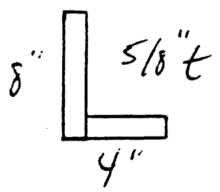
$$\text{CUTTING COSTS} = (36 \text{ min})(\tfrac{1 \text{ hr}}{60 \text{ min}})(\$50/\text{hr})(\tfrac{1}{40 \text{ FT}})$$
$$\text{CUTTING COSTS} = \$0.75/\text{FT}$$

$$\text{SCRAP CREDIT} = (6.5 - .35'')(12'')(.45'')(.286 \tfrac{\text{lb}}{\text{IN}^3})(\$.01/\text{lb})$$
$$\text{CREDIT} = \$0.1/\text{FT}$$

<u>TOTAL COSTS = $8.81/FT</u>

FLANGED PLATE

USE SAME DIMENSIONS AS INVERTED ANGLE FOR MODULUS PURPOSES.



$$\text{WEIGHT} = (11\tfrac{3}{8}'')(12'')(\tfrac{5}{8}'')(.286 \tfrac{\text{lb}}{\text{IN}^3})$$
$$\text{WEIGHT} = 24.4 \text{ lbs}$$

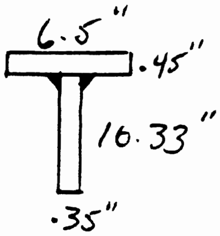
$$\text{MAT'L COST} = (24.4 \text{ lbs})(\$.23/\text{lb})$$
$$\text{MAT'L COST} = \$5.61/\text{FT}$$

$$\text{BENDING COSTS} = (10 \text{ min})(\tfrac{1 \text{ hr}}{60 \text{ min}})(\$36/\text{hr})(\tfrac{1}{20 \text{ FT}})$$
$$\text{BENDING COSTS} = \$0.30/\text{FT}$$

TOTAL COST = $5.91/FT

BUILT-UP TEE

USE SAME DIMENSIONS AS THE W-T



$$\text{Volume} = [(6.5'')(.45'') + (.35'')(10.33 - .45'')](12'')$$

$$\text{Volume} = 76.6\ \text{IN}^3$$

$$\text{MAT'L COST} = (76.6\ \text{IN}^3)(.286\ \text{lb/IN}^3)(\$.23/\text{lb})$$

MAT'L COST = $5.04/FT

$$\text{WELDING COST} = \left(\frac{2\ \text{FT WELD}}{2.5\ \text{FT/min}}\right)\left(\frac{1\ \text{hr}}{60\ \text{min}}\right)(\$50/\text{hr})$$

WELDING COST = $0.67/FT

$$\text{CUTTING COST} = (26\ \text{min})\left(\frac{1\ \text{hr}}{60\ \text{min}}\right)(\$50/\text{hr})(1/20\ \text{FT})$$

CUTTING COST = $1.08/FT

TOTAL COST = $6.79/FT

COST SUMMARY

ANGLE - $6.29/FT

STD TEE - $7.38/FT

W-T - $8.81/FT

FLG PLT - $5.91/FT

BUILT TEE - $6.79/FT

BASIC NAVAL ARCHITECTURE

Unit Number: 39

Title: The strength and structure of ships - 10

Tape Running Time: $36^M\ 3^S$

Reading Assignment: MSD, pp 232-233

Additional References: PNA, pp 182-184 (repeated), 59-62

SDC, pp 19-24, 36-41, 207-230

Scope:

Typical midship section drawings of various types of ships are displayed and features pointed out. SWBS and MARAD weight classification systems are described. Weight estimating, both in early stage design and in later stages of design is discussed.

Key Points to Emphasize:

1. The midship drawings used in the video tape have all been taken from either PNA or SDC. The problem is displaying a crowded drawing on a TV screen should be apparent. The instructor may wish to reproduce transparencies directly from the source materials and display them on a larger screen.

2. The objective should be to lead the student through the maze of crowded notation shown on the drawings to the point at which he can read and understand the drawing and develop a mental picture of the structure it describes.

3. The importance of the weight estimate should be emphasized. The level of detail of the estimate increases rapidly in scope as the design progresses. If the instructor has access to a print-out of a Contractor's Design Weight Estimate showing the thousands of line items, this would be of interest to the students.

4. The importance of a formal weight control program in naval ship construction should be emphasized.

Suggested Problem Assignment: The instructor may wish to develop and assign a problem in calculating the weight of a structural assembly.

THE STRENGTH AND STRUCTURE OF SHIPS

THE MIDSHIP SECTION DRAWING

THE MIDSHIP SECTION DRAWING IS A COMPOSITE DRAWING INTENDED TO PORTRAY THE STRUCTURAL FEATURES OF THE SHIP IN THE MIDSHIPS REGION. OFTEN IT IS NOT THE SAME AS A STRUCTURAL SECTION TAKEN AT MIDSHIPS.

THE DRAWING UTILIZES THE MIDSHIPS GEOMETRY OF THE SHIP (BEAM, DEPTH, DEADRISE, ETC) BUT SHOWS THE STRUCTURAL FEATURES IN WAY OF THE WEAKEST LINK IN THE LONGITUDINAL STRENGTH OF THE SHIP-THE HATCH OPENING.

THERE MAY ACTUALLY BE A SUPERSTRUCTURE IWO THE MIDSHIP SECTION, BUT USUALLY THIS IS NOT DESIGNED TO CONTRIBUTE TO THE LONGITUDINAL STRENGTH OF THE SHIP AND IS NOT SHOWN ON THE MIDSHIP SECTION DRAWING.

THE STRENGTH AND STRUCTURE OF SHIPS

SHIP SECTION MODULUS CALCULATION

- THE FOLLOWING LONGITUDINAL MEMBERS MAY BE INCLUDED PROVIDED THEY ARE CONTINUOUS AND EFFECTIVELY DEVELOPED
  - DECK PLATING
  - SHELL AND INNER BOTTOM PLATING
  - DECK AND BOTTOM GIRDERS
  - DECK, SIDE, BOTTOM AND INNER BOTTOM LONGITUDINALS.

SHIP SECTION MODULUS CALCULATION

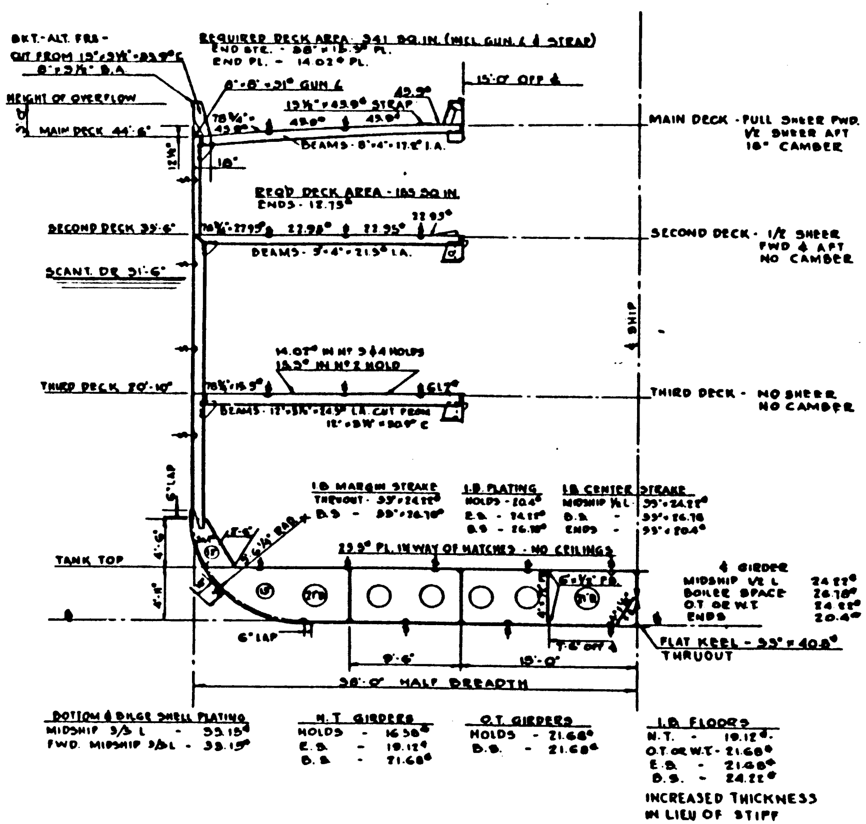
- INCLUDE ALL OF THE ABOVE IN CALCULATING THE Ay^2 COLUMN. AREAS IN INCHES, LEVER ARMS IN FEET, UNITS IN^2-FT^2.

  INCLUDE ONLY VERTICAL PLATING IN Io COLUMN. NOTE THAT FOR VERTICAL PLATING, HEIGHT, h IN FEET AND THICKNESS t IN INCHES,

$$I_o = h^3 t \qquad IN^2-FT^2$$

(P.L.T.S.)

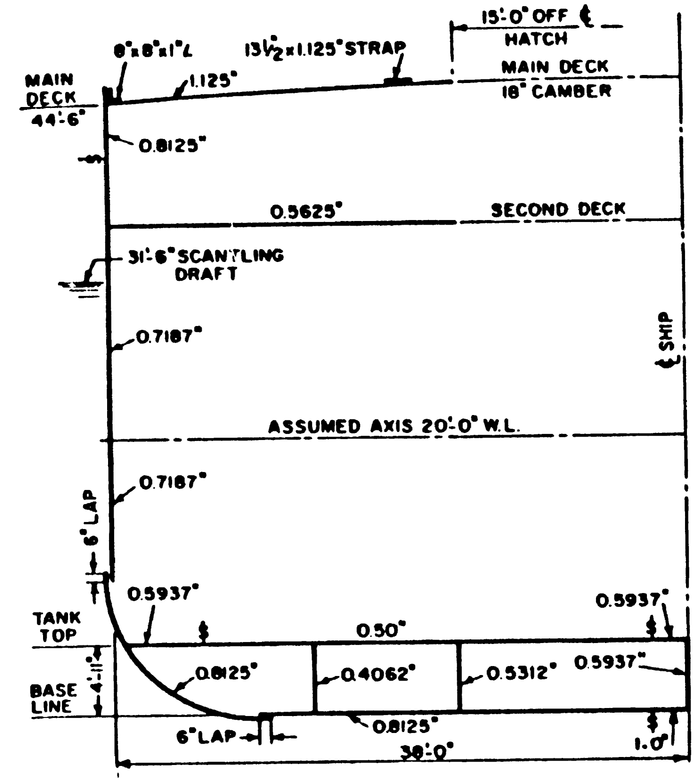
MIDSHIP SECTION - MARINER CLASS SHIPS



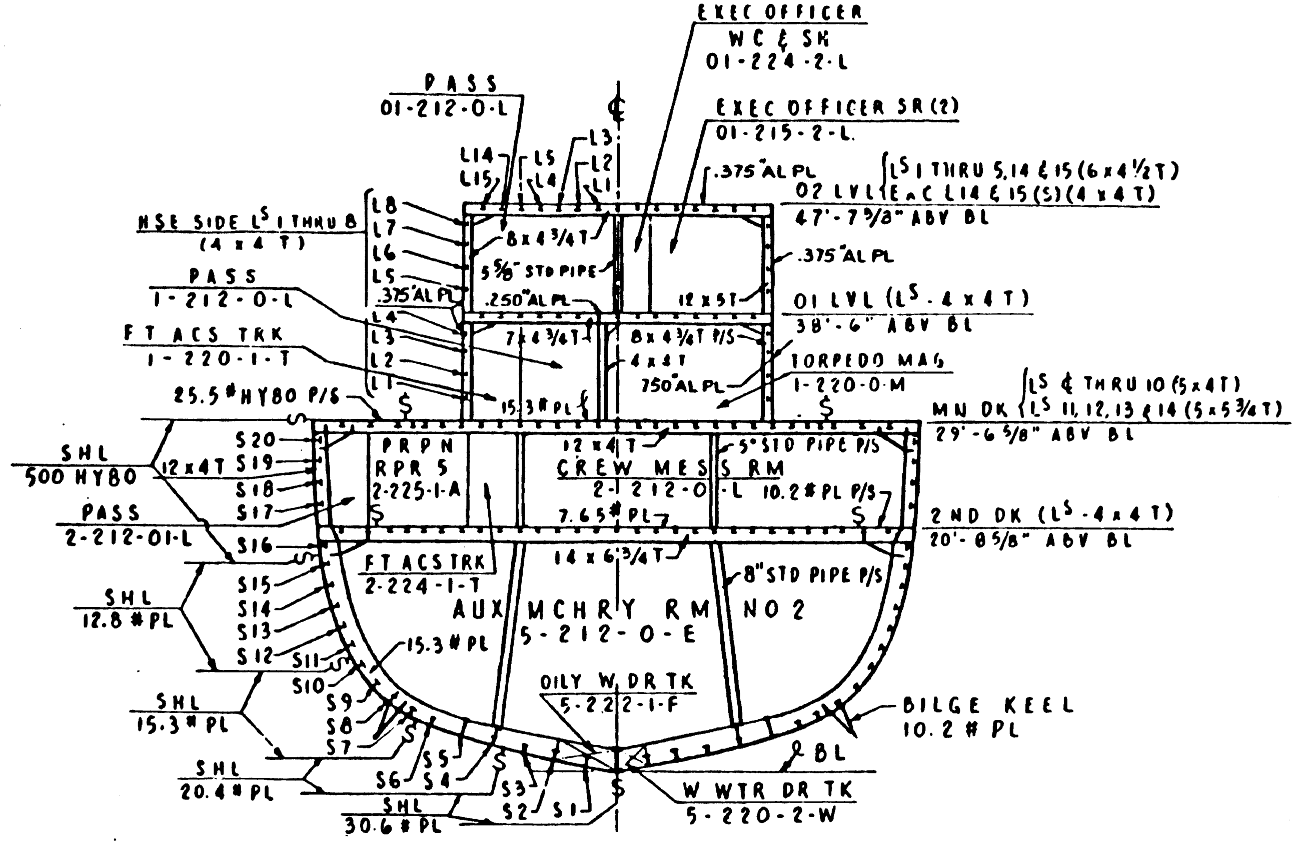
THE STRENGTH AND STRUCTURE OF SHIPS

SHIP SECTION MODULUS CALCULATION

THE EFFECTIVE LONGITUDAL STRUCTURE UTILIZED IN CALCULATING THE SECTION MODULUS OF THE MARINER CLASS SHIPS IS SHOWN BELOW.

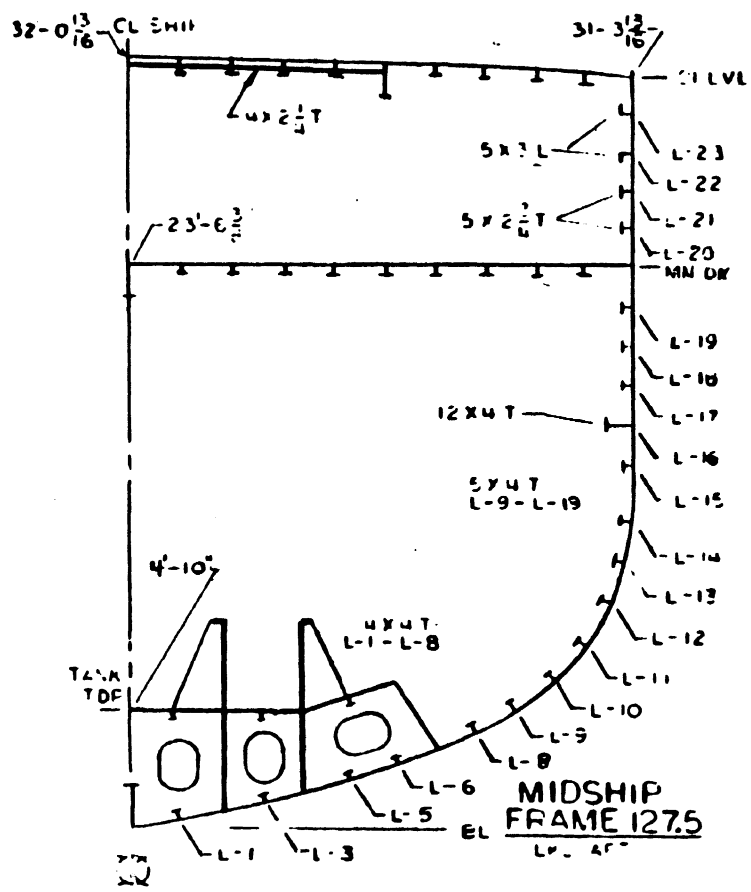


MIDSHIP SECTION - FFG 7



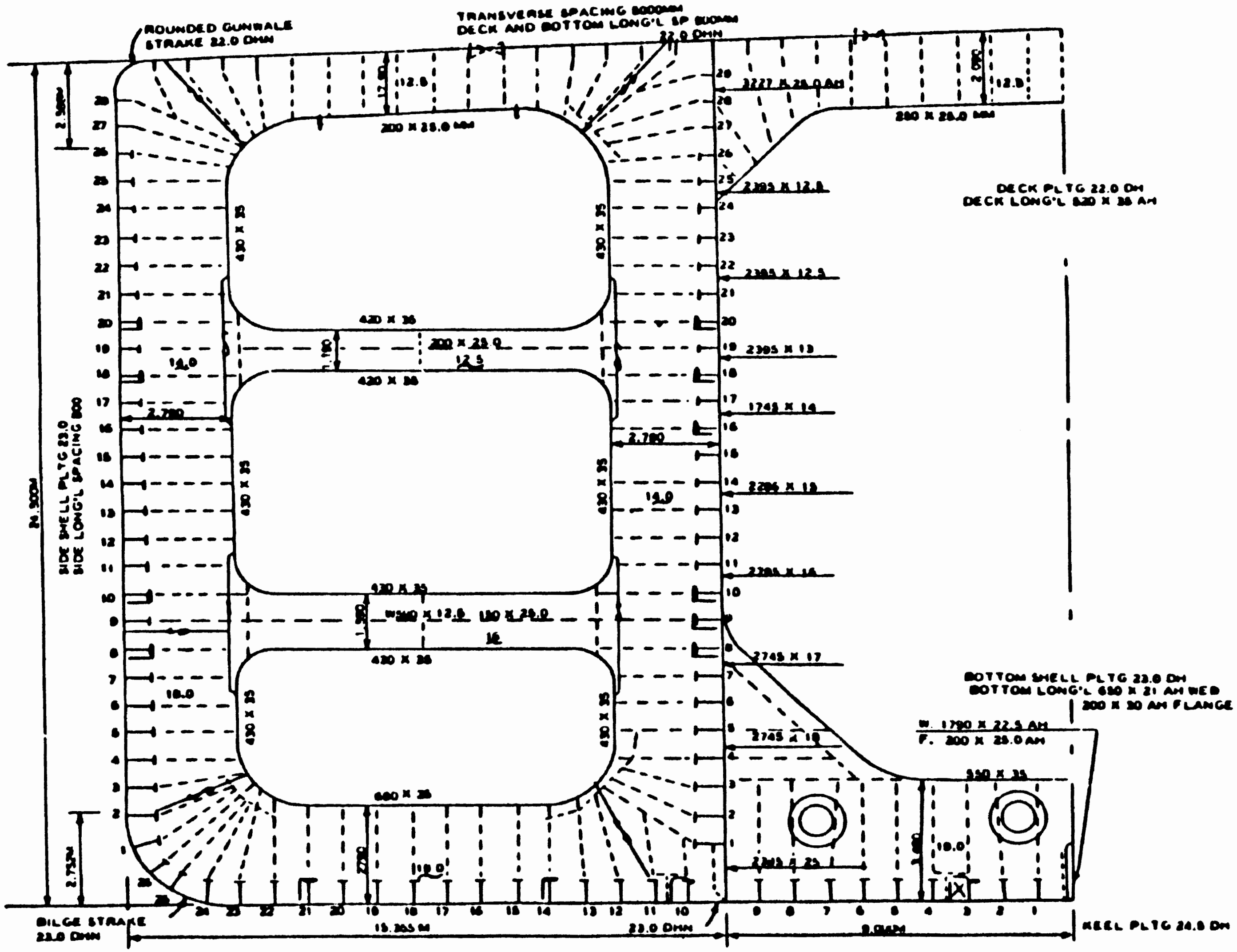
MIDSHIPS
SECT FR 228
LKG AFT

MIDSHIP SECTION - "BEAR" CLASS CUTTER

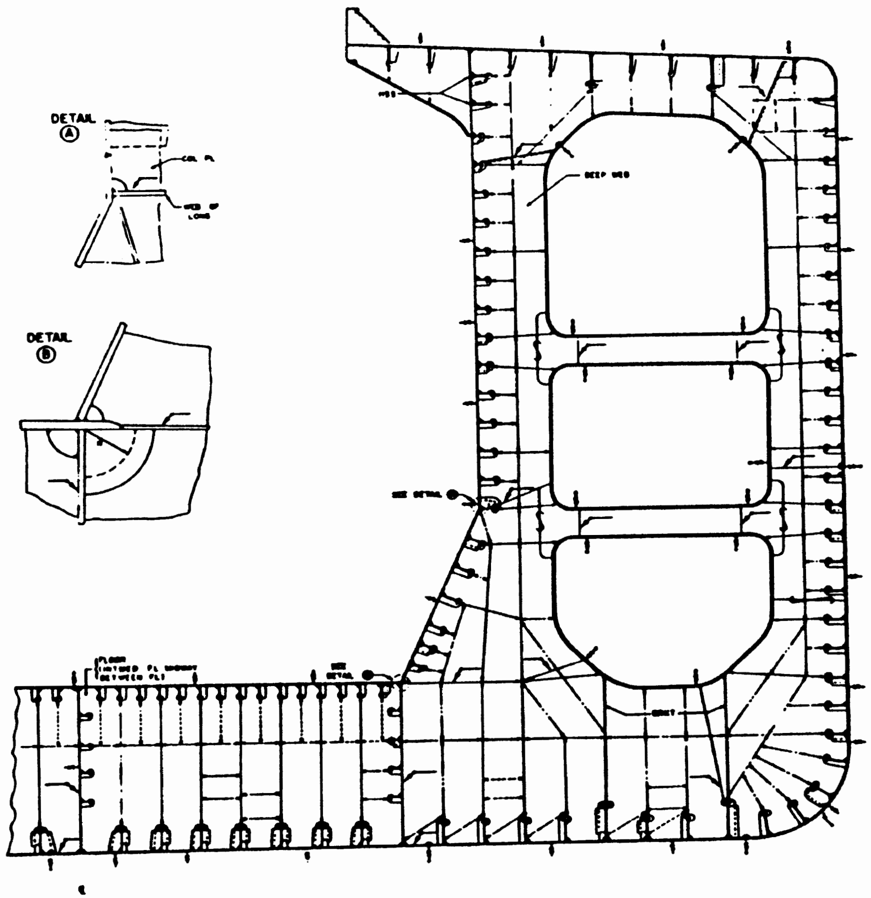


THE STRENGTH AND STRUCTURE OF SHIPS

MIDSHIP SECTION - TANKER

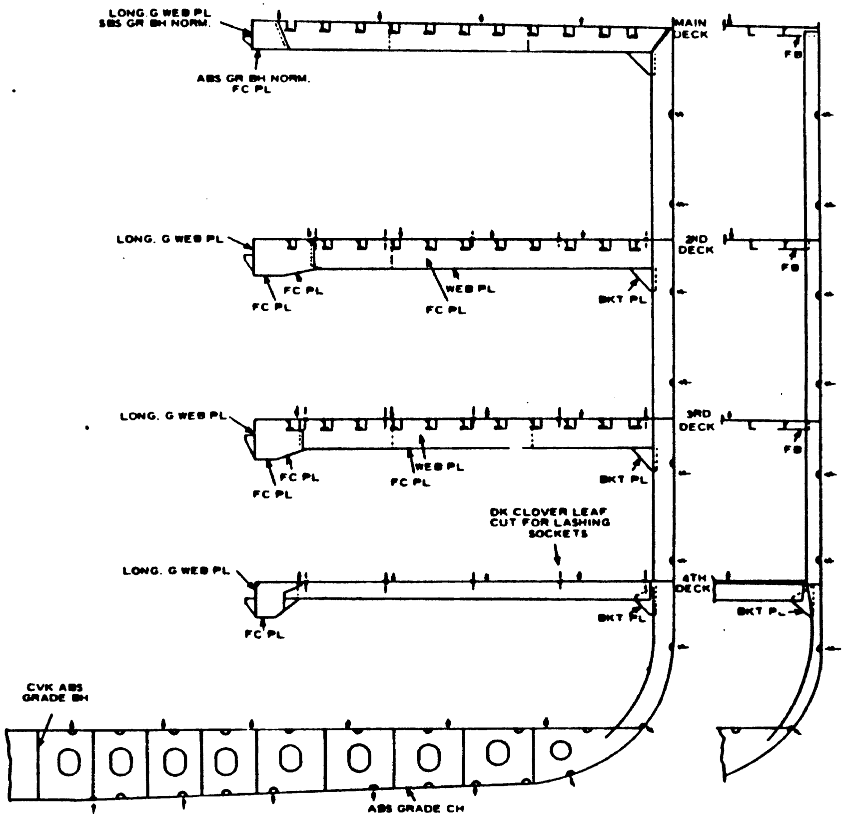


MIDSHIP SECTION-DOUBLE BOTTOM BULK CARRIER



THE STRENGTH AND STRUCTURE OF SHIPS

MIDSHIP SECTION - ROLL-ON/ROLL-OFF SHIP

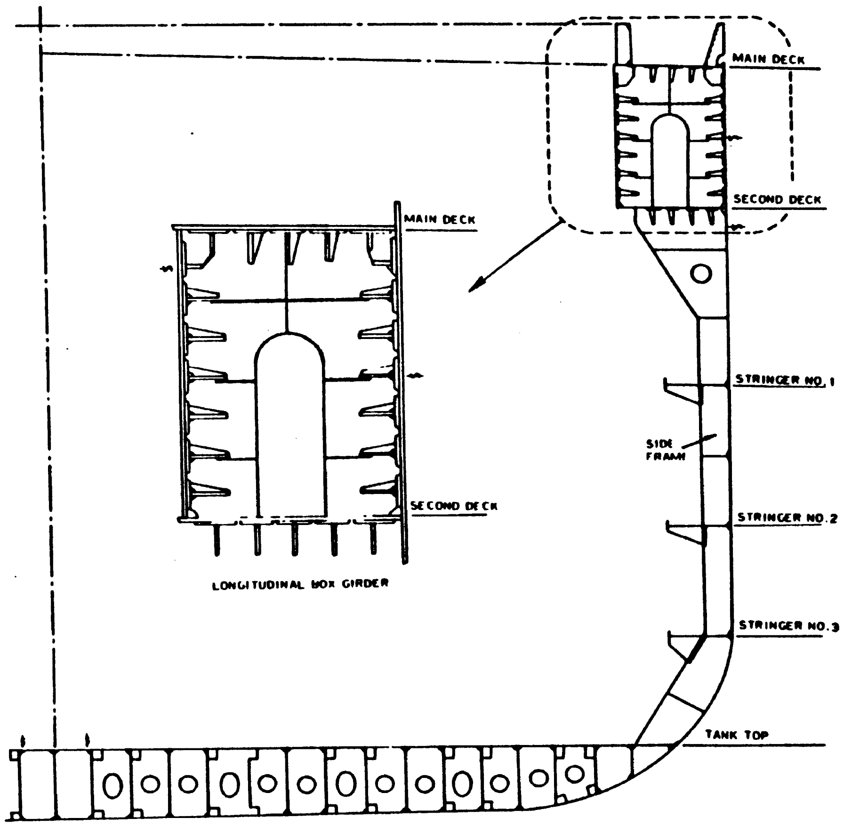


(A) TYP TRANSV WEB FRAME

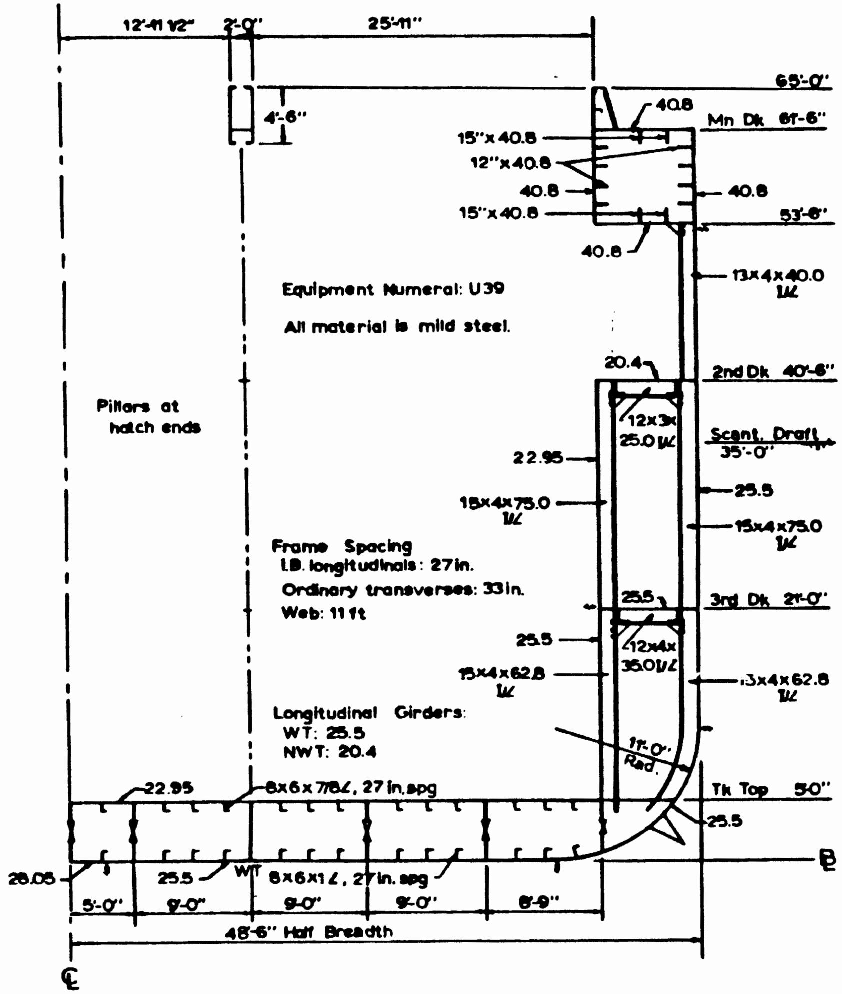
(B) TYP TRANSV SIDE SHELL FR

THE STRENGTH AND STRUCTURE OF SHIPS

MIDSHIP SECTION - SL-7 CONTAINER SHIP



MIDSHIP SECTION-PD 214 CONTAINER VARIANT



THE WEIGHT ESTIMATE

THERE ARE TWO MAJOR WEIGHT CLASSIFICATION SYSTEMS.

A. THE MARAD STANDARD CLASSIFICATION UTILIZES THREE MAJOR CLASSIFICATIONS

- STEEL WEIGHT
- OUTFIT WEIGHT
- MACHINERY WEIGHT

B. THE U.S. NAVY SWBS (STANDARD WORK BREAKDOWN SYSTEM) UTILIZES SEVEN MAJOR WEIGHT CLASSIFICATIONS

GROUP 1	HULL STRUCTURE
GROUP 2	PROPULSION
GROUP 3	ELECTRIC PLANT
GROUP 4	COMMAND AND SURVEILLANCE
GROUP 5	AUXILIARY SYSTEMS
GROUP 6	OUTFIT AND FURNISHINGS
GROUP 7	ARMAMENT

THE WEIGHT ESTIMATE (CON'T)

THE MARAD SYSTEM HAS FURTHER BREAKDOWNS WITHIN EACH OF THE THREE MAJOR CATEGORIES. EXAMPLE.

STEEL (CODES 0 - 9)

CODE	
0	FORGINGS AND CASTINGS
1	SHELL PLATING
2	FRAMING
3	DECK PLATING AND BEAMS
4	BULHEADS AND TRUNKS
5	PILLARS AND GIRDERS
6	HULL MISCELLANEOUS
7	FOUNDATIONS
8	SUPERSTRUCTURES
9	TOTAL

OUTFIT (CODES 10 - 19)

MACHINERY (CODES 20 - 29)

EACH CODE CONTAINS SUBHEADINGS FOR WEIGHT COMPONENTS WITHIN THAT CODE.

THE STRENGTH AND STRUCTURE OF SHIPS

THE WEIGHT ESTIMATE (CON'T)

THE NAVY SWBS SYSTEM USES A THREE DIGIT LEVEL FOR REPORTING SHIP WEIGHT ESTIMATES A FIVE DIGIT LEVEL IS USED FOR WEIGHT TAKE OFFS.

NAVY GROUP	
1	HULL STRUCTURE
100	HULL STRUCTURE, GENERAL
110	SHELL AND SUPPORTING STRUCTURE
111	SHELL PLATING
113	INNER BOTTOM
114	SHELL APPENDAGE
115	STANCHIONS
116	LONGITUDINAL FRAMING
117	TRANSVERSE FRAMING
120	HULL STRUCTURAL BULKHEADS
ETC.	

THE WEIGHT ESTIMATE (CON'T)

INDIVIDUAL SHIPYARDS MAY HAVE THEIR OWN WEIGHT ESTIMATING SYSTEMS.

THE GREAT VALUE OF A SYSTEM IS THE HISTORICAL DATA IT CONTAINS WHICH CAN BE USED FOR ESTIMATING NEW CONSTRUCTION JOBS.

BUT CHANGING A HISTORICAL DATA BASE FROM ONE SYSTEM TO ANOTHER IS A HUGE JOB, USUALLY NOT PRACTICAL.

THE STRENGTH AND STRUCTURE OF SHIPS

THE WEIGHT ESTIMATE (CON'T)

EARLY-STAGE DESIGN ESTIMATES

IN THE FIRST DESIGN CYCLE IT IS NECESSARY TO GET A QUICK ESTIMATE OF THE SHIP WEIGHT, BOTH LIGHT SHIP AND FULL LOAD.

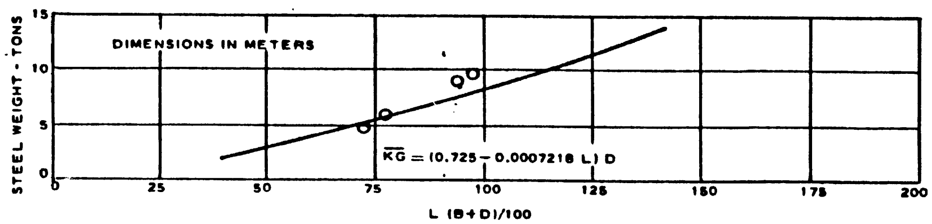
THE BEST SOURCE OF INFORMATION IS A SHIP OF THE SAME TYPE, OF SIMILAR SIZE, AND BUILT BY THE SAME SHIPYARD. MAKE ADJUSTMENTS TO THE WEIGHT ESTIMATE OF THE BASIS SHIP FOR DESIGN CHANGES IN THE NEW SHIP.

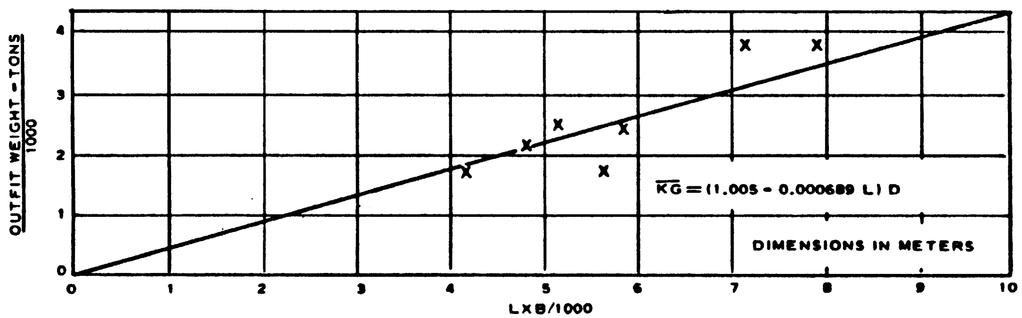
THE MORE COMMON CASE IS TO USE PLOTS OF HISTORICAL WEIGHT DATA OF SHIPS OF THE SAME TYPE.

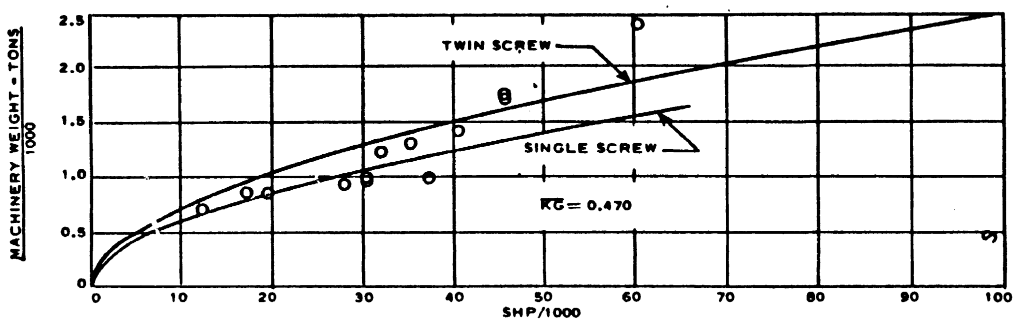
THE STRENGTH AND STRUCTURE OF SHIPS

THE WEIGHT ESTIMATE (CON'T)

EARLY STAGE DESIGN ESTIMATES







THE STRENGTH AND STRUCTURE OF SHIPS

THE WEIGHT ESTIMATE (CON'T)

DETAIL DESIGN WEIGHT ESTIMATE

AS THE DESIGN PROGRESSES THE QUALITY OF THE WEIGHT ESTIMATE MUST BE REFINED.

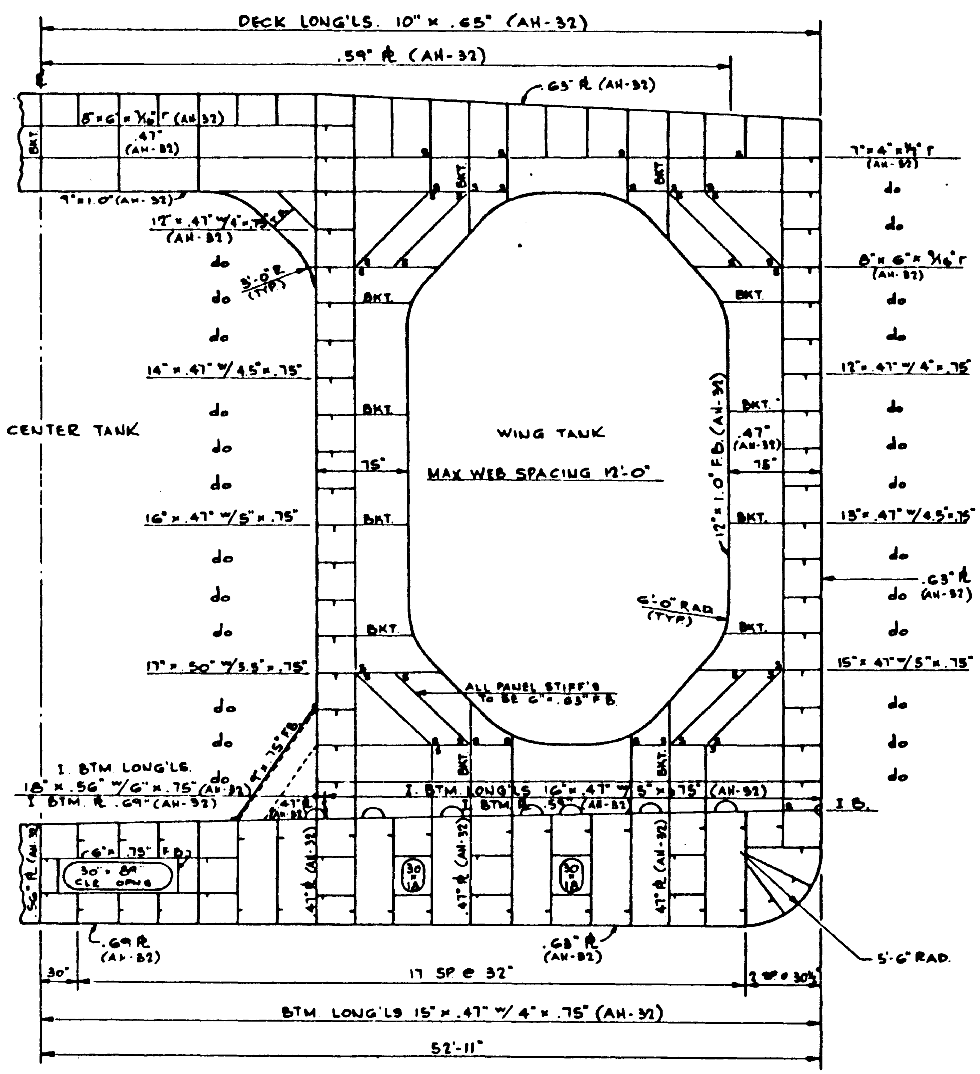
EACH GROUP WITHIN THE DESIGN TEAM WILL PROVIDE THE WEIGHT GROUP WITH UPDATED DESIGN INFORMATION AT PERIODIC INTERVALS.

IT IS CRITICAL THAT WEIGHT AND/OR KG PROBLEMS BE IDENTIFIED EARLY SO THAT TIMELY DESIGN CHANGES MAY BE MADE.

DURING THE DETAIL DESIGN PHASE THE WEIGHT ESTIMATE IS DONE BY PERFORMING DETAILED WEIGHT TAKE-OFFS, THAT IS BY INDIVIDUALLY ESTIMATING AND TABULATING EACH PIECE OF STRUCTURE, OUTFIT AND MACHINERY FROM CONSTRUCTION DRAWINGS AND SPECIFICATIONS.

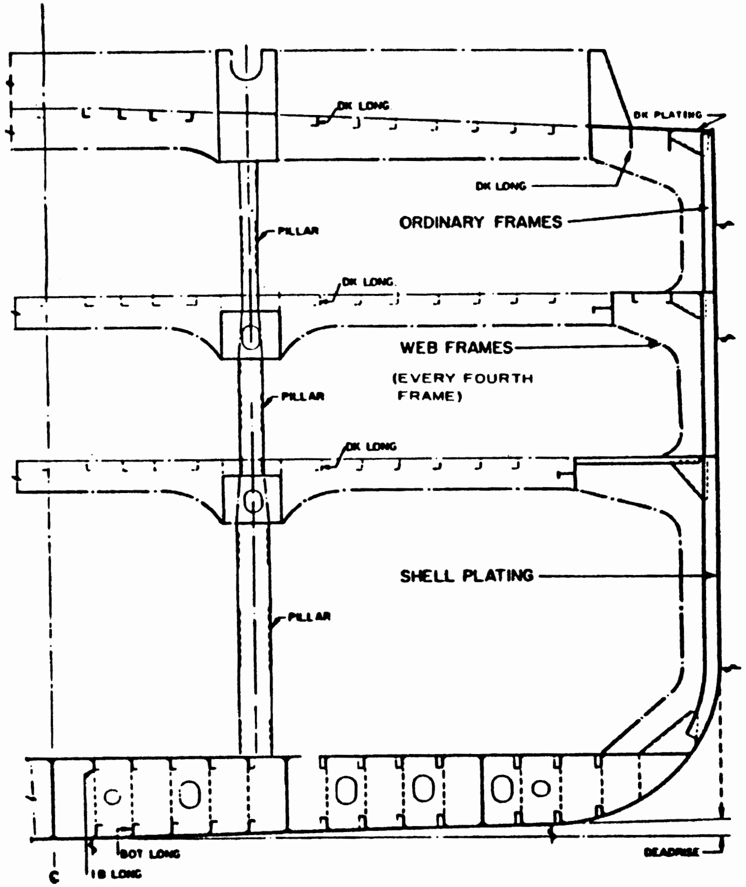
GRAPHICS NOT USED IN PRESENTATION

MIDSHIP SECTION - CHEMICAL/PRODUCT CARRIER



THE STRENGTH AND STRUCTURE OF SHIPS

MIDSHIP SECTION - ALL HATCH CARGO SHIP



BASIC NAVAL ARCHITECTURE

Unit Number: 40

Title: The ship design process - 1

Tape Running Time: $29^M\ 0^S$

Reading Assignment: MSD, pp 257-262

Additional References: SDC, pp 1-46

Scope:

This unit introduces the broad topic of ship design. A typical design spiral is presented. The various phases of design are discussed. Contract design deliverables are described. Emphasis in this unit is on merchant ship design. Naval ship design and procurement will be discussed in Unit 42.

Key Points to Emphasize:

1. In going through the design spiral and the various design stages avoid casting the process in a highly stereotyped light. For example, often a feasibility study or possibly a simple concept design will be performed to establish vessel size, power and capacities. Then the design effort will proceed directly to a contract design. If the ship is only a minor departure from a previous vessel perhaps only a contract design will be prepared, and at that only the drawings and spec items affected by the changes will be changed. What is done is only what needs to be done using the best information available as a baseline.

2. Emphasize the development of a clearly defined set of mission requirements, or owner's requirements, or Top Level Requirements. The document should be a document which evolves over the period of the early stage design efforts using inputs from both naval architect and owner, and is then finalized at the time the contract design package is finalized.

Suggested Problem Assignment: Select from previously unassigned problems.

THE SHIP DESIGN PROCESS

MERCHANT VESSEL DESIGN

GOOD REFERENCE:

"SHIP DESIGN AND CONSTRUCTION", R. TAGGART, EDITOR, SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, 1980.

THE SHIP DESIGN PROCESS

TYPES OF MERCHANT VESSELS

MERCHANT VESSELS MAY BE CLASSIFIED ROUGHLY INTO THREE CLASSES.

COMMERCIAL VESSELS TRANSPORT CARGOES OR PASSENGERS, FOR EXAMPLE, CONTAINER SHIPS, TANKERS, RO/RO SHIPS, CRUISE SHIPS, ETC.

INDUSTRIAL VESSELS PERFORM SPECIALIZED MARINE FUNCTIONS, FOR EXAMPLE, OCEAN DRILLING SHIPS OR DRILLING RIGS, OCEANOGRAPHIC SHIPS, DREDGES, ETC.

SERVICE VESSELS PROVIDE SUPPORT TO COMMERCIAL OR INDUSTRIAL VESSELS, FOR EXAMPLE, OFFSHORE SUPPLY BOATS, CREW BOATS, UTILITY TUGS, FIRE BOATS, ETC.

THE SHIP DESIGN PROCESS

MISSION REQUIREMENTS

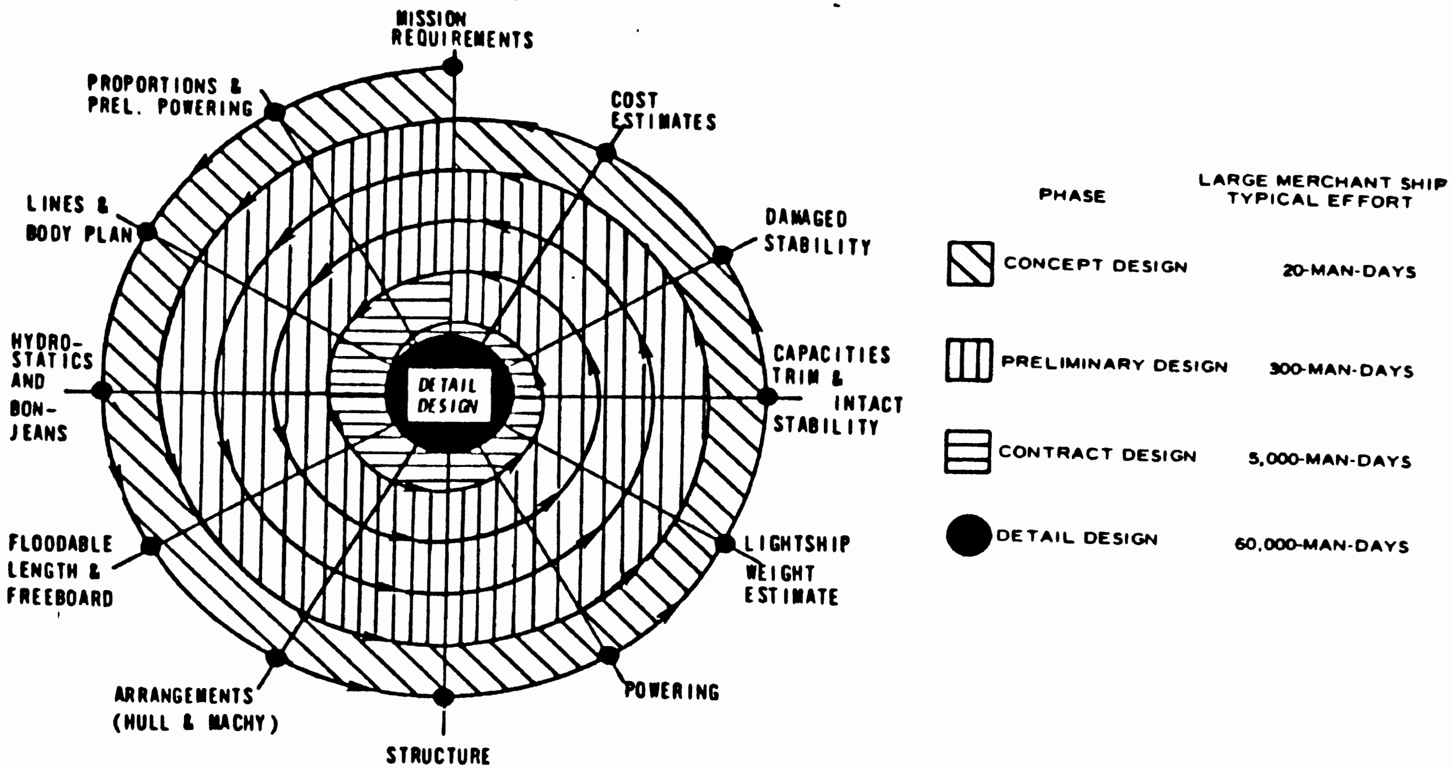
- BEFORE STARTING ON FORMAL DEVELOPMENT OF A SHIP DESIGN THE OWNER SHOULD DEVELOP A SET OF MISSION REQUIREMENTS, OR OWNER'S REQUIREMENTS, FOR THE SHIP, OR SHIPS, TO BE DESIGNED.

- THE NAVAL ARCHITECTURAL DESIGN TEAM MAY ASSIST THE OWNER IN DEFINING HIS REQUIREMENTS WITH ECONOMIC STUDIES, SYSTEMS ANALYSES, FEASIBILITY STUDIES, OR EVEN A CONCEPT DESIGN. MORE OFTEN THE OWNER WILL HAVE DEFINED HIS OWN REQUIREMENTS.

THE SHIP DESIGN PROCESS

DESIGN PHASES

THE DESIGN SPIRAL



THE SHIP DESIGN PROCESS

APPROACH

EARLY-STAGE SHIP DESIGN DEPENDS HEAVILY ON EMPIRICAL DATA COLLECTED FROM PAST SHIP DESIGNS.

IN MANY CASES - PROBABLY MOST CASES - AN EXISTING SHIP WILL BE USED AS A BASELINE FOR A NEW DESIGN. THE OWNER MAY WANT AN INCREASE IN CAPACITY, DIFFERENT SPEED, DIFFERENT POWER PLANT, ETC.

WHEN THE CIRCUMSTANCES PERMIT THE IDEAL METHOD IS TO DEVELOP THE SHIP DIMENSIONS, SPEED, POWERING, CAPACITIES, ETC. BASED ON A PARAMETRIC DESIGN STUDY.

THE SHIP DESIGN PROCESS

PARAMETRIC DESIGN STUDIES

IN THIS APPROACH A SERIES OF PARAMETERS, FOR EXAMPLE LENGTH, SPEED, DEADWEIGHT, ARE VARIED SYSTEMATICALLY, ONE AT A TIME.

FOR EACH VARIATION THE SHIP DIMENSIONS, COEFFICIENTS, CAPACITIES, AND POWERING ARE ESTIMATED USING DESIGN CURVES OR DESIGN ALGORITHMS.

FOR EACH VARIANT THE INITIAL COST, MAINTENANCE AND OPERATING COSTS AND OTHER ANNUALIZED COSTS ARE ESTIMATED.

THE SHIP DESIGN PROCESS

PARAMETRIC DESIGN STUDIES

THE DESIGN IS OPTIMIZED BY FINDING THE SHIP CHARACTERISTICS WHICH OFFER

- MINIMUM FIRST COST FOR A FIXED CARGO CAPACITY PER YEAR, OR
- MINIMUM LIFE CYCLE COST FOR A FIXED CARGO CAPACITY PER YEAR, OR
- MAXIMUM CAPITAL RECOVERY FACTOR (CRF), OR
- MINIMUM REQUIRED FREIGHT RATE (RFR), OR
- OTHER ECONOMIC PARAMETERS.

THE SHIP DESIGN PROCESS

DESIGN PHASES (CON'T)

FEASIBILITY STUDIES

FEASIBILITY STUDIES ARE CONDUCTED TO RESOLVE THE QUESTION OF WHETHER A SHIP OR PLATFORM CAN BE DESIGNED AND CONSTRUCTED TO MEET THE MISSION REQUIREMENTS AND WITHIN THE AVAILABLE FUNDS. OFTEN, SEVERAL SUBSTANTIALLY DIFFERENT ALTERNATIVES ARE EVALUATED (IN TERMS OF THE ECONOMIC RETURN, INITIAL COST AND LIFE CYCLE COST). RECOMMENDATIONS ARE MADE FOR THE MOST FAVORABLE CONFIGURATION TOGETHER WITH ITS APPROXIMATE SIZE AND COST. TECHNICAL AND COST RISK FACTORS ARE EVALUATED.

THE SHIP DESIGN PROCESS

DESIGN PHASES (CON'T)

CONCEPT DESIGN

THE CONCEPT DESIGN IS REALLY THE STARTING POINT IN THE DESIGN SPIRAL. WHILE THE FEASIBILITY STUDY DETERMINES THE BEST TYPE OF SHIP FOR A GIVEN APPLICATION, THE CONCEPT DESIGN ESTABLISHES THE PRINCIPAL DIMENSIONS, COEFFICIENTS, DISPLACEMENT, SPEED, TYPE, SIZE AND LOCATION OF THE POWER PLANT, A WEIGHT ESTIMATE, AND A CONSTRUCTION COST ESTIMATE. USUALLY, PARAMETRIC STUDIES ARE CONDUCTED TO ESTABLISH THE MOST ECONOMIC SOLUTION TO SATISFY THE MISSION REQUIREMENTS.

THE SHIP DESIGN PROCESS

DESIGN PHASES (CON'T)

PRELIMINARY DESIGN

DURING THE PRELIMINARY DESIGN PHASE THE OUTPUT OF THE CONCEPT DESIGN IS REFINED. A SET OF LINES IS DEVELOPED, HYDROSTATIC CHARACTERISTICS AND FLOODABLE LENGTHS ARE CALCULATED FROM OFFSETS. MORE REFINED ESTIMATES OF WEIGHT, CAPACITIES, POWERING, AND COST ARE PREPARED. A MIDSHIP SECTION STRUCTURAL DRAWING IS PREPARED. GENERAL ARRANGEMENT DRAWINGS ARE DEVELOPED. AN OUTLINE SPECIFICATION MAY BE PREPARED.

AT THE END OF THE PRELIMINARY DESIGN PHASE THE SHIP'S MAJOR CHARACTERISTICS SHOULD BE WELL DEFINED AND SUBJECT TO ONLY MINOR CHANGES IN THE CONTRACT DESIGN PHASE.

DESIGN PHASES (CON'T)

CONTRACT DESIGN

THE PURPOSE OF THE CONTRACT DESIGN IS TO DEVELOP A SET OF PLANS AND SPECIFICATIONS TO A LEVEL OF DETAIL WHICH WILL FULLY DEFINE THE SHIP AND ITS EQUIPMENT SUCH THAT SHIPYARDS MAY PREPARE CONSTRUCTION BIDS. THE CONTRACT DESIGN PLANS AND SPECIFICATIONS FORM AN INTEGRAL PART OF THE SHIPBUILDING CONTRACT BETWEEN OWNER AND SHIPBUILDER.

THE SHIP DESIGN PROCESS

DESIGN PHASES (CON'T)

TYPICAL CONTRACT DESIGN DELIVERABLES

BOOK OF CONSTRUCTION SPECIFICATIONS - CONTAINS A DESCRIPTION OF THE SHIP, MATERIALS TO BE USED IN ITS CONSTRUCTION, THE MAIN AND AUXILIARY MACHINERY ITEMS, THE HULL AND OUTFIT ITEMS, AND APPLICABLE REGULATORY BODY REQUIREMENTS WHICH MUST BE SATISFIED. THE CONTRACT DRAWINGS FORM PART OF THE SPECIFICATIONS.

THE CONTRACT PLANS AND SPECIFICATIONS FORM A LEGALLY BINDING CONTRACT DOCUMENT. UNLESS CHANGE ORDERS ARE APPROVED THE SHIP MUST BE BUILT EXACTLY TO CONFORM TO THE CONTRACT REQUIREMENTS.

THE SHIP DESIGN PROCESS

DESIGN PHASES (CON'T)

TYPICAL CONTRACT DESIGN DRAWINGS

- OUTBOARD PROFILE
- INBOARD PROFILE
- GENERAL ARRANGEMENTS OF DECKS, HOLDS, QUARTERS, COMMISSARY SPACES
- ARRANGEMENTS OF MAIN AND AUXILIARY MACHINERY
- ELECTRICAL LOAD ANALYSIS
- ONE-LINE ELECTRICAL DIAGRAMS
- ONE-LINE FLUID SYSTEMS TO DIAGRAMS; FUEL OIL, LUBE OIL, POTABLE WATER, ETC.
- MIDSHIP SECTION DRAWING
- TYPICAL FRAMES AND BULKHEADS
- DECK SCANTLING PLANS
- SHELL EXPANSION DRAWING
- HEATING, VENTILATION AND AIR CONDITIONING (HVAC) LOAD ANALYSIS AND ONE-LINE DIAGRAMS
- CAPACITY PLAN
- LINES DRAWING
- CURVES OF FORM
- FLOODABLE LENGTH CURVES
- PRELIMINARY TRIM AND STABILITY BOOKLET
- PRELIMINARY DAMAGED STABILITY CALCULATIONS
- FIRE ZONE PLAN

THE SHIP DESIGN PROCESS

DESIGN PHASES (CON'T)

DETAIL DESIGN

BASED ON THE CONTRACT PLANS AND SPECIFICATIONS THE SHIPYARD (OR A DESIGN AGENT HIRED BY THE SHIPYARD) WILL PREPARE THE DETAILED WORKING PLANS AND SHOP DRAWINGS WHICH WILL BE USED BY THE SHIPYARD IN CUTTING THE STEEL, ERECTING THE SHIP, AND INSTALLING THE EQUIPMENT.

THE SHIP DESIGN PROCESS

DESIGN PHASES (CON'T)

COMMENTS

- IT IS QUITE INFREQUENT IN MERCHANT VESSEL DESIGN TO EMPLOY ALL THE DESIGN PHASES WHICH HAVE BEEN DESCRIBED. THE AMOUNT OF EFFORT THAT IS PUT INTO EARLY-STAGE DESIGN DEPENDS ON THE DEGREE OF DEPARTURE OF THE DESIGN FROM PAST PRACTICE.
- THE DEFINITIONS OF DESIGN PHASES ARE USED RATHER LOOSELY IN PRACTICE.
- CONCEPT DESIGN MAY INCLUDE FEASIBILITY STUDIES, AND IT MAY EXTEND INTO A LEVEL OF DETAIL NORMALLY ASSOCIATED WITH PRELIMINARY DESIGN.
- IF THE DESIGN IS SIMPLY A MODIFICATION OF AN EXISTING SHIP ONLY A CONTRACT DESIGN MAY BE PREPARED.

BASIC NAVAL ARCHITECTURE

Unit Number: 41

Title: The ship design process - 2

Tape Running Time: 30^{M} 41^{S}

Reading Assignment: MSD, pp 287-309

Additional References: SDC, pp 1-46 (repeated)

Scope:

The concept design example of Chapter 1, SDC is developed step by step.

Key Points to Emphasize:

1. The concept design example of Chapter 1, SDC has been selected because of the ready availability of the text for review by the instructor, but note the bugaboo with SI units.

2. Again, emphasize that this type of early-stage design study is performed only when the proposed ship represents a departure from the previous experience base.

3. This type of study will almost always be accompanied by an economic study. Parametric studies will be performed to evaluate the combination of dimensions and powering which will prove to be the most profitable.

4. The reading assignment covers "advanced marine vehicles" and is not directly supported by video material. The instructor may wish to introduce his own material on this topic.

Suggested Problem Assignment: The instructor may wish to distribute appropriate design curves and assign a problem similar to the example; however very few students in this course can be expected to have future involvement with early-stage design studies. The time may be used more fruitfully in assigning previously unassigned problems.

THE SHIP DESIGN PROCESS

CONCEPT DESIGN EXAMPLE

(TAKEN FROM SHIP DESIGN AND CONSTRUCTION, CHAP. 1)

- FIND THE DIMENSIONS OF A 23 KNOT CONTAINERSHIP CAPABLE OF CARRYING 500 40-FT CONTAINERS AND 500 20-FT CONTAINERS AT AN AVERAGE WEIGHT OF 20 TONS AND 12 TONS RESPECTIVELY.
- CONTAINERS MAY BE CARRIED THREE HIGH ON DECK AND MAY BE 8 FT OR 8.5 FT HIGH.
- FUEL OIL IS TO BE CARRIED IN WING TANKS AND SEGREGATED BALLAST TANKAGE IS TO BE PROVIDED IN THE DOUBLE BOTTOM
- CRUISING RADIUS IS 10,000 MILES
- STEAM TURBINE POWER HAS BEEN SELECTED.

THE SHIP DESIGN PROCESS

SOLUTION

1. EQUIVALENT NUMBER OF 20-FT CONTAINERS
= 500 X 2 + 500 = 1500 T.E.U.
(T.E.U. = TWENTY-FOOT EQUIVALENT UNITS)

2. FROM FIGURE 1, FIND:

L_{pp} = 215m = 705 FT

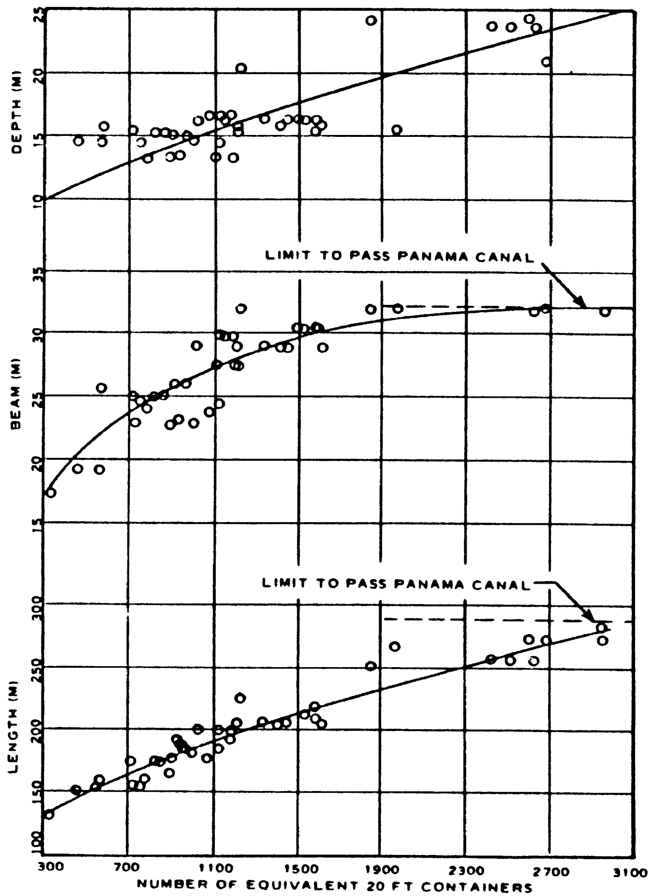
B = 30.5m = 100 FT

D = 17.5m = 59 FT

THE SHIP DESIGN PROCESS

SOLUTION (CON'T)

FIGURE 1



THE SHIP DESIGN PROCESS

SOLUTION (CON'T)

3. ASSUME SIX HIGH CONTAINER STOWAGE BELOW DECK. TAKE CONTAINER HEIGHT AT 8.0 FT.

CONTAINER HEIGHT:	6 × 8.0	= 48.0 FT.
DOUBLE BOTTOM:		= 6.0 FT.
		54.0 FT.

REDUCE DEPTH TO 54.0 FT. ALLOW 3 FT HATCH COAMING FOR 8.5 FT CONTAINERS, IF CARRIED

4. FIND FROUDE NUMBER

$$V = 23.0 \text{ KTS} \times 1.688 \frac{\text{FT/SEC}}{\text{KT}} = 38.82 \text{ FT/SEC}$$

$$g = 32.17 \text{ FT/SEC}^2$$

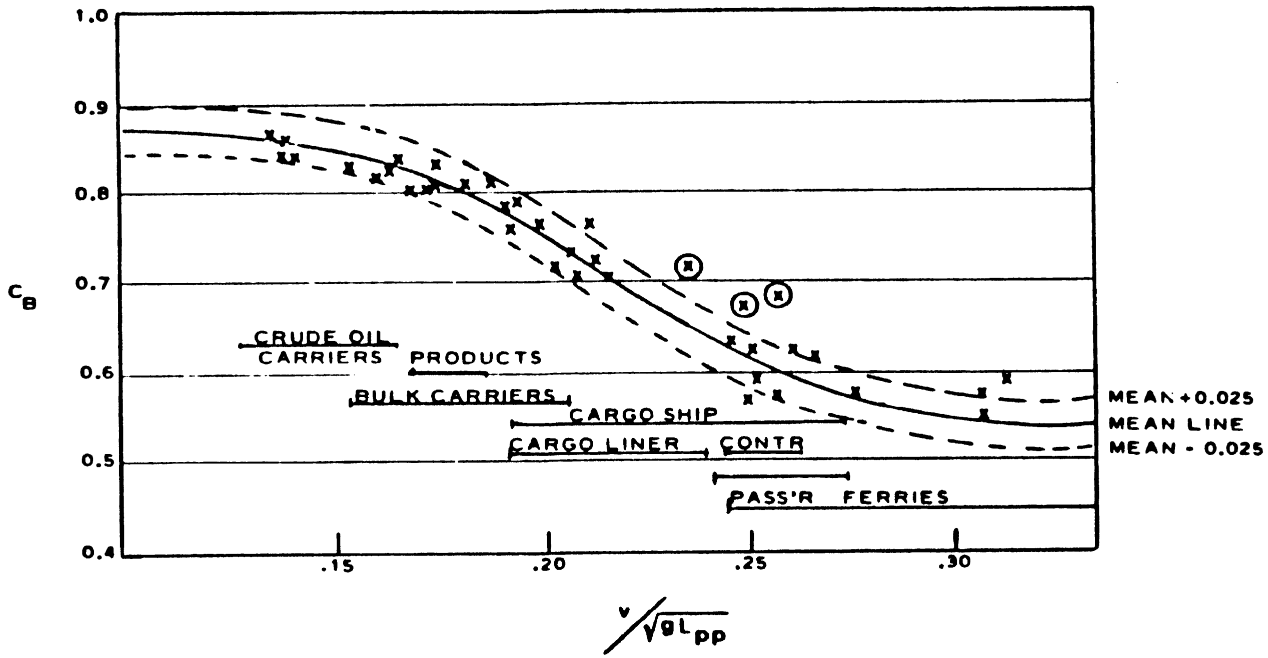
$$L = 705 \text{ FT}$$

$$\frac{V}{\sqrt{gL}} = \frac{38.82 \text{ FT/SEC}}{\sqrt{32.17 \frac{\text{FT}}{\text{SEC}^2} \times 705 \text{ FT}}} = .258$$

THE SHIP DESIGN PROCESS

SOLUTION (CON'T)

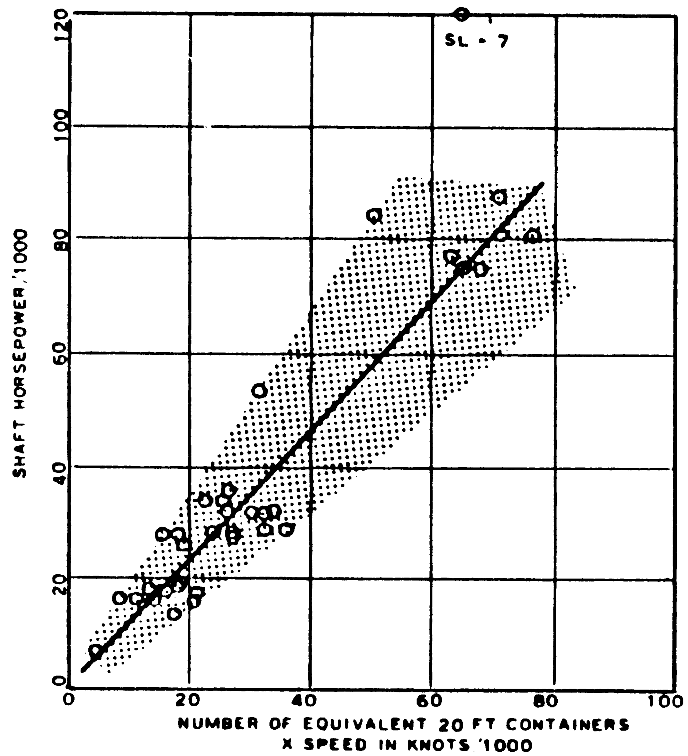
FIGURE 2



5. FROM FIGURE 2, FIND C_B VARIES FROM .58 TO .63. SELECT C_B = .59.

THE SHIP DESIGN PROCESS

SOLUTION (CON'T)



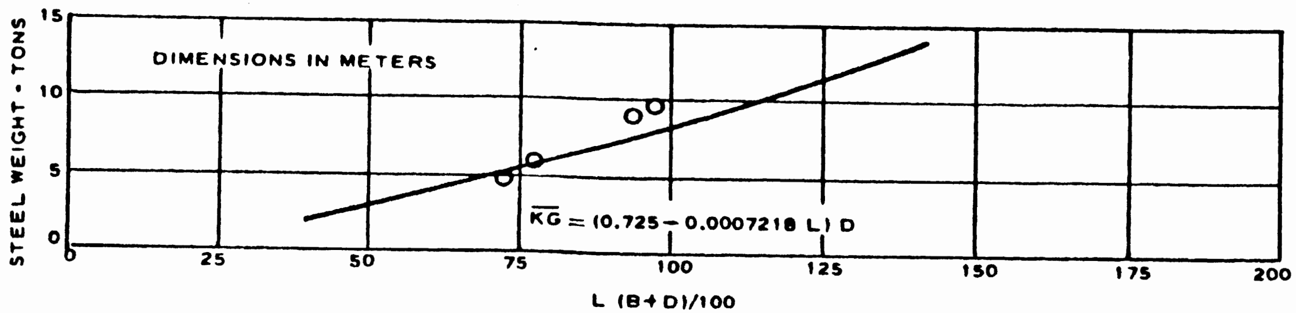
6. ESTIMATE POWERING: $\frac{1500 \text{ T.E.U.} \times 23.0 \text{ KTS}}{1000} = 34.5$

FIND SHP = 40,000 HP

THE SHIP DESIGN PROCESS

SOLUTION (CON'T)

FIGURE 4



7. **ESTIMATE STEEL WEIGHT:**

$$\frac{L(B+D)}{100} = \frac{215m(30.5m + 16.5m)}{100}$$

$$= 101.5$$

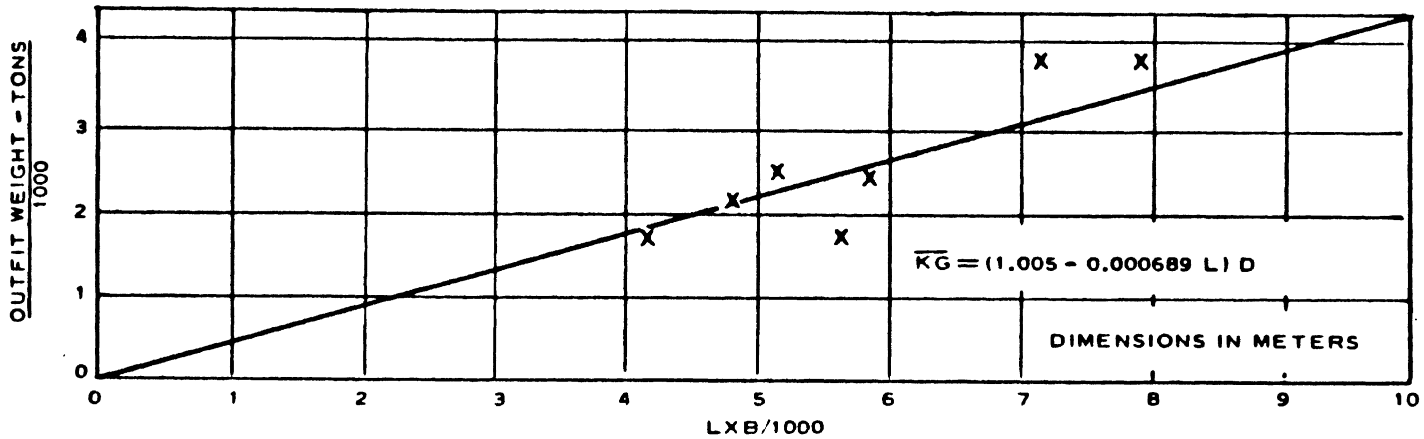
FIND STEEL WEIGHT $= 9300 \text{ TONNES} \times .985 \frac{\text{LT}}{\text{TONNE}}$

$= 9161 \text{ LT}$

THE SHIP DESIGN PROCESS

SOLUTION (CON'T)

FIGURE 5



8. ESTIMATE OUTFIT WEIGHT:

$$\frac{L \times B}{1000} = \frac{215m \times 30.5m}{1000}$$

$$= 6.6$$

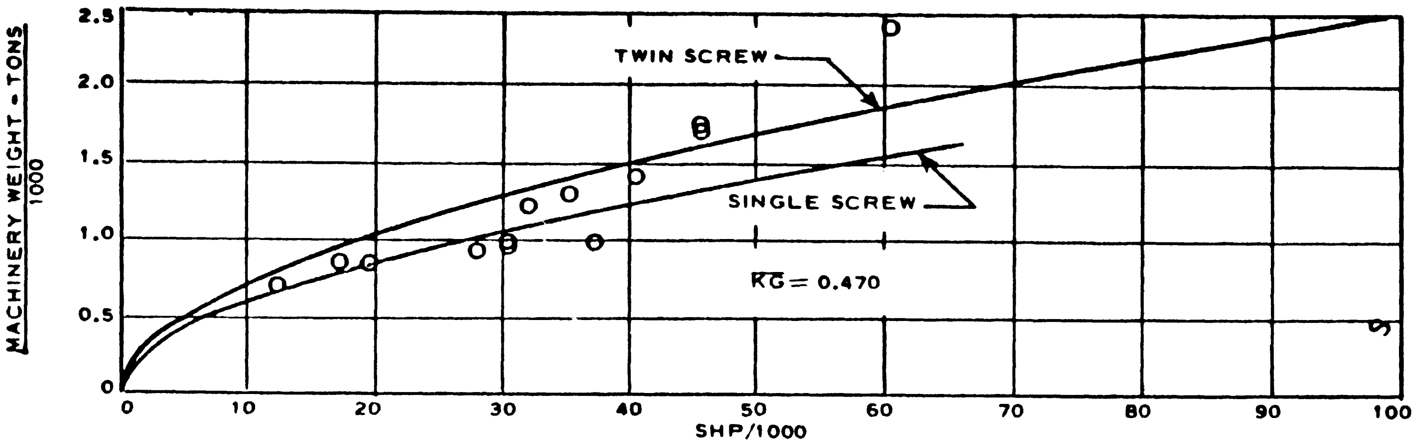
FIND OUTFIT WEIGHT $= 2800 \text{ TONNES} \times .985 \frac{LT}{TONNE}$

$$= 2758 \text{ LT}$$

THE SHIP DESIGN PROCESS

SOLUTION (CON'T)

FIGURE 6



9. ESTIMATE MACHINERY WEIGHT. FIRST ESTIMATE OF SHP WAS 40,000 HP WHICH GIVES:

MACHINERY WEIGHT = 1280 TONNES × .985 $\frac{LT}{TONNE}$

= 1261 LT

41-110

THE SHIP DESIGN PROCESS

SOLUTION (CON'T)

10. ESTIMATE FUEL WEIGHT:

TAKE FUEL RATE AT: $.50 \frac{LBS}{SHP\text{-}HR}$

NUMBER OF STEAMING HOURS $= \frac{10{,}000\ MI}{23\ MI/HR}$

$= 435\ HRS$

FUEL BURNED $= .50 \frac{LBS}{SHP\text{-}HR} \times 40{,}000\ SHP \times 435\ HRS$

$= 8{,}700{,}000\ LBS \qquad = 3884\ LT$

ADD 10% MARGIN $388\ LT$

$4272\ LT$

FUEL WEIGHT, ROUND TO $4300\ LT$

THE SHIP DESIGN PROCESS

SOLUTION (CON'T)

11. CHECK WEIGHTS:

LIGHT SHIP WEIGHT:

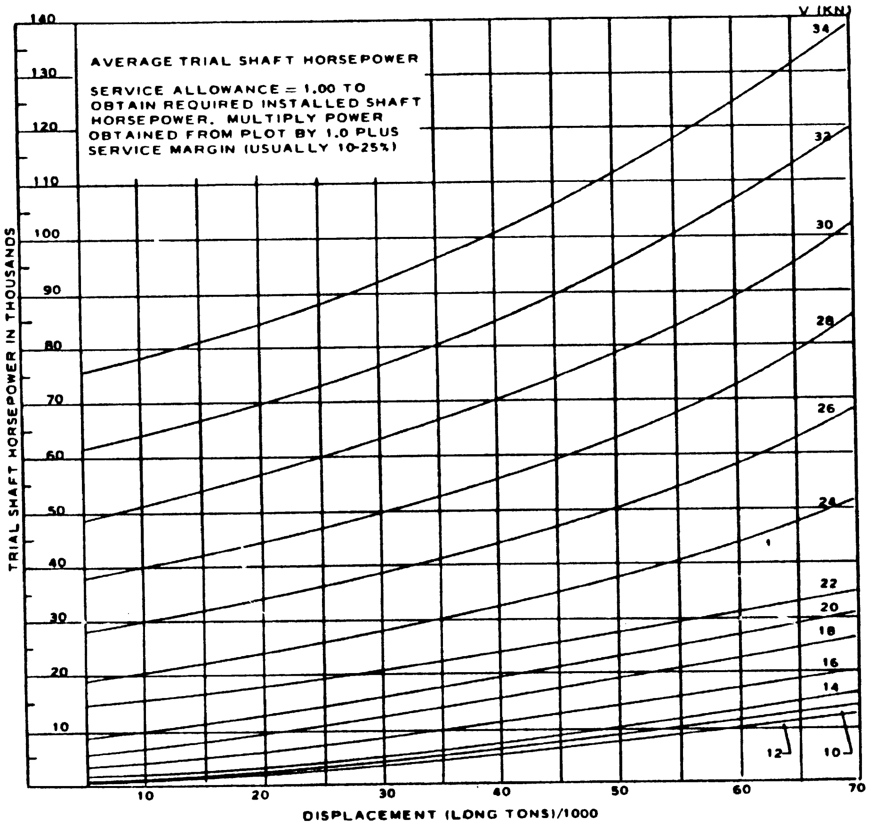
	WEIGHT TONNES	WEIGHT LT
STEEL WEIGHT	9,300	9,161
OUTFIT WEIGHT	2,800	2,758
MACH'Y WEIGHT	1,280	1,261
SUBTOTAL	13,380	13,180
MARGIN @ 3%	400	395
TOTAL LIGHT SHIP	13,780	13,575

	TONNES	LT
DEADWEIGHT:		
20 FT CONTAINERS (500 x 12 MT)	6,000	5,910
40 FT CONTAINERS (500 x 20 MT)	10,000	9,850
FUEL OIL	4,365	4,300
CREW & EFFECTS, POTABLE WATER	400	394
TOTAL DEADWEIGHT	20,765	20,454
FULL LOAD DISPLACEMENT	34 545	34 079

THE SHIP DESIGN PROCESS

SOLUTION (CON'T)

FIGURE 7



THE SHIP DESIGN PROCESS

SOLUTION (CON'T)

THIS REDUCES THE MACHINERY WEIGHT AND THE FUEL WEIGHT AND THUS THE DISPLACEMENT.

CONTINUE FOR A THIRD CUT ESTIMATE. THE RESULT IS:

$$\text{SHP} = 32{,}500 \text{ HP}$$
$$\text{FUEL WEIGHT} = 3{,}385 \text{ TONNES}$$
$$\Delta = 33{,}485 \text{ TONNES}$$

THE SHIP DESIGN PROCESS

SOLUTION (CON'T)

12. WE NOW HAVE A FIRST CUT AT THE DIMENSIONS, C_B, AND THE DISPLACEMENT.

    WE NOW CAN MAKE A SECOND CUT ESTIMATE OF THE POWERING AND FUEL WEIGHT.

    USING FIGURE 7 (NEXT GRAPHIC) AND A SERVICE POWER MARGIN FACTOR OF 1.25 FIND:

$$SHP = 27{,}000 \text{ HP}$$

THE SHIP DESIGN PROCESS

SOLUTION (CON'T)

13. CHECK THE DRAFT

$$C_B = \frac{35\Delta}{L \times B \times T}$$

$$T = \frac{35\Delta}{C_B \times L \times B}$$

$$T = \frac{35\ \text{FT}^3/\text{LT} \times 34{,}029\ \text{LT}}{.59 \times 705\ \text{FT} \times 100\ \text{FT}}$$

$$T = 28.6\ \text{FT}$$

THE SHIP DESIGN PROCESS

SOLUTION (CON'T)

14. CHECK KG. USE FORMULAE IN FIGS 4, 5, 6. THE RESULT IS:

	WEIGHT		KG
	TONNES	LT	(FT)
LIGHT SHIP	13,680	13,475	33.5
CARGO	16,000	15,760	46.6
FUEL	3,385	3,334	20.0
MISC.	400	394	27.2
TOTAL	33,465	32,963	38.4

SOLUTION (CON'T)

15. CHECK STABILITY. (GM_T)

WE HAVE KG. WE NEED KM = KB + BM

USE APPROXIMATE FORMULAE:

$$KB = .54\ T$$

$$I_T = C_{IT} \times L_{WL} \times B^3$$

$$C_{IT} = .937\ C_p - .0122$$

$$L_{WL} = 1.02\ L_{pp}$$

ALSO $BM = I_T / \nabla$

AND $GM_T = KB + BM - KG$

THE SHIP DESIGN PROCESS

SOLUTION (CON'T)

15. CHECK STABILITY. (GM_T)

WE HAVE KG. WE NEED KM = KB + BM

USE APPROXIMATE FORMULAE:

$$KB = .54\ T$$

$$I_T = C_{IT} \times L_{WL} \times B^3$$

$$C_{IT} = .937\ C_p - .0122$$

$$L_{WL} = 1.02\ L_{pp}$$

ALSO $BM = I_T / \nabla$

AND $GM_T = KB + BM - KG$

SOLUTION

15. CHECK STABILITY (CON'T)

THE RESULT IS:

$$GM_T = 3.3 \text{ FT} = .033B$$

GM_T IS GREATER THAN CRITERIA VALUE OF .025B AND IS SATISFACTORY

THE SHIP DESIGN PROCESS

CONCEPT DESIGN

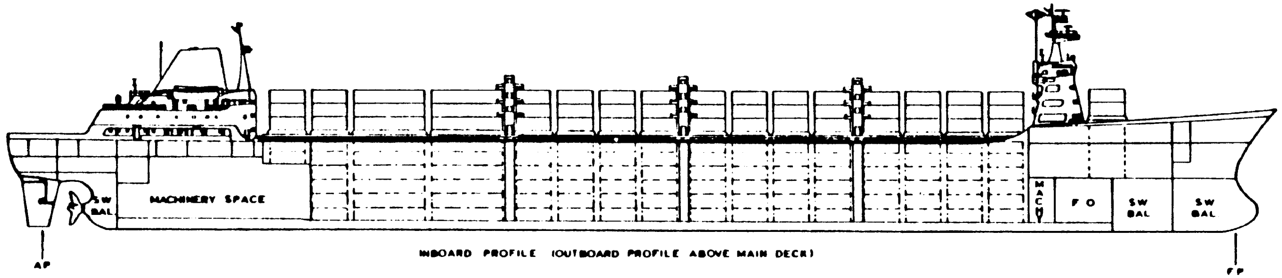
THE BASIC STARTING DIMENSIONS, POWERING AND DISPLACEMENT AND STABILITY OF THE DESIGN HAVE NOW BEEN SELECTED. AT THIS POINT IT IS ALSO ADVISABLE TO DEVELOP SMALL SCALE SKETCHES, SAY 8 1/2" x 11", OF THE GENERAL ARRANGEMENTS AND AN INBOARD PROFILE. THESE SHOULD ESTABLISH LOCATION AND DIMENSIONS OF THE MACHINERY SPACES AND SUPERSTRUCTURES, PRELIMINARY LOCATION OF BULKHEADS AND MAJOR TANKAGE.

A FIRST CUT COST ESTIMATE SHOULD ALSO BE PREPARED USING COARSE ESTIMATORS SUCH AS:

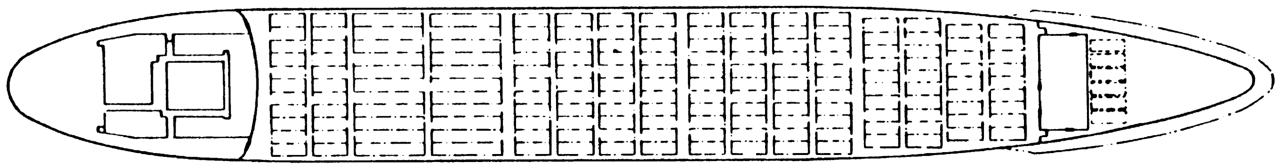
- $ PER TON OF ERECTED STEEL WEIGHT
- $ PER TON OF OUTFIT WEIGHT
- $ PER SHAFT HORSEPOWER FOR MACHINERY

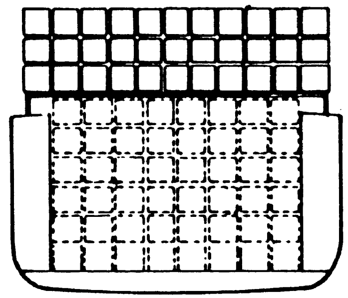
THE SHIP DESIGN PROCESS

CONCEPT DESIGN SKETCHES



INBOARD PROFILE (OUTBOARD PROFILE ABOVE MAIN DECK)


UPPER DECK


MIDSHIP OUTLINE

Unit Number: 42

Title: The ship design process - 3

Tape Running Time: 28^M 53^S

Reading Assignment: MSD, pp 263-269

Additional References:

Scope:

Preliminary and contract design phases are discussed further. The type and use of weight margins is introduced. The naval ship design process is described.

Key Points to Emphasize:

1. Gillmer makes good reading on the subject of naval ship design although the jargon has changed. But then the jargon will change again over the life-cycle of this course. The key thing is to avoid having the student become bogged down in a quagmire of acronyms. Emphasize that each new weapons system, including naval ships, must go through a series of gates or checkpoints where the need, the technical viability and the cost viability must be re-established before the system can proceed to the next checkpoint. The whole problem of defense systems procurement is enormously complex, and it is necessary to keep modifying the process as national conditions change, but the essential ingredients of the process remain surprisingly constant.

2. Emphasize the length of time it takes from the statement of the initial operational requirement to the time the ship joints the fleet -- ten years typically.

Suggested Problem Assignment: None

<u>THE SHIP DESIGN PROCESS</u>

<u>PRELIMINARY DESIGN</u>

THE NECESSARY INFORMATION TO START THE PRELIMINARY DESIGN HAS NOW BEEN DEVELOPED.

<u>STEPS IN PRELIMINARY DESIGN</u>

- DEVELOP A PRELIMINARY SET OF LINES AND OFFSETS
- USING THESE OFFSETS RUN A HYDROSTATICS COMPUTER PROGRAM TO GET <u>CURVES OF FORM</u> AND <u>FLOODABLE LENGTHS</u>
- USING <u>FLOODABLE LENGTH CURVES</u> CONFIRM OR ADJUST LOCATION OF SUBDIVISION BULKHEADS
- PERFORM A FIRST CUT <u>LOAD LINE</u> CALCULATION TO ESTABLISH REQUIRED <u>FREEBOARDS</u>

THE SHIP DESIGN PROCESS

PRELIMINARY DESIGN (CON'T)

- MAKE A FIRST CHECK OF TANKAGE, STOREROOM, REEFER CAPACITIES
- DEVELOP BLOCK GENERAL ARRANGEMENTS TO INSURE ADEQUATE DECK AREA FOR CONTROL SPACES, QUARTERS, MESSING AREAS, ETC.
- CHECK THE CUBIC FOR CARGO SPACE. CHECK ARRANGEMENT OF SPECIAL CARGO, E.G., CONTAINERS
- REFINE THE POWERING ESTIMATE USING STANDARD SERIES DATA OR OTHER MODEL TEST DATA. IF LINES ARE FIRM MODEL TESTS MAY BE CONDUCTED.

THE SHIP DESIGN PROCESS

PRELIMINARY DESIGN (CON'T)

- DEVELOP THE STRUCTURAL MIDSHIP SECTION DRAWING. DECK SCANTLING DRAWINGS AND TYPICAL FRAMES AND BULKHEADS MAY BE DEVELOPED AT THIS DESIGN LEVEL OR MAY BE DEFERRED TO THE CONTRACT DESIGN STAGE
- DEVELOP MACHINERY ARRANGEMENT DRAWING SHOWING LOCATION OF MAIN MACHINERY AND PRINCIPAL AUXILIARY MACHINERY ITEMS

THE SHIP DESIGN PROCESS

PRELIMINARY DESIGN (CON'T)

- MAKE A FIRST CUT ELECTRICAL LOAD ANALYSIS AND SIZE THE ELECTRICAL GENERATOR SETS
- FLUID SYSTEM SCHEMATICS ARE USUALLY DEVELOPED DURING THE CONTRACT DESIGN CYCLE, BUT IF THERE ARE MAJOR UNCERTAINTIES THESE SHOULD BE RESOLVED HERE
- IMPORTANT! AS THE DESIGN PROGRESSES THE WEIGHT ESTIMATE SHOULD GO THROUGH SEVERAL CYCLES OF REFINEMENT
- AN OUTLINE SPECIFICATION MAY BE DEVELOPED.

THE SHIP DESIGN PROCESS

CONTRACT DESIGN

BY THE END OF THE PRELIMINARY DESIGN CYCLE MAJOR DESIGN ISSUES SHOULD HAVE BEEN RESOLVED AND THERE SHOULD BE NO UNPLEASANT SURPRISES IN THE CONTRACT DESIGN CYCLE.

EMPHASIS SHOULD NOW SHIFT TO THE PRODUCTION OF CONTRACT DRAWINGS AND SPECIFICATIONS.

OFTEN, THE SAME DRAWINGS DEVELOPED DURING THE PRELIMINARY DESIGN CYCLE ARE CARRIED INTO CONTRACT DESIGN AND ADDITIONAL DETAILS ADDED.

ADDITIONAL DRAWINGS ARE PREPARED AS NECESSARY.

THE WEIGHT ESTIMATE IS FURTHER REFINED

<u>DAMAGED STABILITY</u> IS EXAMINED. A PRELIMINARY <u>TRIM AND STABILITY BOOKLET</u> IS PREPARED.

THE STRENGTH AND STRUCTURE OF SHIPS

DESIGN MARGINS

THERE ARE TWO TYPES OF MARGINS WHICH ARE APPLIED TO THE WEIGHT AND KG ESTIMATES DURING THE DESIGN PHASE.

- DESIGN AND CONSTRUCTION MARGINS
- FUTURE GROWTH MARGINS.

DESIGN AND CONSTRUCTION MARGINS ARE PROVIDED TO ACCOUNT FOR-

- PREDICTION ERRORS IN ESTIMATING
- UNKNOWNS AT THE TIME A PREDICTION IS MADE
- MINOR CHANGES IN THE DESIGN DURING CONSTRUCTION.

THE STRENGTH AND STRUCTURE OF SHIPS

DESIGN MARGINS

FUTURE GROWTH MARGINS ARE MARGINS PROVIDED IN A NEW SHIP WHEN IT IS DELIVERED TO THE USER. THIS MARGIN IS INTENDED TO PROVIDE FOR BOTH FUTURE MODIFICATIONS TO THE SHIP AND ALSO FOR UNPLANNED (BUT INEVITABLE) WEIGHT GROWTH DURING THE SERVICE LIFE OF THE SHIP.

FUTURE GROWTH MARGINS MAY VARY FROM 5% (TIGHT) TO 15% (HIGH).

DESIGN MARGINS (CON'T)

THE U.S. NAVY HAS A FORMAL MARGIN POLICY WHICH IS USED IN ASSIGNING WEIGHT AND KG. MARGINS TO EACH WEIGHT CATEGORY.

TYPICALLY THE SUM OF THE MARGINS ON LIGHT SHIP WEIGHT IS 10% - 15%.

THE SHIP DESIGN PROCESS

NAVAL SHIP DESIGN

NAVAL SHIP DESIGN CYCLES ARE MUCH MORE FORMALIZED BECAUSE OF THE COMPLEX REQUIREMENTS OF INTEGRATING THE ACQUISITION OF ALL TYPES OF DEFENSE SYSTEMS WITH THE ANTICIPATED FUTURE BUDGET APPROPRIATIONS, AND BECAUSE OF THE LONG RANGE PLANNING THAT IS REQUIRED.

FROM THE BEGINNING OF DESIGN STUDIES TO ACCEPTANCE OF A SHIP CLASS IN SERVICE MAY TAKE TEN YEARS. ADVANCE PLANNING STUDIES, CALLED CONFORM STUDIES CAN PRECEDE THIS BY ANOTHER FIVE YEARS.

THE SHIP DESIGN PROCESS

NAVAL SHIP DESIGN

THE DESIGN PROCESS IS INITIATED BY A DOCUMENT FROM THE CHIEF OF NAVAL OPERATIONS (CNO), THE TENTATIVE OPERATIONAL REQUIREMENT (TOR) WHICH DESCRIBES THE REQUIRED CAPABILITIES OF THE NAVAL SYSTEM IN GENERAL TERMS.

THE TOR IS REVIEWED BY THE SHIP CHARACTERISTICS AND IMPROVEMENT BOARD (SCIB), A PANEL OF CNO EXECUTIVE BOARD (CEB), WHICH, WHEN APPROVED BY CNO, IS TRANSMITTED TO THE NAVAL SEA SYSTEMS COMMAND (NAVSEA).

NAVSEA CONDUCTS FEASIBILITY STUDIES WHICH IDENTIFIES ALTERNATIVES WITH THE CAPABILITIES, COSTS, AND DEVELOPMENT TIMES TO SATISFY THE TOR. THE DOCUMENT GENERATED IS A DEVELOPMENT OPTIONS PAPER (DOP).

THE SHIP DESIGN PROCESS

NAVAL SHIP DESIGN

THE DOP DESCRIBES THE VARIOUS OPTIONS IN TERMS OF SYSTEMS WHICH MAY INCLUDE A MIX OF COMBATANTS, AUXILIARIES, AIRCRAFT, AMPHIBIOUS CRAFT, HIGH PERFORMANCE VEHICLES SUCH AS ACV'S, SES, ETC.

THE OFFICE OF THE CHIEF OF NAVAL OPERATIONS (OPNAV) SELECTS THE SYSTEM WHICH BEST MATCHES THE REQUIRED CAPABILITIES TO THE EXPECTED AVAILABLE FUNDING. OPNAV MAY ISSUE A JUSTIFICATION FOR MAJOR SYSTEMS NEW START (JMSNS), OR AN OPERATIONAL REQUIREMENT (OR) FOR A MORE LIMITED PROGRAM.

FOR MAJOR PROGRAMS THE JMSNS OR THE OR IS REVIEWED BY THE SCIB AND THE DEFENSE RESOURCES BOARD (DRB) WHICH RECOMMENDS TO THE SECRETARY OF DEFENSE (SECDEF) WHETHER TO PROCEED FURTHER WITH THE PROCUREMENT.

THE SHIP DESIGN PROCESS

NAVAL SHIP DESIGN

FOR SMALLER PROGRAMS APPROVAL FOR PROGRAM INITIATION MAY BE MADE BY THE SECRETARY OF THE NAVY (SECNAV).

UPON RECEIPT OF AUTHORIZATION OPNAV BEGINS DEVELOPMENT OF A DRAFT TOP LEVEL REQUIREMENT (TLR) DOCUMENT WHICH IS THE PRIMARY STATEMENT OF DESIGN REQUIREMENTS. CONCURRENTLY NAVSEA BEGINS DEVELOPMENT OF THE PRELIMINARY DESIGN. THE SCIB REVIEWS THIS DESIGN AND MAKES RECOMMENDATIONS TO CNO. UPON APPROVAL OF THE TLR NAVSEA (OR ONE OF ITS DESIGN CONTRACTORS) ENTERS INTO THE CONTRACT DESIGN PHASE. TOP LEVEL SPECIFICATIONS (TLS) ARE DEVELOPED IN RESPONSE TO THE TLR. AT THE CONCLUSION OF THE CONTRACT DESIGN A CONTRACT DESIGN REPORT (CDR) IS ISSUED.

THE SHIP DESIGN PROCESS

NAVAL SHIP DESIGN

FURTHER REVIEWS ARE CONDUCTED AT THREE DIFFERENT MILESTONES AS THE PROGRAM CONTINUES. IF THE PROGRAM EXPERIENCES DIFFICULTY IN ACHIEVING ITS TECHNICAL OBJECTIVES, COST OBJECTIVES OR READINESS OBJECTIVES IT MAY BE CURTAILED OR CANCELED AT ANY ONE OF THESE MILESTONES.

FINALLY, THE DETAIL DESIGN AND CONSTRUCTION PHASE IS BEGUN FOR THE LEAD SHIP. THE REVIEW AT MILESTONE III IS CONDUCTED BEFORE PROCEEDING WITH CONSTRUCTION OF FOLLOW SHIPS IN THE CLASS.

THE SHIP DESIGN PROCESS

NAVAL SHIP DESIGN

WHAT TO REMEMBER

- THE OPERATIONAL REQUIREMENT (OR) AND THE TOP LEVEL REQUIREMENT ARE THE NAVY'S STATEMENT OF MISSION REQUIREMENTS.
- THE DESIGN CYCLES ARE (1) FEASIBILITY STUDIES, (2) PRELIMINARY DESIGN, (3) CONTRACT DESIGN WHICH ARE DONE BY NAVSEA OR ONE OF ITS CONTRACTORS, (4) DETAIL DESIGN IS DONE BY THE LEAD SHIP YARD.
- THE DESIGN IS REVIEWED AND APPROVED AT VARIOUS STAGES BY THE SHIP CHARACTERISTICS AND IMPROVEMENT BOARD (SCIB) FOR CNO AND BY THE DEFENSE RESOURCES BOARD (DRB) FOR SECDEF, OR BY SECNAV FOR SMALLER PROGRAMS.
- TYPICALLY, THE ENTIRE PROCESS TAKES TEN YEARS -- A LITTLE LESS FOR SMALLER PROGRAMS -- MORE FOR PROGRAMS WHICH REQUIRE A GREAT DEAL OF DEVELOPMENT.

BASIC NAVAL ARCHITECTURE

Unit Number: 43

Title: Shipbuilding methods - 1

Tape Running Time: 31^{M} 13^{S}

Reading Assignment: MSD, pp 271-287

Additional References: SDC, pp 609-629

Engineering for Ship Production (ESP), 1986, T. Lamp, University of Michigan, pp 1-88

Ship Production (SP), 1988, Cornell Maritime, pp 108-235

Scope:

This unit emphasizes the role of the computer in modern ship design and shipbuilding technology. CAD/CAM applications are discussed. Use of computers in scheduling, work measurement, progress reporting, inventory control and other applications is discussed.

Key Points to Emphasize:

1. There is a substantial amount of background material which the instructor should read in preparation for Units 43, 44 and 45. This includes Chapters 16 and 17, SDC. ESP, pp 1-88 provides a good introduction to modern shipbuilding technology; however the entire book should be studied by persons intending to become shipbuilding professionals. A similar comment applies to SP, but Chapters 4 and 5 are most relevant to the subject matter in these units.

2. Throughout these three units the instructor should emphasize three things:

   a) need for the adoption of a positive attitute toward change in the shipbulding industry
   b) need for improvement in work quality to become quality-competitive with other countries
   c) need for the reduction in work content of shipbuilding operations to become cost-competitive with other countries.

3. This is an overview of the use of computers in ship design and construction. The instructor should supplement the video with a description of the computer capabilities and facilities in his shipyard.

Suggested Problem Assignment: None

SHIPBUILDING METHODS

CAD/CAM

TODAY COMPUTER-AIDED DESIGN (CAD) AND COMPUTER-AIDED MANUFACTURING (CAM) IS AN INTEGRAL PART OF EVERY PHASE OF SHIP DESIGN AND CONSTRUCTION.

COMPUTER-AIDED DESIGN INCLUDES THE USE OF COMPUTER PROGRAMS BOTH IN ANALYSIS AND DRAFTING IN THE VARIOUS DESIGN PHASES.

COMPUTER-AIDED MANUFACTURING INCLUDES THE USE OF THE COMPUTER IN VIRTUALLY EVERY ASPECT OF SHIP CONSTRUCTION, BUT THE EXTENT TO WHICH COMPUTER IS USED, THE STATE-OF-THE-ART AND THE SOPHISTICATION OF COMPUTER USAGE VARIES WIDELY BETWEEN SHIPYARDS.

SOME EXAMPLES OF CAD/CAM AND COMPUTER APPLICATIONS FOLLOW.

CAD/CAM (CON'T)

COMPUTERS PROGRAMS FOR DESIGN ANALYSES:

- LINES FAIRING
- INTACT AND DAMAGED CONDITION HYDROSTATICS
- SHIP RESISTANCE AND POWERING PREDICTION
- PROPELLER DESIGN CHARACTERISTICS FROM
  - PROPELLER STANDARD SERIES
  - LIFTING LINE/LIFTING SURFACE THEORY
- STRUCTURAL DESIGN
  - MIDSHIP SECTION DESIGN
  - SCANTLING CALCULATIONS BASED ON STRUCTURAL FORMULAE
  - STRUCTURAL ANALYSIS AND OPTIMIZATION USING FINITE ELEMENT TECHNIQUES

SHIPBUILDING METHODS

CAD/CAM

DESIGN ANALYSIS PROGRAMS (CON'T)

- SHIP MOTION PREDICTION PROGRAMS
  - FREQUENCY DOMAIN
  - TIME DOMAIN
- MANEUVERING PROGRAMS
  - MANEUVERING CHARACTERISTICS
  - RUDDER DESIGN
- VIBRATION ANALYSES
  - PROPELLER INDUCED
  - MACHINERY INDUCED
  - SHOCK INDUCED

SHIPBUILDING METHODS

CAD/CAM

DESIGN ANALYSIS PROGRAMS (CON'T)

- MARINE ENGINEERING PROGRAMS
  - HEAT BALANCE
  - ELECTRIC LOAD ANALYSIS
  - PIPING SYSTEM DESIGN
  - HVAC SYSTEM LOAD ANALYSIS AND DESIGN
- DESIGN SYNTHESIS AND OPTIMIZATION
  - VARIOUS SHIP TYPES -- DD, CV, AUXILIARIES, SWATH, ETC.
- DECK ARRANGEMENT PROGRAMS
  - INPUT COORDINATES OF BULKHEADS AND PARTITIONS -- OUTPUT DECK AREAS CUBICS.

SHIPBUILDING METHODS

CAD/CAM

THE CONCEPT DESIGN PROCESS LENDS ITSELF TO COMPUTERIZATION.

MANY SUCH DESIGN SYNTHESIS COMPUTER PROGRAMS HAVE BEEN DEVELOPED FOR VARIOUS SHIP TYPES. DIMENSIONS AND PROPORTIONS ARE SYSTEMATICALLY VARIED AND LITERALLY HUNDREDS OF CANDIDATE DESIGN SOLUTIONS MAY BE GENERATED. THE PROGRAM WILL OFTEN CONTAIN SOME TYPE OF OPTIMIZATION CRITERIA WHICH WILL SELECT THE OPTIMUM SOLUTIONS.

MOST DESIGN SYNTHESIS PROGRAMS ARE CLOSELY HELD BY THE NAVY OR PRIVATE FIRMS AND ARE NOT AVAILABLE TO THE SHIP DESIGN COMMUNITY AT LARGE.

CAD/CAM

COMPUTER-AIDED DRAFTING

THERE ARE A NUMBER OF COMMERCIALLY AVAILABLE COMPUTER-AIDED DRAFTING PROGRAMS WHICH CAN BE APPLIED TO ALMOST ANY FORM OF DRAFTING. TYPICAL PROGRAMS INCLUDE PRODESIGN, AUTOCAD, AUTOKON, COMPUTER VISION, AND MANY OTHERS.

ATTRACTIVE FEATURES:

- ONCE A LIBRARY OF SYMBOLS HAS BEEN GENERATED DRAWINGS CAN BE PREPARED IN MUCH LESS TIME THAN MANUAL DRAFTING.
- DRAWINGS CAN BE PRINTED AT ANY DESIRED SCALE.
- CHANGES CAN BE MADE QUICKLY.
- PARTS LISTS AND BILLS OF MATERIAL CAN BE GENERATED EASILY.
- PICTORIAL VIEWS CAN BE GENERATED FROM TWO VIEW ORTHOGRAPHIC PROJECTIONS.
- INTERFERENCES BETWEEN SYSTEMS -- E.G,. PIPING AND VENTILATION RUNS -- CAN BE READILY IDENTIFIED.

GULF PACIFIC CRUISE LINES

CRUISE SHIP OUTBOARD PROFILE

43.2

SHIPBUILDING METHODS

CAD/CAM

COMPUTER PROGRAMS FOR SHIP PRODUCTION

THERE ARE PROGRAMS WHICH CAN BE PRUCHASED OR LEASED FOR SHIP PRODUCTION USE. LARGER SHIPYARDS MAY HAVE THEIR OWN PROPRIETARY PROGRAMS.

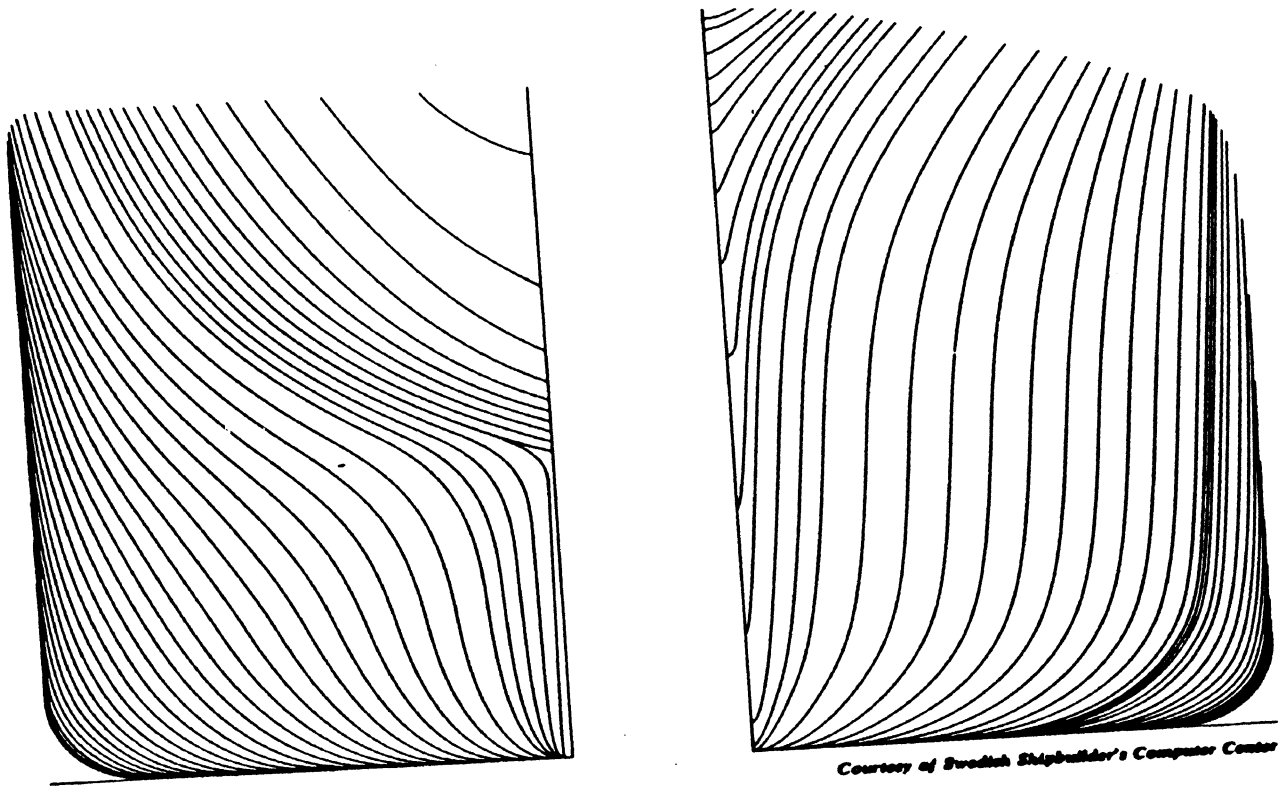
SOME APPLICATIONS INCLUDE:

- LOFTING. FULL SCALE MANUAL LOFTING OF LINES AND GENERATION OF TMEPLATES IS RAPIDLY DISAPPEARING. LINES ARE FAIRED TO AN EXTREMELY HIGH DEGREE OF ACCURACY BY LINES FAIRING COMPUTER PROGRAMS. THE SHAPE OF INTERSECTIONS OF PLANES SUCH AS TRANSVERSE FRAMES AND BULKHEADS AND DECKS WITH THE MOLDED HULL SURFACE CAN BE GENERATED.

SHIPBUILDING METHODS

CAD/CAM

LINES FAIRING AND LOFTING



Courtesy of Swedish Shipbuilder's Computer Center

SHIPBUILDING METHODS

CAD/CAM

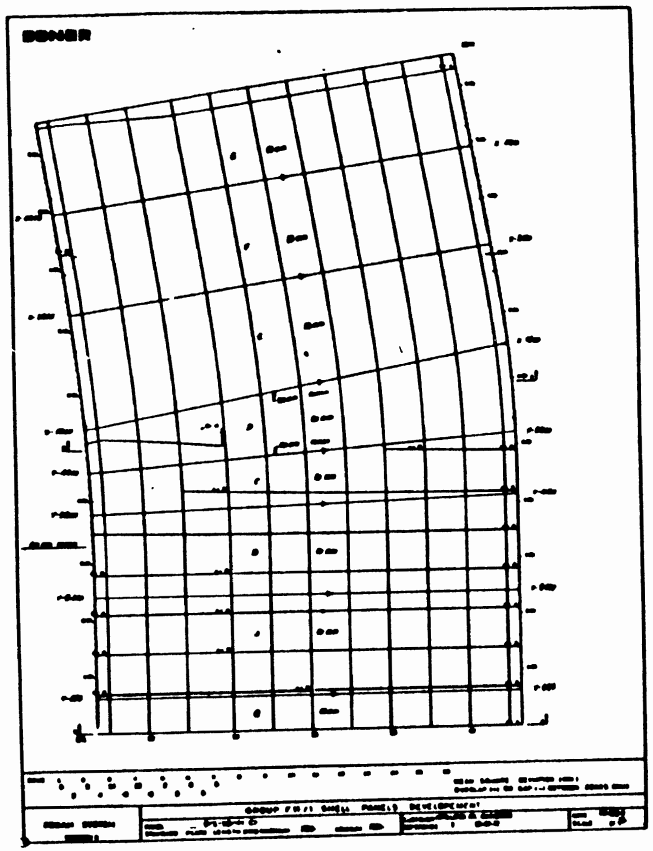
SHIP PRODUCTION PROGRAMS

- SHELL DEVELOPMENT. A SHELL EXPANSION CAN BE GENERATED AND INDIVIDUAL SHELL PLATES DEVELOPED IN THEIR FLAT SURFACE SHAPE.
- INTEGRATED N/C PRODUCTION SYSTEMS. THESE PROGRAMS CAN BE USED TO GENERATE THE SHAPES OF ALL PLATE STEEL PARTS. NESTING OF VARIOUS PARTS ON STEEL PLATES FOR MINIMUM WASTAGE CAN BE DONE AUTOMATICALLY OR WITH MANUAL INTERCESSION. PARTS NUMBERS, INVENTORY CONTROL NUMBERS, BILLS OF MATERIALS, AND OTHER PRODUCTION DOCUMENTATION CAN BE PRODUCED. N/C TAPES CAN BE FED DIRECTLY INTO N/C CUTTING MACHINES AND WELDING MACHINES TO CONTROL AUTOMATIC CUTTING AND WELDING OPERATIONS.

SHIPBUILDING METHODS

CAD/CAM

SHELL PLATE DEVELOPMENT



SHIPBUILDING METHODS

PRODUCTION CONTROL AND MANAGEMENT SYSTEMS

SCHEDULE AND COST MONITORING AND CONTROL. THE OPERATION OF THIS FUNCTION VARIES WIDELY BETWEEN SHIPYARDS; HOWEVER, IT IS NECESSARY TO TRACK MANHOURS EXPENDED VERSUS PERCENTAGE COMPLETION FOR ASSEMBLY UNITS IN THE PRODUCTION SCHEDULE. IT IS IMPORTANT TO DETECT POSSIBLE SCHEDULE DELAYS AND COST OVERRUNS AT ANY EARLY STAGE SO THAT TIMELY CORRECTIVE ACTION MAY BE TAKEN. ASSEMBLY AND REPORTING OF ALL THIS INFORMATION IS DONE BY COMPUTER PROGRAM.

SHIPBUILDING METHODS

CAD/CAM

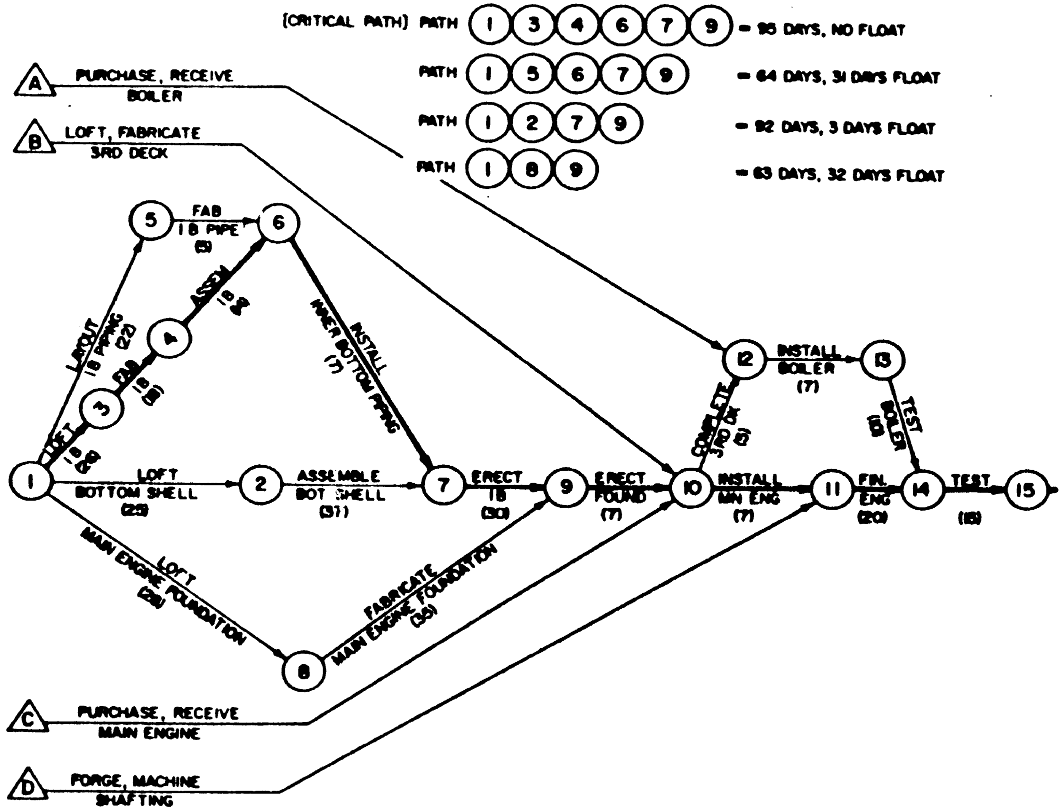
SHIP PRODUCTION PROGRAMS (CON'T)

SCHEDULING NETWORK ANALYSIS. THE VARIOUS OPERATIONS THAT MAKE UP A PROJECT, THE SQUENCE AND LENGTH OF TIME REQUIRED FOR EACH OPERATION ARE INPUT TO PROGRAMS SUCH AS PERT (PROGRAM EVALUATION AND REVIEW TECHNIQUE) AND CPM (CRITICAL PATH METHOD) AND THE CRITICAL PATH DETERMINED. THE CRITICAL PATH IS THE LONGEST OF THE PATHS THROUGH THE SCHEDULE AND IS THE PATH WHICH GOVERNS THE DELIVERY SCHEDULE, BY SHORTENING THE LENGTH OF TIME REQUIRED FOR EVENTS ON THE CRITICAL PATH THE DELIVERY SCHEDULE CAN BE ENHANCED.

SHIPBUILDING METHODS

CAD/CAM

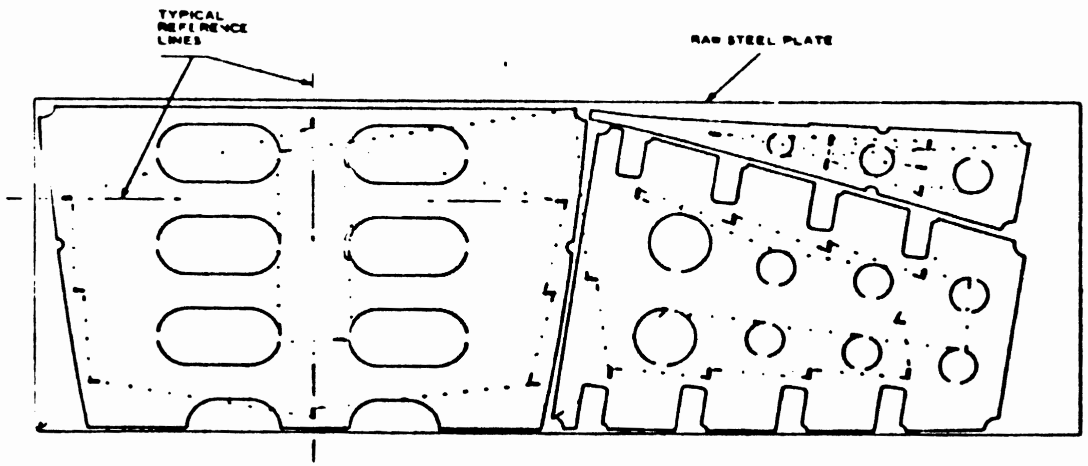
SCHEDULING NETWORKS AND CRITICAL PATH ANALYSIS



SHIPBUILDING METHODS

CAD/CAM

PARTS NESTING



SHIPBUILDING METHODS

PRODUCTION CONTROL AND MANAGEMENT SYSTEMS (CON'T)

WORK MEASUREMENT AND ANALYSIS. TRADITIONALLY THE WORK CONTENT IN VARIOUS SHIPYARD OPERATIONS ARE BASED ON RATHER SIMPLE WORK CONTENT MODELS, E.G,. MANHOURS PER TON OF STEEL FOR SPECIFIC TYPES OF STEEL OPERATIONS, MAN-HOURS PER RUNNING FOOT OF WELD, ETC. IN FACT, THE WORK CONTENT OF VARIOUS OPERATIONS MAY BE MUCH MORE COMPLEX. COMPUTER PROGRAMS EXIST FOR THE ANALYSIS AND MEASUREMENT OF THE WORK CONTENT OF SHIPYARD OPERATIONS, BUT THE SPECIFIC INPUT DATA MUST BE DEVELOPED BY THE SHIPYARD.

SHIPBUILDING METHODS

PRODUCTION CONTROL AND MANAGMENT SYSTEMS

ORDERING AND INVENTORY CONTROL. STEEL, EQUIPMENT, PARTS, SUBCONTRACTED WORK ITEMS (E.G., CASTINGS AND FORGINGS) MUST BE ORDERED WITH DELIVERY PLANNED SO THAT THE MATERIAL WILL ARRIVE WHEN NEEDED SO THAT STORAGE REQUIREMENTS ARE MINIMIZED. WHEN RECEIVED THE MATERIAL IS ASSIGNED VARIOUS TYPES OF NUMBERS -- PARTS NUMBERS, INVENTORY CONTROL NUMBERS, PRODUCTION CONTROL NUMBERS, DEPENDING ON THE PARTICULAR SHIPYARD SYSTEM. THESE NUMBERS ARE USED IN INVENTORY TRACKING, IN STORAGE AND TO CONTROL DELIVERY OF THE PART TO THE LOCATION IN THE SHIPYARD WHERE AND WHEN IT IS NEEDED. COMPUTER PROGRAMS ARE USED HEAVILY IN PERFORMING THESE FUNCTIONS.

SHIPBUILDING METHODS

WEIGHT MANAGEMENT AND CONTROL

FOR NAVAL SHIPS, PARTICULARLY COMBATANTS, CONTROL OF THE WEIGHT OF THE SHIP DURING CONSTRUCTION AND AT DELIVERY IS AN IMPORTANT CONSTRUCTION REQUIREMENT.

THE NAVY REQUIRES THAT THE SHIPYARD HAVE IN PLACE AN APPROVED WEIGHT CONTROL PROGRAM ADMINISTERED BY A WEIGHT CONTROL MANAGER AND SUPPORTED BY A WEIGHT CONTROL GROUP TO MONITOR AND CONTROL THE WEIGHT OF THE SHIP AS CONSTRUCTION PROGRESSES.

A DESIGN AND BUILDING WEIGHT MARGIN IS ADDED TO THE CONTRACT DESIGN WEIGHT ESTIMATE. THIS MARGIN IS INTENDED TO ACCOUNT FOR SMALL ERRORS AND OMISSIONS IN THE ESTIMATE AND FOR VARIATIONS IN ESTIMATED WEIGHTS DUE TO MILL TOLERANCE, WEIGHT DEVIATIONS IN SUBCONTRACTED ITEMS ETC..

SHIPBUILDING METHODS

WEIGHT MANAGEMENT AND CONTROL (CON'T)

AS CONSTRUCTION PROGRESSES CUT PLATES, SUBASSEMBLIES, CONSTRUCTION MODULES AND DELIVERED EQUIPMENT ITEMS ARE ACTUALLY WEIGHED. NOT EVERY ITEM MAY BE WEIGHED BUT A SUFFICIENTLY LARGE AND DIVERSE SAMPLING IS MADE SO THAT STATISTICALLY RELIABLE TRENDS ARE ESTABLISHED. WEIGHT TRACKING IS DONE BY SWBS GROUPS AND THE CONSUMPTION OF THE D&B MARGIN IN EACH GROUP IS PLOTTED AS A FUNCTION OF COMPLETION.

COMPUTER PROGRAMS ARE THE CHIEF TOOL USED IN ESTIMATING THE WEIGHT OF THE UNITS TO BE WEIGHED AND TO CLASSIFY AND REPORT RESULTS.

BASIC NAVAL ARCHITECTURE

Unit Number: 44

Title: Shipbuilding methods - 2

Tape Running Time: $43^M\ 11^S$

Reading Assignment: MSD, pp 185-203

Additional References: SDC, pp 629-656, 358-371

ESP, pp 1-7

Scope:

Basic shipyard operations and processes are described, including cutting, cold forming and hot forming. Principal types of welding processes are described. Older shipbuilding methods are described and contrasted with modern methods. Necessity of integrating design and production is cited. Zone outfitting and modular construction are described. Detail design features to improve producibility are outlined. Production flow in a shipyard is discussed.

Key Points to Emphasize:

1. The instructor should relate the discussion of topics in this unit to his own shipyard wherever possible. Use photo slides and transparencies showing shipyard facilities, processes and process flow for illustration.

2. Wherever possible, indicate needed areas of change in the national shipbuilding picture to the competitiveness of the industry.

Suggested Problem Assignment: None

SHIPBUILDING METHODS

STEEL CUTTING AND FORMING PROCESSES

SHIPYARD OPERATIONS ON STEEL PLATES TO FORM STRUCTURAL PIECES FALL INTO THREE GENERAL CATEGORIES:

- CUTTING OPERATIONS
  - OXY-ACETYLENE
  - PLASMA ARC
  - AIR CARBON ARC
- COLD FORMING OPERATIONS
  - ROLLING
  - PRESSING
- HOT FORMING OPERATIONS
  - FURNACING
  - LINE HEATING

SHIPBUILDING METHODS

STEEL CUTTING AND FORMING PROCESSES (CON'T)

- OXYGEN CUTTING UTILIZES OXYGEN AND A FUEL GAS, TYPICALLY ACETYLENE TO BURN THRU THE STEEL. LARGE STEEL PLATES ARE PLACED ON A BED. MULTIPLE CUTTING HEADS ARE MOUNTED ON A CARRIAGE WHICH TRAVERSES THE PLATE. N/C (NUMERICALLY CONTROLLED) MACHINES CAN BE PROGRAMMED TO CUT COMPLEX PLATE PARTS AUTOMATICALLY.

- PLASMA-ARC CUTTING HEADS ARE ALSO USED ON N/C MACHINES. PLASMA-ARC CUTTING IS FASTER AND CLEANER, BUT THE SPEED ADVANTAGE DECREASES AS THE PLATE THICKNESS INCREASES. OFTEN, WATER BASINS ARE INSTALLED DIRECTLY BELOW THE PLATE LINE TO REDUCE NOISE AND FUMES.

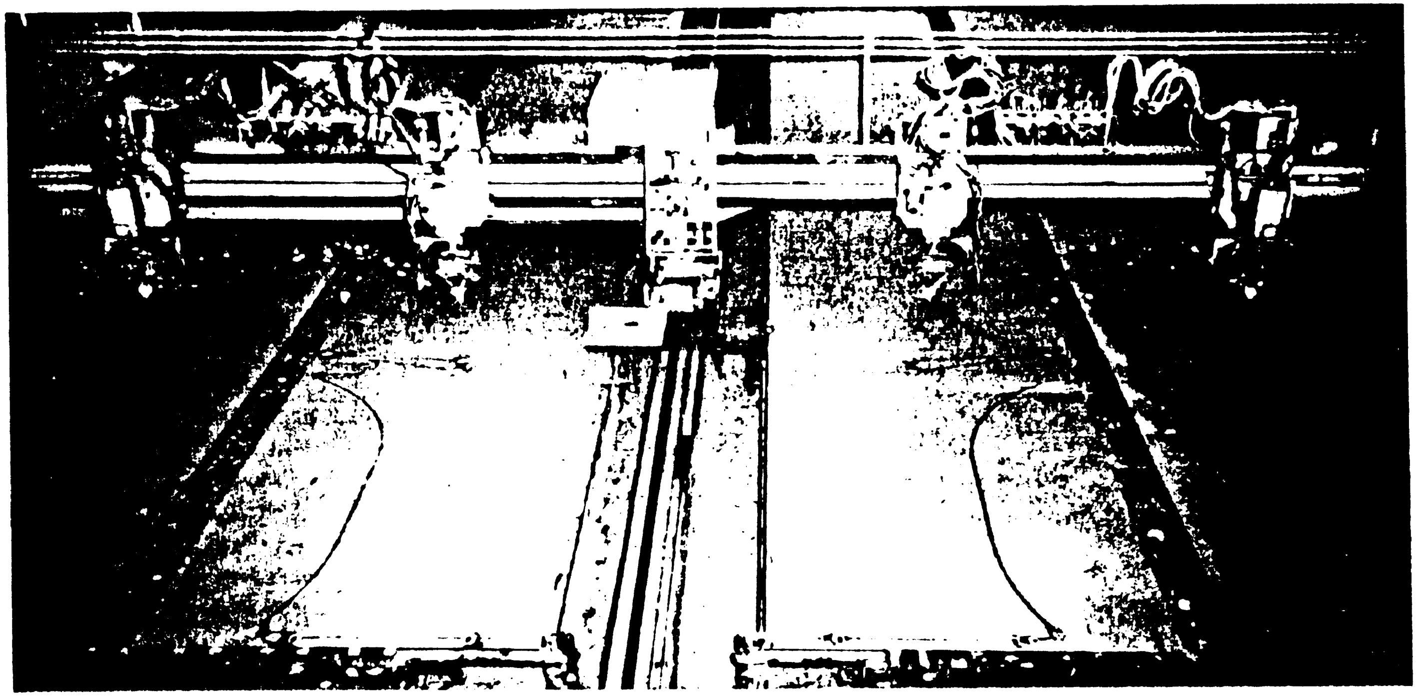
SHIPBUILDING METHODS

STEEL CUTTING AND FORMING PROCESSES (CON'T)

- AIR CARBON ARC CUTTING IS USED TOGETHER WITH HIGH PRESSURE AIR FOR BACK GOUGING AND EXCAVATION OF DEFECTIVE STEEL AREAS. THE HIGH PRESSURE AIR BLOWS AWAY MOLTEN METAL AND KEEPS THE TEMPERATURE OF THE SURROUNDING MATERIAL LOWER THAN WITH THE OXY-ACETYLENE METHOD. THIS IS PARTICULARLY USEFUL IN EXCAVATING DEFECTS WHERE THE EXTENT OF WELD CRACKS BELOW THE SURFACE CAN READILY BE SEEN.

SHIPBUILDING METHODS

N/C CONTROLLED AUTOMATIC BURNING MACHINE



44

SHIPBUILDING METHODS

STEEL CUTTING AND FORMING PROCESSES

- COLD FORMING INCLUDES:

  1. ROLLING, AND
  2. PRESSING

- ROLLING IS USED TO FORM STEEL PLATES INTO SHAPES WITH ONLY ONE DEGREE OF CURVATURE, SUCH AS BILGE PLATES IWO PARALLEL MIDDLE BODY. THE PLATES ARE PASSED THROUGH BENDING ROLLS WHICH CONSIST OF ONE LARGE ROLLER ON TOP AND TWO SMALLER ROLLERS ON THE BOTTOM.

SHIPBUILDING METHODS

STEEL CUTTING AND FORMING PROCESSES (CON'T)

- PLATES MAY BE SHAPED IN HYDRAULIC BENDING PRESSES WITH HYDRAULIC RAMS CONTROLLING THE BENDING FORCE. SOME BENDING PRESSES ARE NUMERICALLY CONTROLLED. SIDE FRAMES AND OTHER CURVED SHAPES MAY BE FORMED BY APPLYING AN ADJUSTABLE STROKE RAM TO THE PIECE LOCATED BETWEEN FIXED SUPPORTS.

- BY ITS VERY NATURE COLD FORMING WILL INDUCE STRESSES IN THE OUTER FIBERS OF THE MATERIAL. IF THE RADIUS OF THE BEND IS VERY SHARP THE STRESSES PRODUCED MAY BE UNACCEPTABLE FOR USE IN A HIGHLY STRESSED AREA. IN THIS EVENT IT MAY BE NECESSARY TO STRESS RELIEVE THE PIECE BY LOCAL HEATING OR BY FURNACING.

SHIPBUILDING METHODS

STEEL CUTTING AND FORMING PROCESSES (CON'T)

HOT FORMING

- WHERE COLD FORMING PROCESSES CAN NOT BE USED THE PLATE OR SHAPE MAY BE FURNACED TO A RED HEAT. THE FLOOR AREA IN FRONT OF THE FURNACE IS MADE OF PERFORATED CAST IRON BLOCKS. DRIFT PINS AND DOGS ARE INSTALLED TO PROVIDE THE FORM FOR THE FURNACED PLATE OR SHAPE AND TO HOLD IT IN PLACE.

FOR PLATES WITH TWO-DIMENSIONAL CURVATURE A JIG MUST BE FABRICATED AND THE PLATE FORCED INTO THE SHAPE DEFINED BY THE JIG.

FURNACING IS AN EXPENSIVE AND LABOR-INTENSIVE PROCESS. ONE OBJECTIVE OF DESIGN IS TO MINIMIZE THE USE OF FURNACED PLATES AND SHAPES.

SHIPBUILDING METHODS

STEEL CUTTING AND FORMING PROCESSES (CON'T)

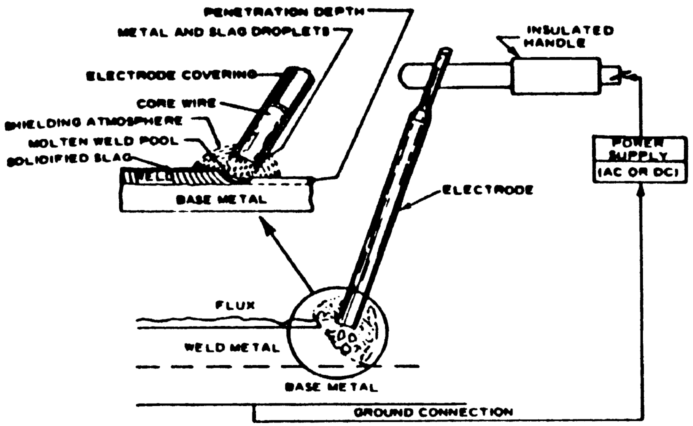
- PLATES WITH A LIMITED AMOUNT OF COMPUND CURVATURE MAY ALSO BE FORMED BY A PROCESS KNOWN AS LINE HEATING. A COMPLEX PATTERN OF HEATING LINES IS MARKED ON THE PLATE. THE PATTERN IS DETERMINED BOTH BY CALCULATION AND EXPERIENCE. THE PLATE IS HEATED BY TORCH ALONG THE HEATING LINE ACCORDING TO A PRE-DETERMINED SEQUENCE. THE STEEL IS QUENCHED BY A WATER SPRAY FOLLOWING BEHIND THE TORCH. THE DISTORTION OF THE PLATE DUE TO THE LOCAL HEATING AND COOLING CREATES THE CURVATURE. A JIG WILL BE USED TO DEFINE THE REQUIRED SHAPE OF THE FINISHED PLATE.

THE METHOD IS APPLICABLE PRIMARILY TO MILD STEELS.

SHIPBUILDING METHODS

WELDING PROCESSES

SHIELDED METAL ARC WELDING. HEAT IS PRODUCED BY AN ELECTRIC ARC BETWEEN A COVERED METAL ELECTRODE AND THE WORK. THE ARC MELTS THE METAL OF THE ELECTRODE. THE MELTED METAL COALESCES AS A MOLTEN POOL BEFORE SOLIDIFYING AS WELD DEPOSIT. UNIVERSALLY USED IN STEEL SHIP CONSTRUCTION FOR MANUAL STEEL WELDING.



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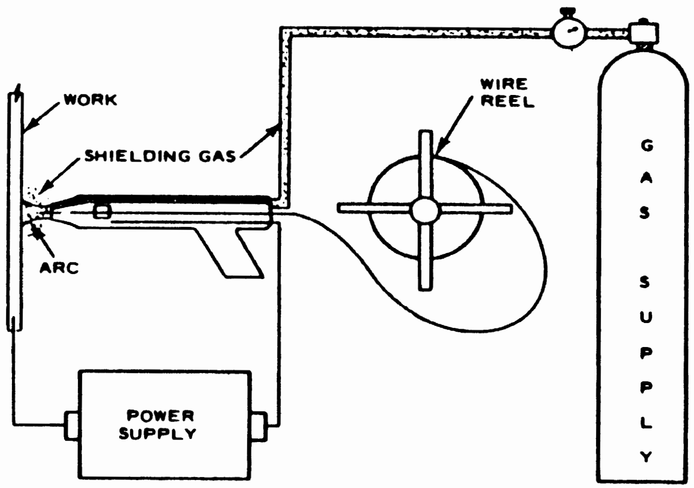
WELDING PROCESSES (CON'T)

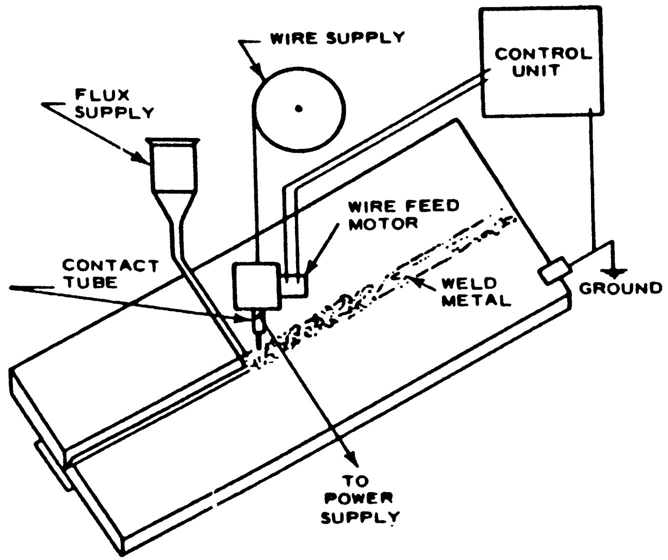
GAS METAL ARC WELDING IS USED FOR AUTOMATIC OR SEMI-AUTOMATIC WELDING OF STAINLESS STEELS, ALUMINUM OR OTHER NON-FERROUS METALS. A WELDING ARC IS FORMED BETWEEN THE WORK AND A BARE ELECTRODE. THE ELECTRODE IS CONTINUOUSLY FED FROM A SPOOL. AN INERT GAS SHIELDS THE ARC AND THE MOLTEN WELD AREA FROM THE ATMOSPHERE.



SHIPBUILDING METHODS

WELDING PROCESSES (CON'T)

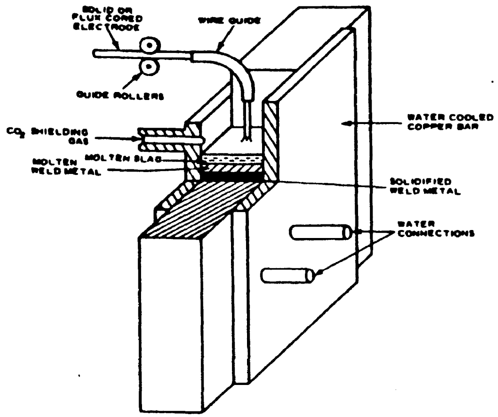
SUBMERGED ARC WELDING IS THE MOST WIDELY USED AUTOMATED PROCESS FOR STEELS. AN ARC IS MAINTAINED BETWEEN A CONTINUOUSLY FED SPOOL AND THE WORK. THE WELDING ZONE IS COMPLETELY BURIED AND SHIELDED UNDER A GRANULAR FLUX OR MELT PROVIDED FROM AN INDEPENDENT FEED TUBE. THE MOLTEN MELT PRODUCES A HIGH HEAT AND INDUCES MELTING OF THE BASE METAL AS WELL AS THE ELECTRODE. THE METHOD IS CAPABLE OF HIGH WELDING SPEEDS AND DEEP WELD PENETRATION.



WELDING PROCESSES (CON'T)

ELECTROSLAG AND ELECTROGAS WELDING PROCESSES ARE CAPABLE OF HIGH WELDING SPEEDS AND HIGH WELD DEPOSITION RATES. MOVEABLE COPPER SHOES ARE FITTED ON EITHER SIDE OF THE WELD JOINT. THE ELECTRODE IS CONTINUOUSLY FED FROM A SPOOL AND INERT GAS OR CO2 IS FED TO SHIELD THE WELD ZONE FROM THE ATMOSPHERE.

IN THE ELECTROSLAG PROCESS A BAR OR STRIP MAY BE SUBSTITUTED FOR THE ELECTRODE. THE METHOD MAY BE APPLIED TO VERY THICK STEELS BUT MAY ONLY BE USED WHEN THE JOINT IS VERTICALLY ORIENTED.



SHIPBUILDING METHODS

OLDER SHIPBUILDING METHODS

IMMEDIATELY FOLLOWING CONTRACT AWARD THE DETAIL DESIGN PHASE IS INITIATED. BILLS OF MATERIAL AND EQUIPMENT LISTS ARE PREPARED. STEEL ORDERS ARE PLACED AND DELIVERY SCHEDULES ESTABLISHED. LONG-LEAD EQUIPMENT ITEM OREDERS ARE PLACED. THE BUILDING SCHEDULE IS ESTABLISHED.

THE LINES OF THE SHIP ARE LOFTED, FULL SIZE IN THE MOLD LOFT. TEMPLATES FOR FRAMES AND BULKHEADS ARE CONSTRUCTED.

SHIPBUILDING AND LAUNCHING WAYS ARE PREPARED.

SHIPBUILDING METHODS

OLDER SHIPBUILDING METHODS (CON'T)

THE KEEL IS LAID, FRAMES AND BULKHEADS SET IN PLACE AND ASSEMBY OF THE SHIP STARTS FROM THE KEEL UP, THE METHOD IS OFTEN CALLED "STICK" CONSTRUCTION.

DURING WORLD WAR II WITH THE ADVENT OF FULLY WELDED SHIPS THE MASS PRODUCTION OF SHIPS REALLY BEGAN. A KEY FACTOR WAS THE SERIES PRODUCTION OF SHIPS OF A SINGLE DESIGN. ONE OF THE FEATURES OF MODERN SHIPBUILDING--THE CONSTRUCTION OF LARGE ASSEMBLIES AWAY FROM THE BUILDING SITES--REALLY BEGAN AT THIS TIME.

SHIPBUILDING METHODS

MODERN SHIPBUILDING METHODS

INTEGRATED ENGINEERING REPRESENTS THE INTEGRATION OF THE REQUIREMENTS OF SHIP PRODUCTION INTO THE DESIGN PROCESS FROM EARLY STAGE DESIGN THROUGH THE TOTAL PRODUCTION PROCESS SO THAT THE SHIPYARD'S FACILITIES MAY BE UTILIZED TO BEST ADVANTAGE, UNNECESSARY ENGINEERING WORK MAY BE AVOIDED, AND THE WORK CONTENT OF PRODUCTION OPERATIONS MAY BE MINIMIZED.

MOST U.S. SHIPYARDS FALL SOMEWHERE IN BETWEEN THE EXTREMES OF ISOLATED AND INTEGRATED ENGINEERING APPROACHES. THERE ARE MANY EUROPEAN AND ASIAN SHIPYARDS WHICH ARE FAR AHEAD OF U.S. SHIPYARDS IN THE INTEGRATION OF DESIGN AND PRODUCTION.

SHIPBUILDING METHODS

MODERN SHIPBUILDING METHODS

NAVAL ARCHITECTURE FIRMS MAY HAVE AS CLIENTS THE GOVERNMENT, A SHIPYARD, OR PRIVATE OWNER. REGARDLESS OF WHO THE CLIENT IS WHEN THE FIRM IS EMPLOYED AN AGENCY RELATIONSHIP IS CREATED BETWEEN THE FIRM AND THE CLIENT. THIS MEANS THAT THE FIRM IS ACTING ON BEHALF OF THE CLIENT AND OWES HIS ALLEGIANCE TO THE CLIENT.

WHEN A NAVAL ARCHITECTURAL FIRM ACTS AS DESIGN AGENT FOR AN OWNER IT IS REPRESENTING THE OWNER'S INTERESTS, NOT THE SHIPYARD'S INTEREST. THUS, WITH THIS SYSTEM AN ADVERSERIAL RELATIONSHIP IS CREATED.

PROBLEM: AN ADVERSERIAL RELATIONSHIP MAKES DIFFICULT THE KIND OF COOPERATION BETWEEN OWNER AND SHIPYARD THAT WOULD LEAD TO OPTIMUM PRODUCIBILITY OF THE DESIGN.

SHIPBUILDING METHODS

MODERN SHIPBUILDING METHODS

THE SYSTEM IN EUROPE AND ASIA IS DIFFERENT THAN THAT IN THE UNITED STATES.

IT IS MORE COMMON IN EUROPE AND ASIA FOR THE SHIPYARD TO DEVELOP THE TOTAL DESIGN. THIS TENDS TO LEAD THE DEVELOPMENT OF STANDARDIZED DESIGNS WITH VARIATIONS TO SUIT INDIVIDUAL OWNERS. THE STANDARDIZED DESIGN IS DEVELOPED FOR OPTIMUM PRODUCIBILITY.

SADLY FOR THE U.S., PRODUCTIVITY IN EUROPEAN AND ASIAN SHIPYARDS IS FAR BETTER THAN THAT IN THE U.S.

SHIPBUILDING METHODS

DESIGN FOR SHIP PRODUCTION

TO ACHIEVE FULL INTEGRATION OF DESIGN AND PRODUCTION IT IS NECESSARY TO INCORPORATE PRODUCTION DECISIONS FROM THE EARLIEST STAGE OF DESIGN. THESE DECISIONS SHOULD BE BASED ON THE SPECIFIC CAPABILITIES AND PRODUCTION METHODS OF THE SHIPYARD WHERE THE SHIP IS TO BE BUILT.

THERE ARE MEASURES WHICH THE DESIGN AGENT CAN TAKE TO HELP ACHIEVE THIS END.

FOR EXAMPLE, IN PREPARING THE CONTRACT DESIGN BID PACKAGE THE DESIGN AGENT CAN PROVIDE GREATER FREEDOM TO THE SHIPBUILDER BY GREATER USE OF CONTRACT GUIDANCE DRAWINGS AND "OR EQUAL" CLAUSES IN EQUIPMENT SPECIFICATIONS.

SHIPBUILDING METHODS

CONTRACT GUIDANCE DRAWINGS

CONTRACT DRAWINGS AND SPECIFICATIONS ARE LEGALLY BINDING ON THE SHIPYARD AND MAY NOT BE CHANGED WITHOUT AUTHORIZATION BY THE OWNER. ON THE OTHER HAND, CONTRACT GUIDANCE DRAWINGS PROVIDE THE SHIPBUILDER WITH MORE LATITUDE TO MODIFY THE DESIGN TO SUIT HIS PRODUCTION METHODS. "OR EQUAL" CLAUSES IN EQUIPMENT SPECIFICATIONS ALLOW THE SHIPBUILDER TO SEEK THE MOST FAVORABLE PRICES IN PURCHASING EQUIPMENT.

THE MODERN TREND IS TO LIMIT THE NUMBER OF CONTRACT DRAWINGS IN THE CONTRACT DESIGN PACKAGE AND TO USE MORE CONTRACT GUIDANCE DRAWINGS AND MORE "OR EQUAL" CLAUSES IN THE SPECIFICATIONS.

SHIPBUILDING METHODS

DESIGN FOR SHIP PRODUCTION

TRADITIONALLY SHIPS HAVE BEEN DESIGNED BY INDIVIDUAL SYSTEMS, FOR EXAMPLE

- SHIP STRUCTURAL SYSTEM
- MAIN PROPULSION MACHINERY SYSTEM
- AUXILIARY PROPULSION SYSTEM
- ELECTRICAL SYSTEM
- PIPING SYSTEM

  ETC.

EFFICIENT DESIGN FOR SHIP PRODUCTION REQUIRES THAT, RATHER THAN FITTING A SYSTEM WITHIN AN AVAILABLE SPACE, THE SPACE SHOULD BE DESIGNED AS A PRODUCTION UNIT WITH THE SYSTEM DESIGN SUBORDINATED TO THE PRODUCIBILITY OF THE SPACE.

SHIPBUILDING METHODS

DESIGN FOR SHIP PRODUCTION

THE MODERN TREND IS TOWARD THE ASSEMBLY OF LARGER CONSTRUCTION MODULES.

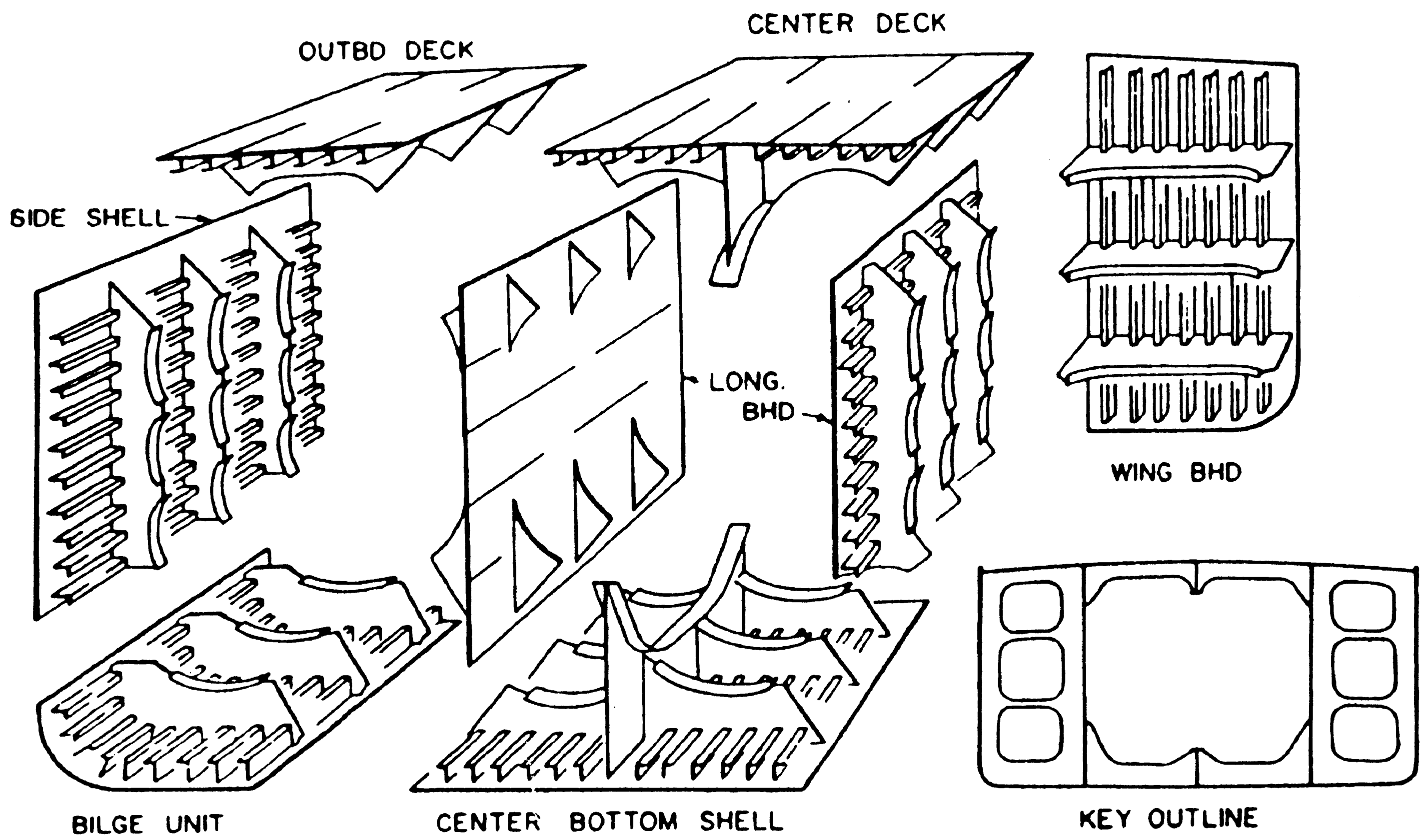
MACHINERY, PIPING, OUTFITTING, AND SOMETIMES ELECTRICAL SYSTEMS ARE INSTALLED TO THE MAXIMUM FEASIBLE EXTENT IN THE MODULES WHILE ACCESS IS EASY. THIS IS KNOWN AS ZONE OUTFITTING.

MODULES ARE MOVED TO THE SHIP ASSEMBLY SITE ACCORDING TO A SCHEDULE WHICH WILL MINIMIZE THE TIME REQUIRED TO JOIN THE MODULES TO FORM THE SHIP.

THIS REQUIRES THE CAPABILITY OF MOVING THESE HEAVY STRUCTURES BY CRANES, GANTRIES AND TRANSPORTERS.

SHIPBUILDING METHODS

SUBASSEMBLIES



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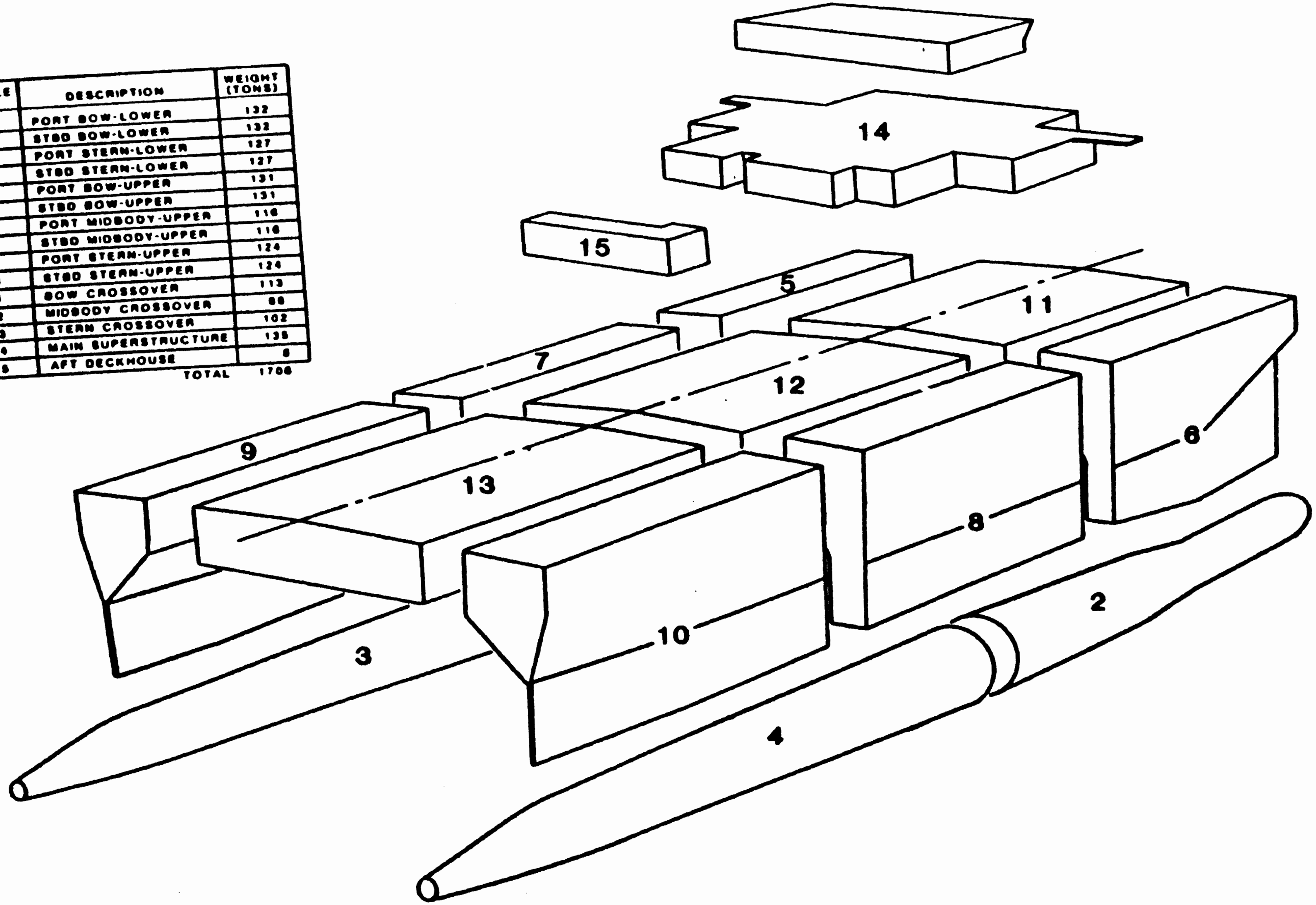
SHIPBUILDING METHODS

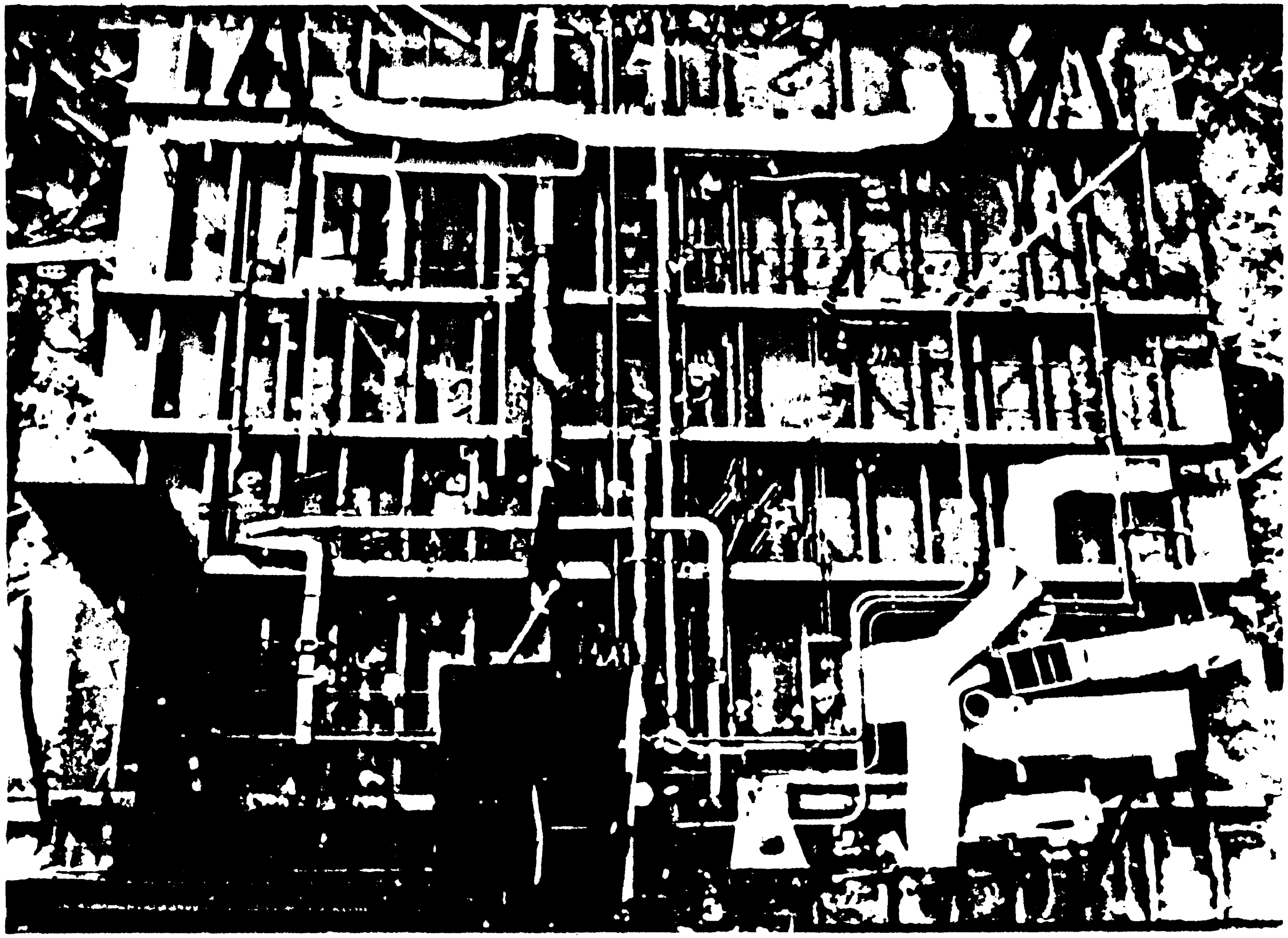
CONSTRUCTION MODULES

MODULE NO.	DESCRIPTION	WEIGHT (TONS)
1	PORT BOW-LOWER	132
2	STBD BOW-LOWER	132
3	PORT STERN-LOWER	127
4	STBD STERN-LOWER	127
5	PORT BOW-UPPER	131
6	STBD BOW-UPPER	131
7	PORT MIDBODY-UPPER	116
8	STBD MIDBODY-UPPER	116
9	PORT STERN-UPPER	124
10	STBD STERN-UPPER	124
11	BOW CROSSOVER	113
12	MIDBODY CROSSOVER	88
13	STERN CROSSOVER	102
14	MAIN SUPERSTRUCTURE	135
15	AFT DECKHOUSE	8
	TOTAL	1708



SHIPBUILDING METHODS

ZONE OUTFITTING



SHIPBUILDING METHODS

DESIGN FOR SHIP PRODUCTION

DESIGN DETAILS CONDUCIVE TO EASE OF CONSTRUCTION

- FLAT SURFACES RATHER THAN CURVED SURFACES
- SINGLE CURVATURE RATHER THAN COMPOUND CURVATURE
- FLAT BOTTOM INSTEAD OF DEADRISE
- FLAT SHEER, FLAT CAMBER
- WELD DETAILS THAT PERMIT MACHINE WELDING
- ASSEMBLY PROCEDURES THAT MINIMIZE THE AMOUNT OF OVERHEAD AND VERTICAL WELDING
- FEATURES THAT PERMIT THE MAXIMUM INSTALLATION OF MACHINERY, FLUID SYSTEMS AND OUTFIT ITEMS IN SUBASSEMBLIES AND MODULES RATHER THAN ON SHIP

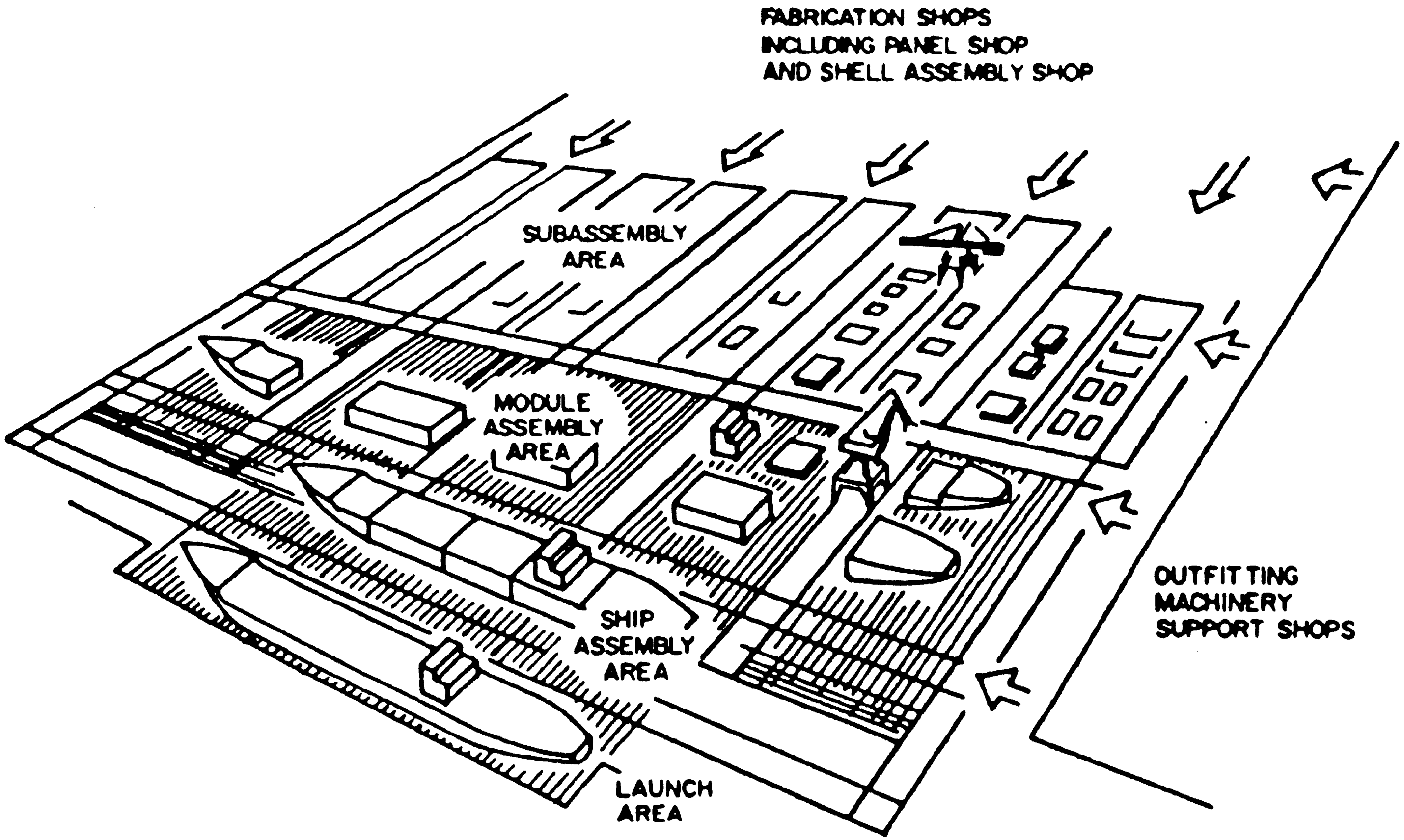
SHIPBUILDING METHODS

DESIGN FOR SHIP PRODUCTION

- STANDARD STRUCTURAL AND WELDING DETAILS THAT BEST SUIT THE INDIVIDUAL SHIPYARD
- SIMPLIFICATION THROUGH REDUCTION OF THE NUMBER OF PIECES TO BE CUT AND HANDLED
- SIMPLIFICATION THROUGH REDUCTION OF THE NUMBER OF DIFFERENT SIZES AND TYPES OF MATERIALS AND EQUIPMENT ORDERED.
- DESIGN FOR ACCESS DURING CONSTRUCTION. CONSTRUCTION SEQUENCE SHOULD PROVIDE FOR OPENINGS, PASSAGES AND LADDERS WHICH WILL FACILITATE FLOW OF WORKERS AND EQUIPMENT INTO SPACES WITH MINIMUM SUBSEQUENT REWORK.

SHIPBUILDING METHODS

ASSEMBLY LINE FLOW -- LITTON, PASCAGOULA



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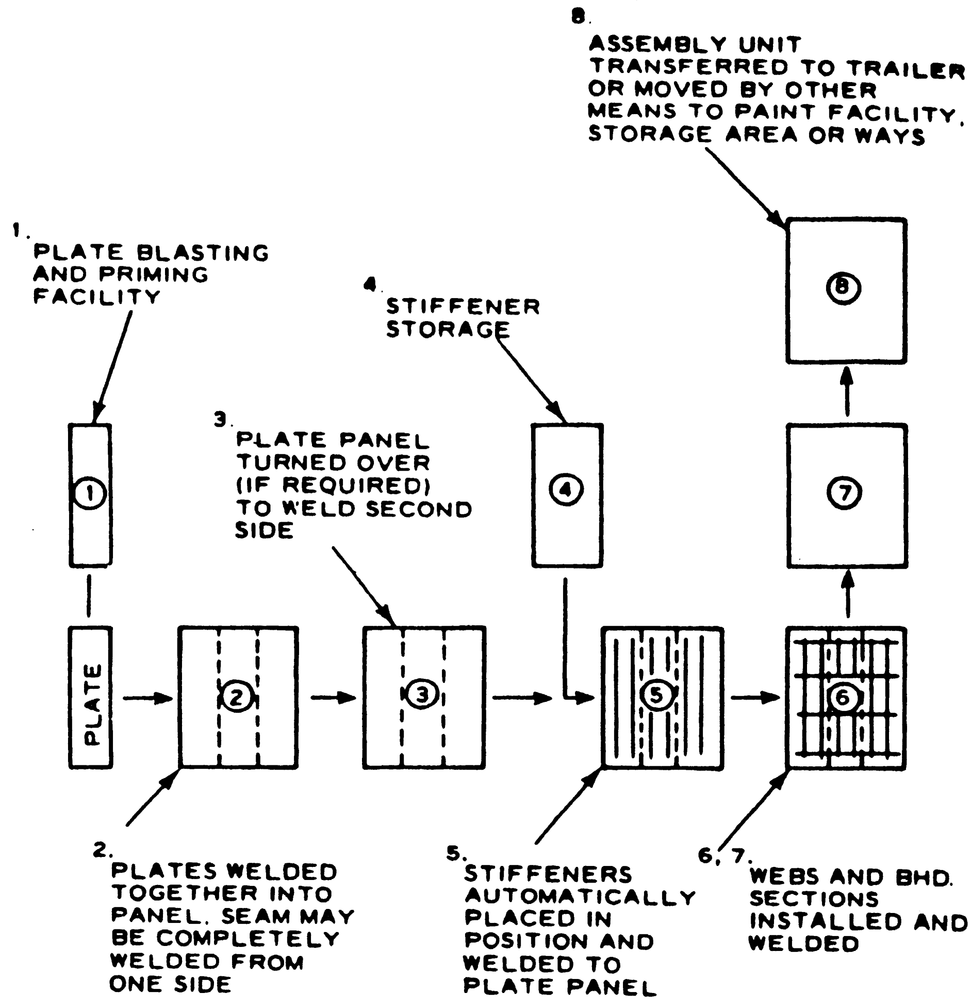
SHIPBUILDING METHODS

PLATE LINE AND SUBASSEMBLY FABRICATION

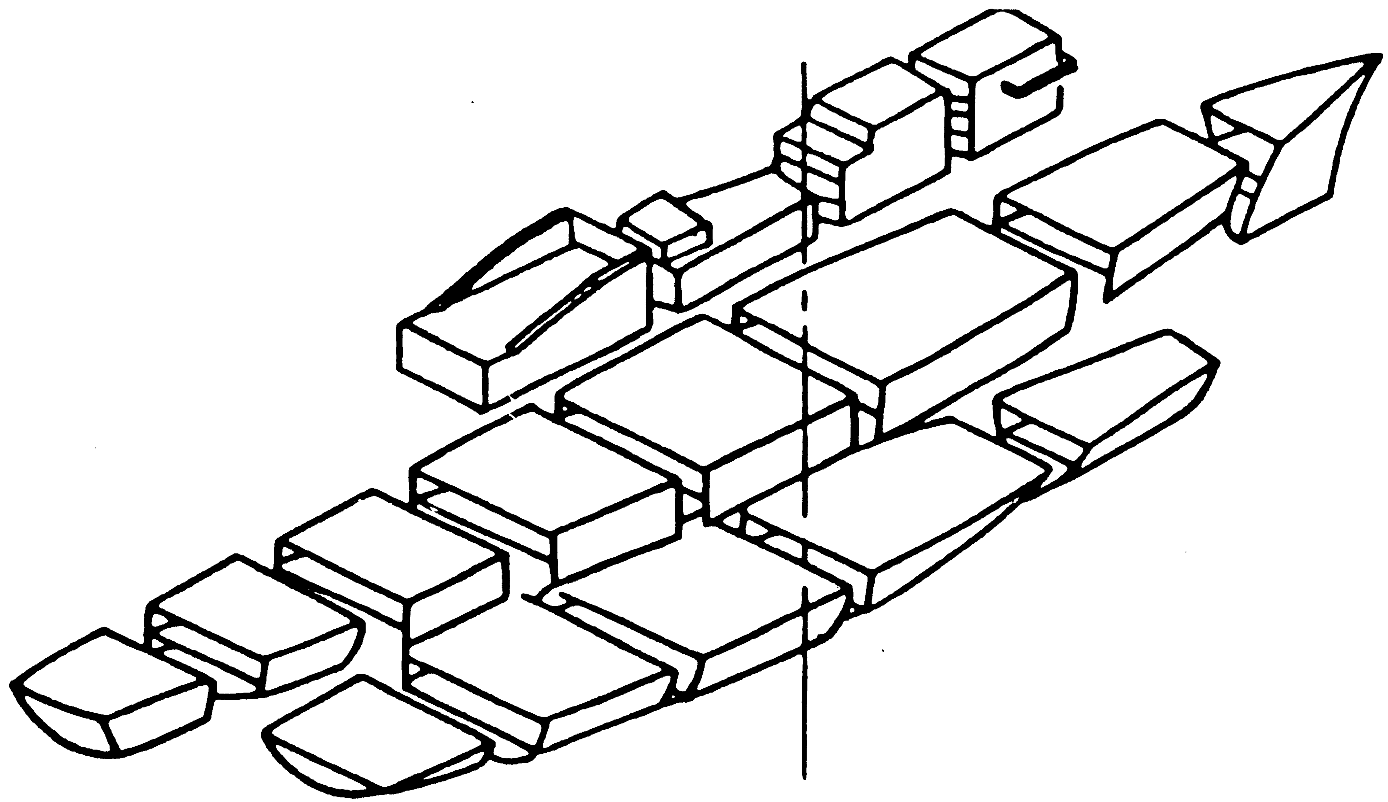


44-3C

GRAPHICS NOT USED IN PRESENTATION

SHIPBUILDING METHODS

CONSTRUCTION MODULES



SHIPBUILDING METHODS

MODERN SHIPBUILDING METHODS

SHIPBUILDING METHODS, WORLDWIDE, HAVE BEEN UNDERGOING MAJOR CHANGES FOR THE PAST TWENTY FIVE YEARS. MODERN SHIPBUILDING METHODS EMPHASIZE SHIP PRODUCIBILITY TO A MUCH GREATER EXTENT THAN WAS DONE IN THE TRADITIONAL APPROACH.

THE TWO EXTREMES IN THE DESIGN FOR SHIP PRODUCTION CAN BE DESCRIBED AS ISOLATED ENGINEERING AND INTEGRATED ENGINEERING. (LAMB, "ENGINEERING FOR SHIP PRODUCTION", 1985)

SHIPBUILDING METHODS

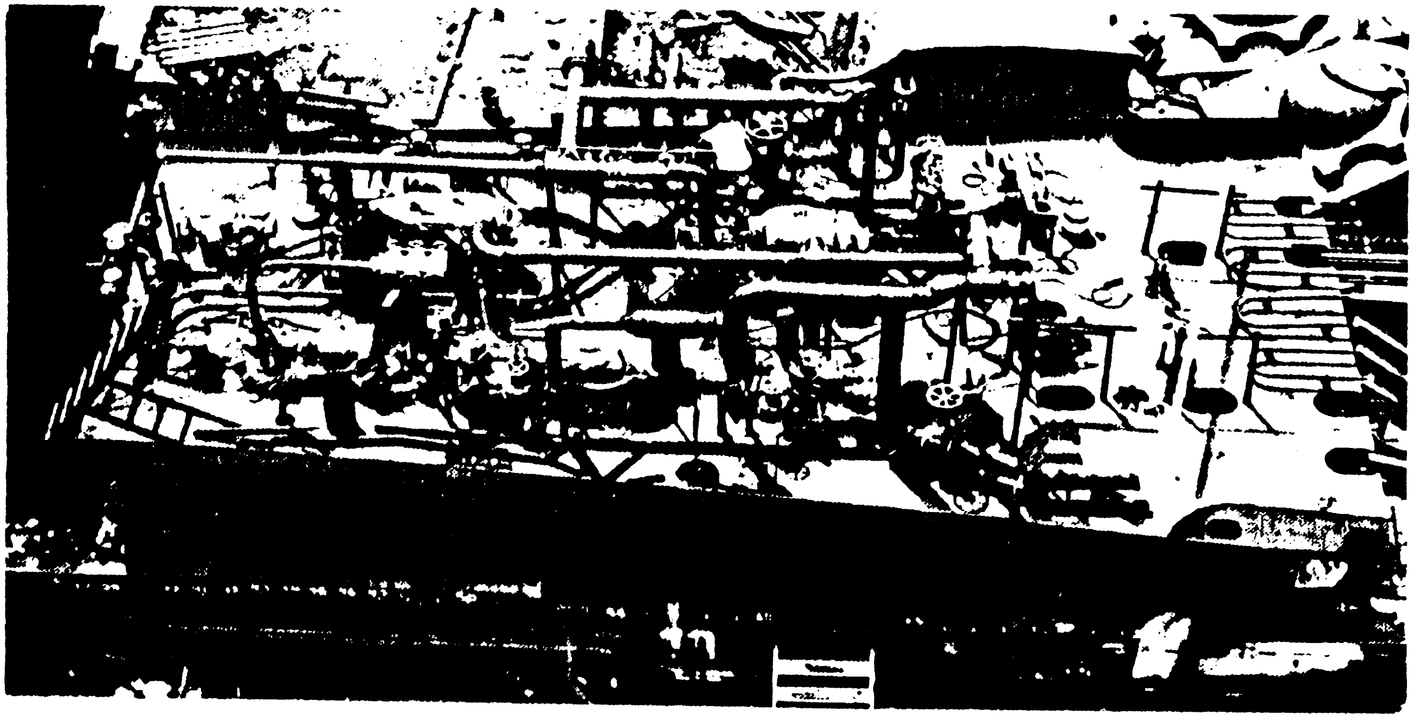
MODERN SHIPBUILDING METHODS

ISOLATED ENGINEERING REPRESENTS THE TRADITIONAL APPROACH IN WHICH, ALTHOUGH DESIGN DETAILS ARE SHOWN, PRODUCIBILITY DECISIONS SUCH AS THE DEFINITION OF PRODUCTION MODULE BOUNDARIES, ZONE OUTFITTING DECISIONS, SELECTION OF DETAILS TO SUIT PRODUCTION METHODS, WERE NOT REALLY EMPHASIZED DURING THE DESIGN STAGES.

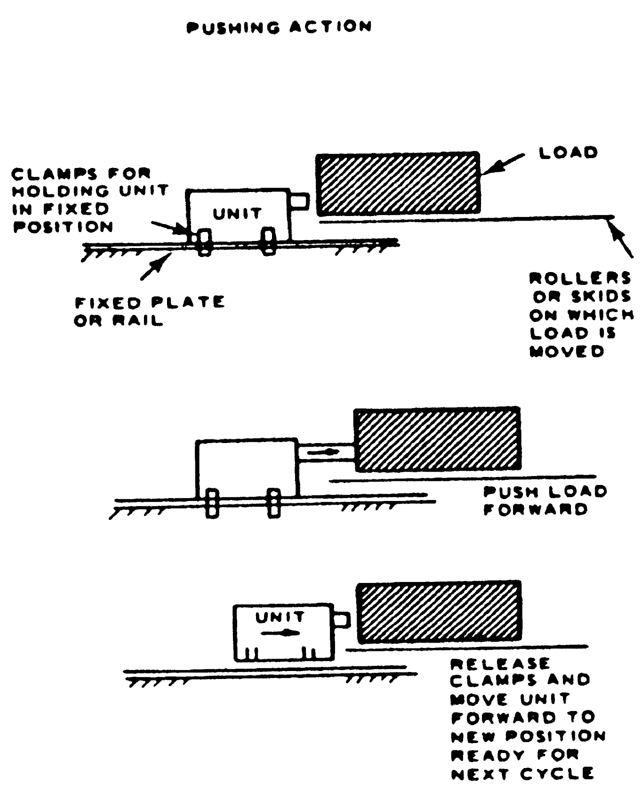
PART OF THE REASON FOR THIS IS THAT, IN THE UNITED STATES, DESIGNS ARE USUALLY PREPARED BY THE OWNER'S DESIGN AGENT THROUGH THE CONTRACT DESIGN STAGE THEN BID COMPETITIVELY BY VARIOUS SHIPYARDS. DESIGN AGENTS ARE ORIENTED TOWARD OPTIMUM SHIP PERFORMANCE RATHER THAN OPTIMUM PRODUCIBILITY. PRODUCTION FEATURES ARE VERY SHIPYARD SPECIFIC AND ARE NOT WELL KNOWN BY THE DESIGN AGENT.

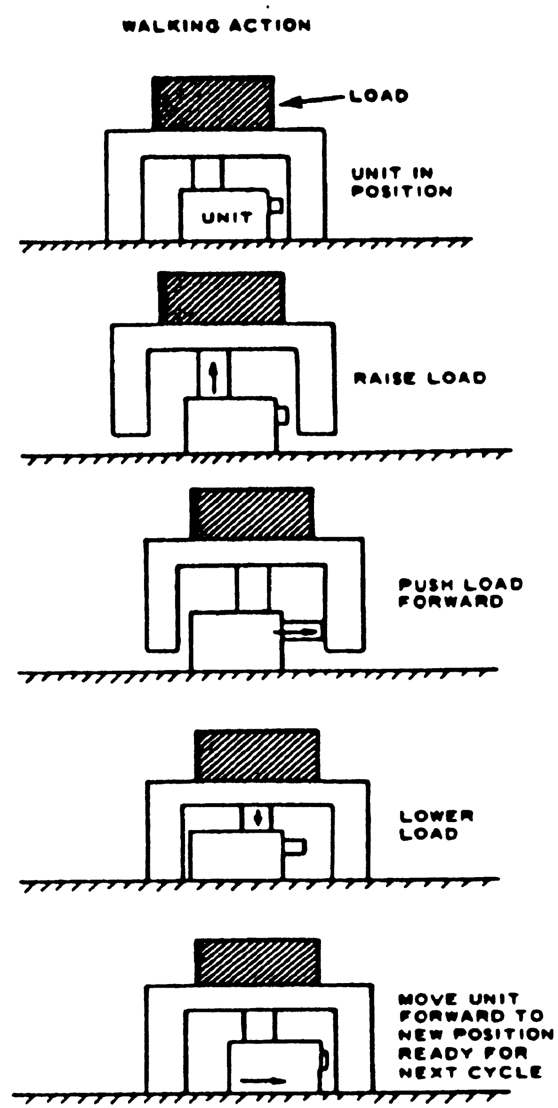
SHIPBUILDING METHODS

ZONE OUTFITTING

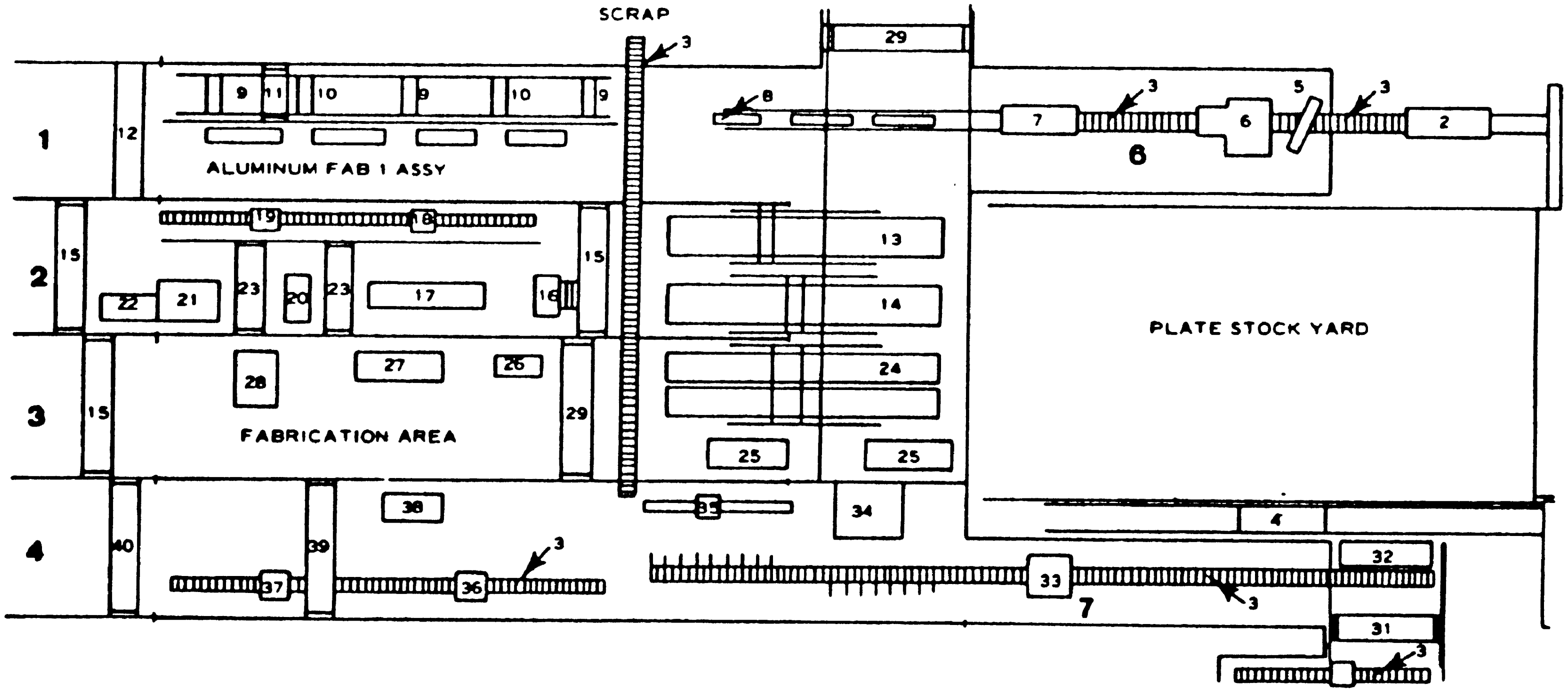


TRANSPORT OF A MODULE





STEEL FABRICATION SHOP



BAY-6
1 - 20T MAG GANTRY
2 - PLATE SELECTOR CAR
3 - CONVEYOR
4 - COLLOCATOR CAR

5 - BRUSH
6 - PLATE DESCALER
7 - PLATE STACKER CAR
8 - PLATE STACKS

BAY-1
9 - FLAME BURNER - BUTTS
10 - FLAME BURNER - SEAMS
11 - 20T SEMI-GANTRY
12 - 20T BRIDGE CRANE WITH 5T VACULIFT

BAY-2
13 FLAME PLANER
14 - 3 AXIS FLAME CUTTER
15 - 20T BRIDGE CRANE
16 - SHEAR

17 - PLATEROLLS & FLANGER
18 - T BEAM WELDER
19 - T BEAM STRAIGHTENER
20 - RING FRAME PRESS
21 - PIN SLAB
22 - FURNACE

23 - 10T SEMI-GANTRY

BAY-3
24 - 2 AXIS FLAME PLANER
25 - HAND BURNING TABLE
26 - PLATE SHEAR
27 - HYD PRESS BRAKE

28 - VERT BEND PRESS
29 - 20T MAG BRIDGE-CRANE

BAY-4..7
30 - CUTOFF SAW
31 - 5T SEMI-GANTRY
32 - SECTION SORTING TABLE
33 - SHAPE DESCALING

34 - FRAME BENDER
35 - IRON WORK
36 - PUNCH
37 - STRAIGHTENER
38 - SHAPE TWISTER
39 - 15T BRIDGE CRANE WITH FORK LIFT
40 - 10T BRIDGE CRANE

Unit Number: 45

Title: Shipbuilding methods - 3

Tape Running Time: 38^M 12^S

Reading Assignment: None

Additional References: PNA, pp 752-780

SDC, pp 657-691

Scope:

The course concludes with a description of the various ways of launching a ship. End launching, side launching, platform launching, and other methods are described. In the course closure, the present position of the U.S. shipbuilding industry is discussed together with measures which must be taken to improve the competitive position of the industry.

Key Points to Emphasize:

1. Again, the instructor should relate launching methods to methods in use in his own shipyard. Use photo slides to show docks and historic launchings.

2. Close the course by re-emphasizing the measures which need to be taken to improve shipyard productivity. Emphasis should be on the positive developments which have occurred in recent years and on changes which will occur in the future.

Suggested Problem Assignment: None

SHIPBUILDING METHODS

LAUNCHING

THERE ARE A NUMBER OF WAYS OF LAUNCHING A SHIP.

- END LAUNCHING
- SIDE LAUNCHING
- FLOATING DRYDOCK
- LIFT PLATFORMS
- GRAVING DOCK

FOR SMALL SHIPS AND SMALL CRAFT:

- MARINE RAILWAY
- "TRAVEL-LIFT" SLING TRANSPORTERS
- CRANE

FOR OFFSHORE DRILLING JACKETS AND PLATFORMS:

- BARGE
- SIDE LAUNCHING
- HEAVY LIFT CRANES

SHIPBUILDING METHODS

END LAUNCHING

END LAUNCHING IS THE TRADITIONAL METHOD OF LAUNCHING. ALTHOUGH END LAUNCHING WAS THE MOST COMMON TYPE OF LAUNCH FOR MANY YEARS IT ALSO CONTAINS THE LARGEST NUMBER OF RISK FACTORS AND IS GRADUALLY BEING REPLACED BY OTHER METHODS.

THE SHIP IS CONSTRUCTED ON BUILDING WAYS CONSISTING OF KEEL BLOCKS, SIDE BLOCKS, SHORES AND CRIBBING. LAUNCHING WAYS ARE IN PLACE IN THE BUILDING SLIP. AS CONSTRUCTION OF THE SHIP PROGRESSES A LAUNCHING CRADLE IS CONSTRUCTED UNDER THE SHIP. SLIDING WAYS ARE MOUNTED ON THE GROUND WAYS. AS THE TIME FOR LAUNCHING APPROACHES THE WEIGHT OF THE SHIP IS TRANSFERRED FROM THE BUILDING WAYS TO THE CRADLE BY DRIVING WEDGES IN THE SLIDING WAYS. AT THIS TIME THE BLOCKS, SHORES AND CRIBBING ARE REMOVED FROM UNDER THE SHIP.

45-3

SHIPBUILDING METHODS

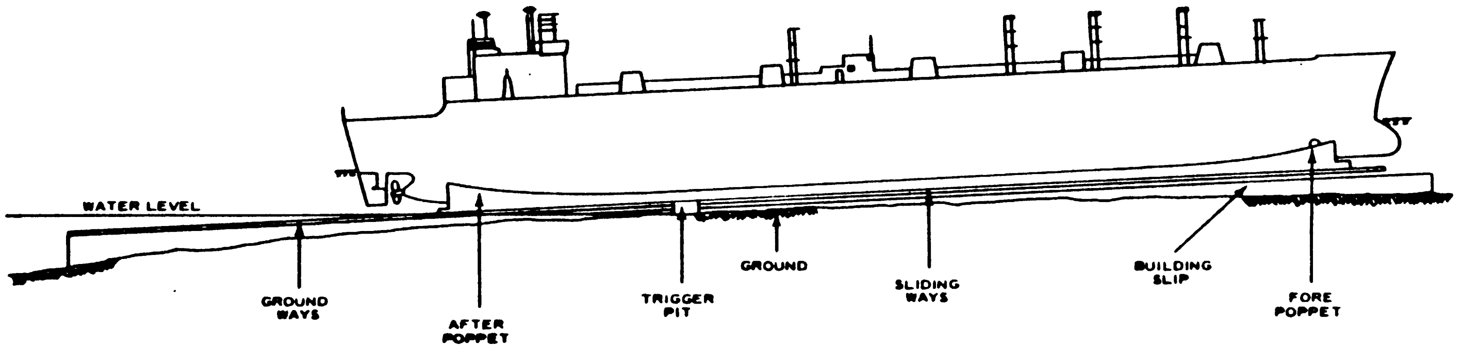
END LAUNCHING (CON'T)

THE GROUND WAYS ARE WELL GREASED PRIOR TO MOUNTING THE CRADLE. THE SHIP IS HELD IN PLACE BY A HOLDING MECHANISM WITH SETS OF TRIGGERS. WHEN THE TRIGGERS ARE RELEASED THE SHIP BEGINS TO SLIDE DOWN THE WAYS UNDER THE ACTION OF GRAVITY. A HYDRAULIC JACK OR OTHER MEANS OF STARTING THE SHIP DOWN THE WAYS IS PROVIDED AS BACK-UP.

THE CRADLE IS COMPOSED OF THE SLIDING WAYS, THE WEDGES AND WEDGE RIDERS, PACKING, AND FORE POPPET AND AFTER POPPET STRUCTURES. AS THE STERN ENTERS THE WATER AND PICKS UP BUOYANCY PRESSURE IS TRANSFERRED TO THE FORE POPPET AND THE SHIP PIVOTS IN THE FORE POPPET STRUCTURE. A MEANS OF STOPPING THE SHIP AFTER IT IS WATERBORNE MUST BE PROVIDED.

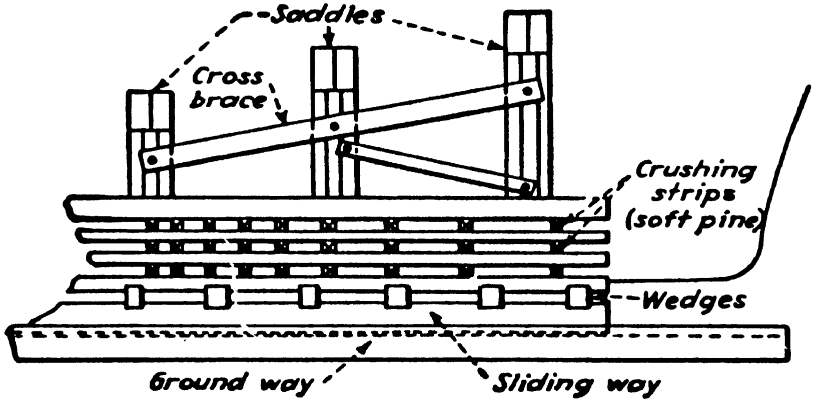
SHIPBUILDING METHODS

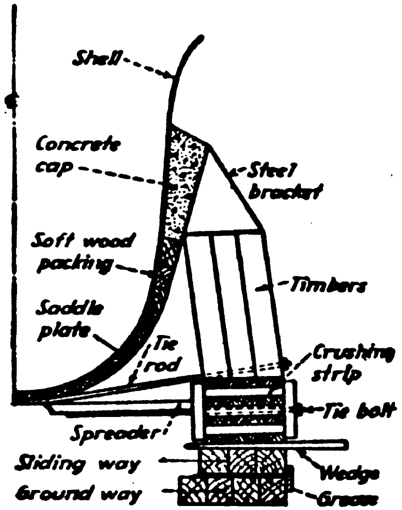
END LAUNCHING (CON'T)



SHIPBUILDING METHODS

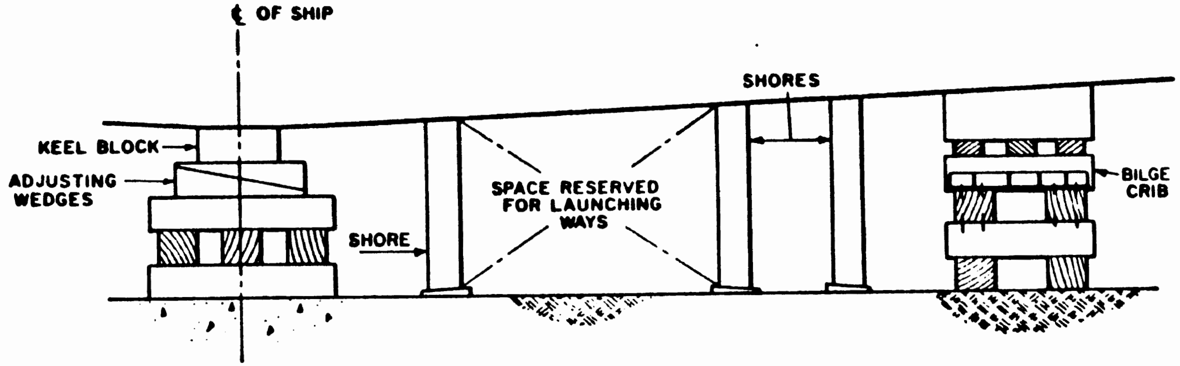
END LAUNCHING (CON'T)

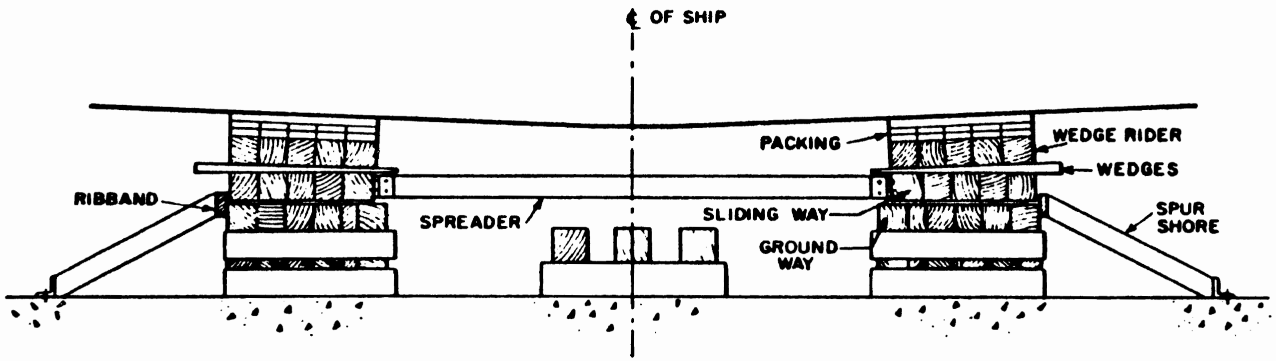




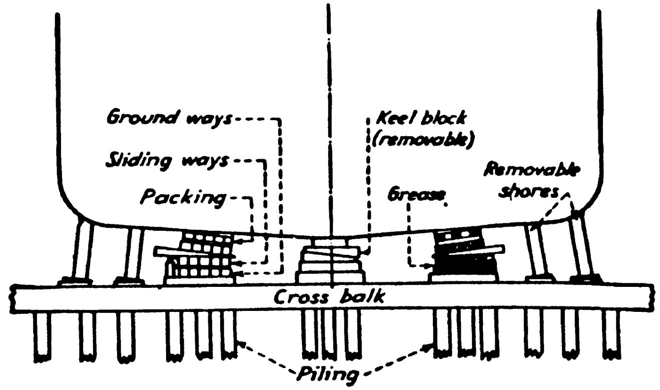
SHIPBUILDING METHODS

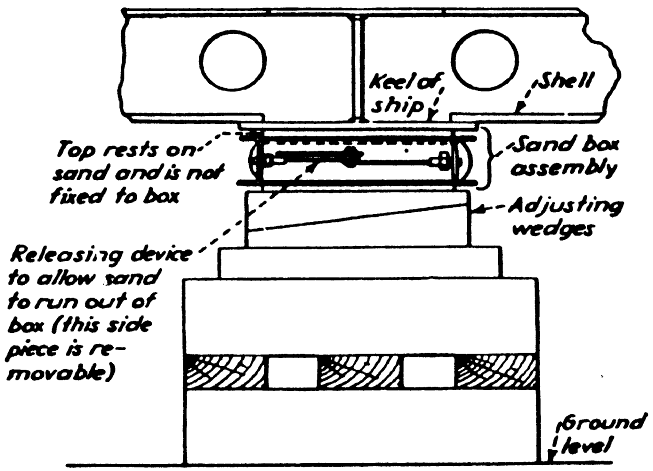
END LAUNCHING (CON'T)





END LAUNCHING (CON'T)



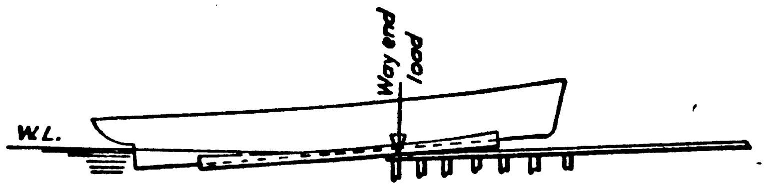


END LAUNCHING (CON'T)

KEY EVENTS

1. STARTING. FOR AN UNASSISTED START THE GRAVITATIONAL COMPONENT ACTING DOWN THE WAYS MUST BE GREATER THAN THE FRICTIONAL RESISTANCE BETWEEN SLIDING WAYS AND GROUND WAYS. KEY FACTORS: DECLIVITY OF THE WAYS AND TEMPERATURE OF THE GREASE AND PRESSURE ON THE GREASE.

2. TIPPING. IF THE BUOYANCY OF THE STERN IS INSUFFICIENT AFTER THE CENTER OF GRAVITY OF THE SHIP HAS PASSED OVER THE END OF THE WAYS THE SHIP WILL DIP DOWNWARD AT THE STERN AND THUS CAUSE A HEAVY CONCENTRATION OF WAY END PRESSURE, AND ON THE BOTTOM OF THE SHIP. KEY FACTOR: HEIGHT OF WATER OVER THE WAY ENDS AT THE TIME OF LAUNCH.

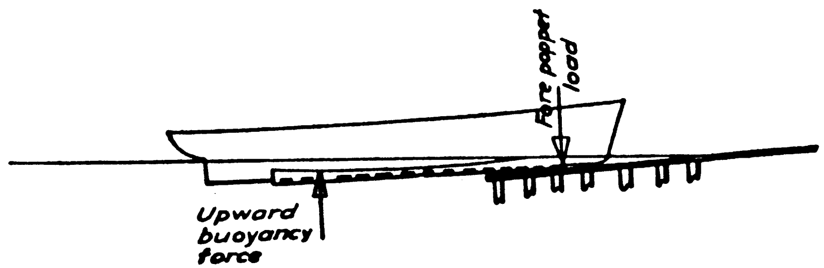


SHIPBUILDING METHODS

END LAUNCHING (CON'T)

KEY EVENTS

3. PIVOTING. AS THE SHIP MOVES FURTHER INTO THE WATER THE BUOYANCY OF THE AFTER PORTION INCREASES UNTIL IT IS SUFFICIENT TO RAISE THE STERN. AS THE STERN RISES THE SHIP PIVOTS ABOUT THE FORE POPPET. KEY FACTORS: THE DESIGN OF THE FORE POPPET MUST BE SUCH THAT IT WILL BE ADEQUATE TO CARRY THIS LOAD. THE PRESSURE ON THE WAYS CAN NOT EXCEED THE CRITICAL PRESSURE FOR THE LUBRICANT. PRESSURE ON THE SHIP HULL IS DISTRIBUTED BY MEANS OF SOFT WOOD CRUSHING STRIPS IN THE FORE POPPET. THE SHIP STRUCTURE MAY REQUIRE SPECIAL STRENGTHENING IWO THE FORE POPPET.



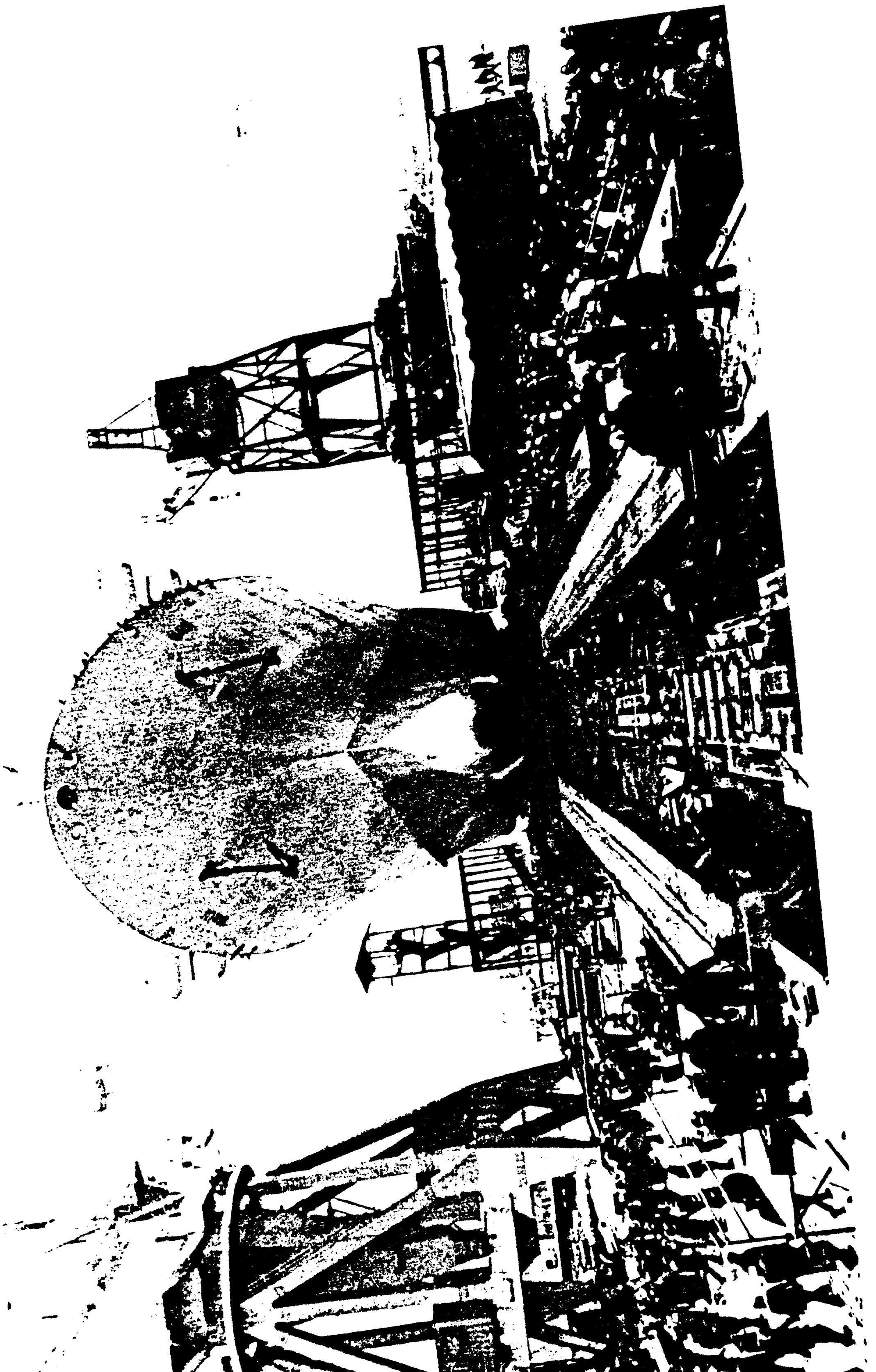
SHIPBUILDING METHODS

END LAUNCHING (CON'T)

KEY EVENTS

4. DROP OFF. AFTER THE FORE POPPET PASSES OVER THE ENDS THE BOW DROPS. THE MAGNITUDE OF THE DROP OFF CAN NOT BE SUCH THAT THE BOW WILL IMPACT ON THE BOTTOM.

5. STOPPING. TRAVEL OF THE SHIP WHEN FULLY WATERBORNE MUST BE RESTRAINED. THIS IS OFTEN DONE BY THE USE OF CHAIN DRAGS WHICH PAY OUT AS THE SHIP TRAVELS ASTERN AND SLOW ITS RATE OF TRAVEL. A SET OF CHAIN DRAGS MAY ALSO BE USED TO SLEW THE SHIP TO PREVENT IT FROM GROUNDING ON AN OPPOSITE SHORE. TUGS WILL BE STANDING BY WITH LINES TO THE SHIP SECURED BUT SLACK.



45-12

SHIPBUILDING METHODS

SIDE LAUNCHING

SIDE LAUNCHING IS THE PREFERRED METHOD OF LAUNCHING FOR SHIPYARDS LOCATED ON NARROW RIVERS OR CHANNELS.

HOWEVER, SIDE LAUNCHING OFFERS OTHER ADVANTAGES.

- THE BUILDING WAYS ARE HORIZONTAL THUS SIMPLIFYING ERECTION OF THE HULL STRUCTURE.
- CONSTRUCTION AND MAINTENANCE OF UNDERWATER GROUND WAYS IS ELIMINATED.
- THE LAUNCHING CRADLE IS LESS COMPLICATED AND LESS EXPENSIVE -- NO FORE AND AFTER POPPETS.
- INTERNAL SHORING AGAINST WAY END PRESSURES AND PIVOTING LOADS IS NOT NECESSARY.
- SIDE LAUNCHING IS BETTER SUITED TO MODULAR CONSTRUCTION TECHNIQUES THAN END LAUNCHING.

SHIPBUILDING METHODS

SIDE LAUNCHING (CON'T)

THE SHIP IS ERECTED ON BUILDING WAYS WHICH ARE PERPENDICULAR TO THE GROUND WAYS.

THE CRADLE MAY BE OF THE SLED TYPE OR THE BUTTERBOARD TYPE.

SLEDS ARE TRIANGULAR TRANSVERSE STRUCTURES WHICH CONSIST OF SLIDING WAYS, WEDGES, WEDGE RIDERS, PACKING AND FITTINGS.

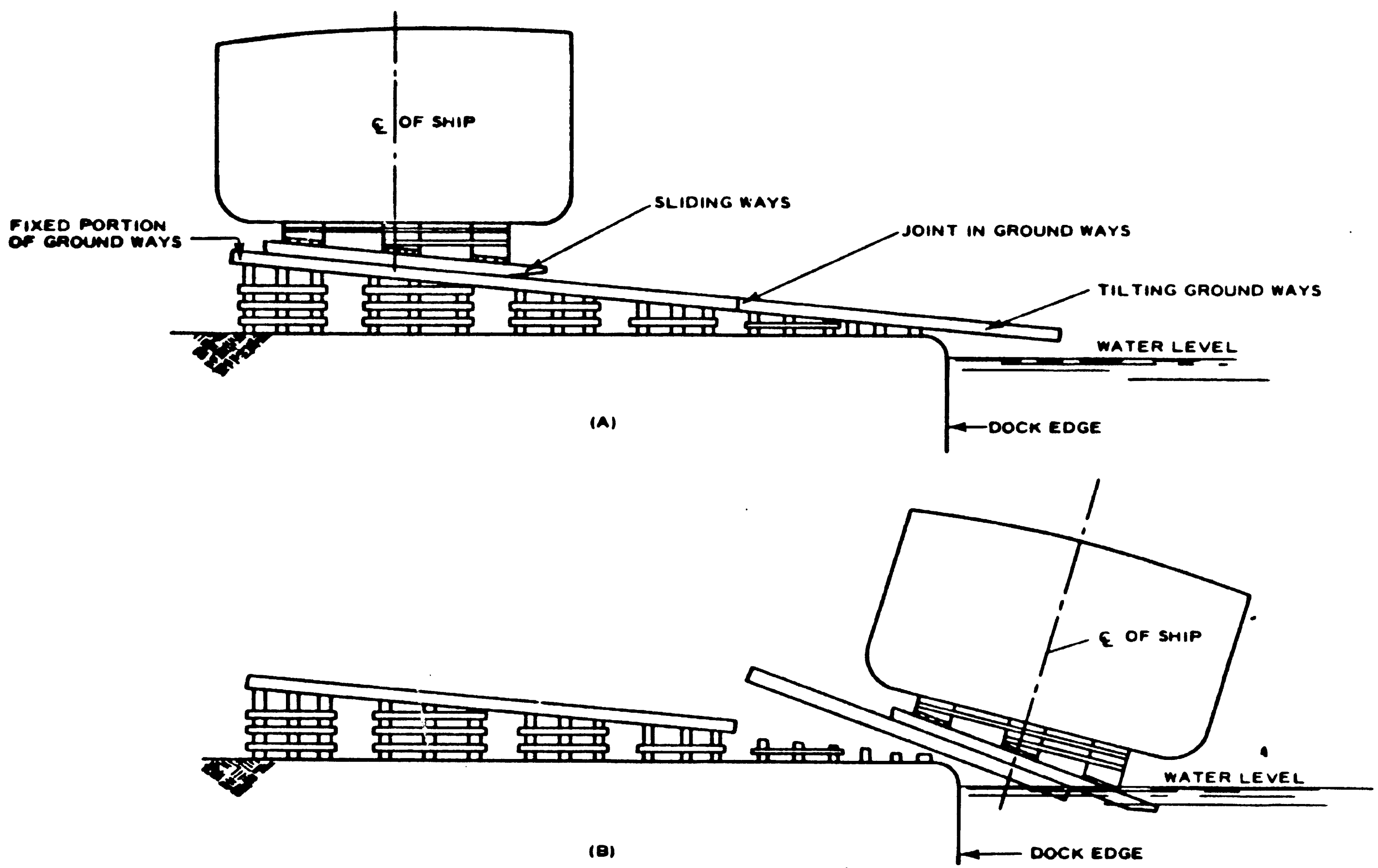
BUTTERBOARDS ARE LONGITUDINALLY ORIENTED AND SPAN TWO OR MORE GROUND WAYS AND ARE ARRANGED IN GROUPS.

THE USE OF BUTTERBOARDS PERMITS THE SHIP SOME FREEDOM TO SLEW AS IT TRAVELS DOWN THE WAYS.

SHIPBUILDING METHODS

SIDE LAUNCHING (CON'T)

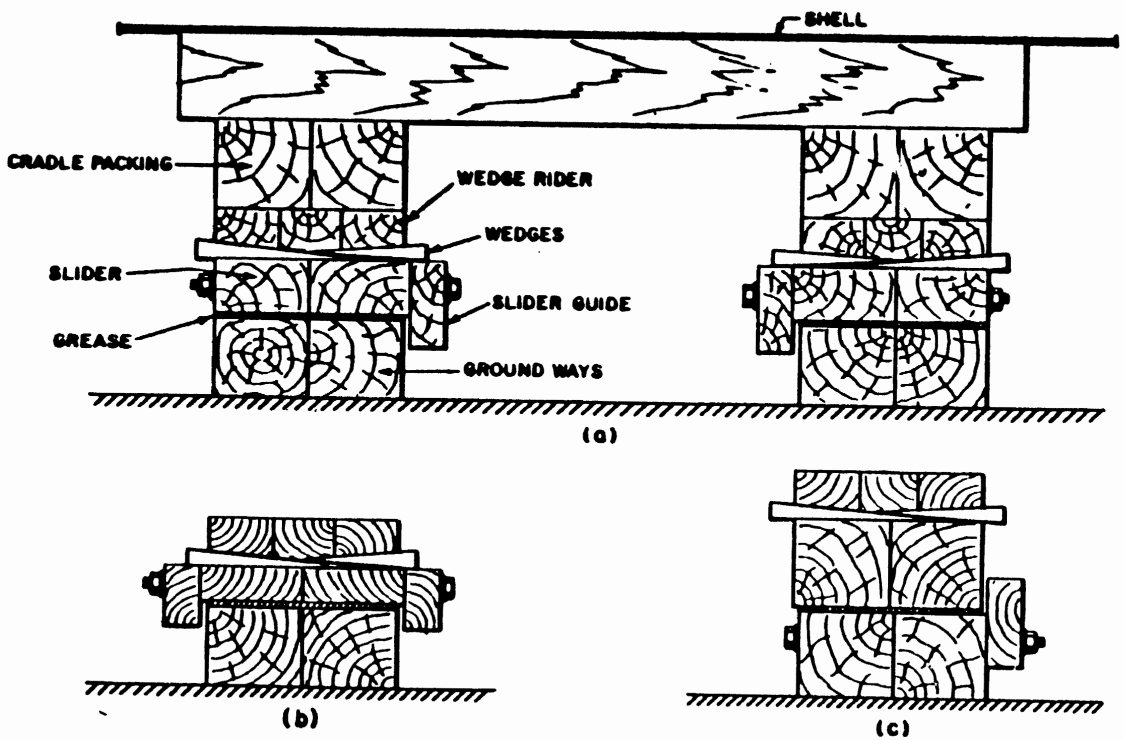
SLED CRADLE WITH TILTING GROUND WAYS



SHIPBUILDING METHODS

SIDE LAUNCHING (CON'T)

GROUND AND SLIDING WAYS



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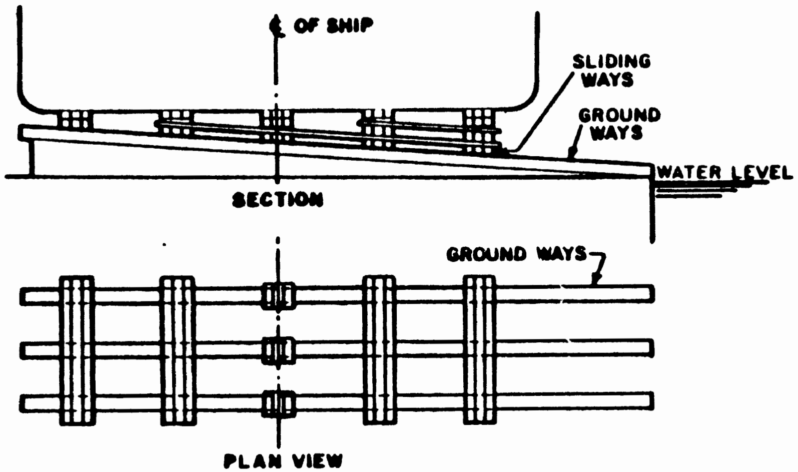
SHIPBUILDING METHODS

SIDE LAUNCHING (CON'T)

BUTTERBOARD TYPE CRADLE



(a) LONGITUDINAL SLIDING WAYS

PHOTO

(AO 180 SIDE LAUNCH)

(AVONDALE)

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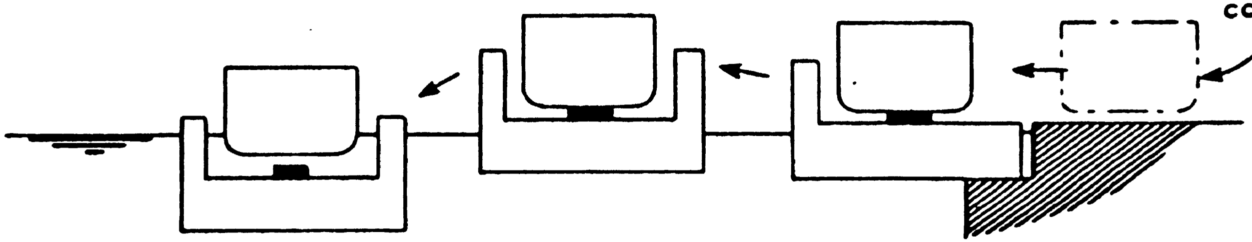
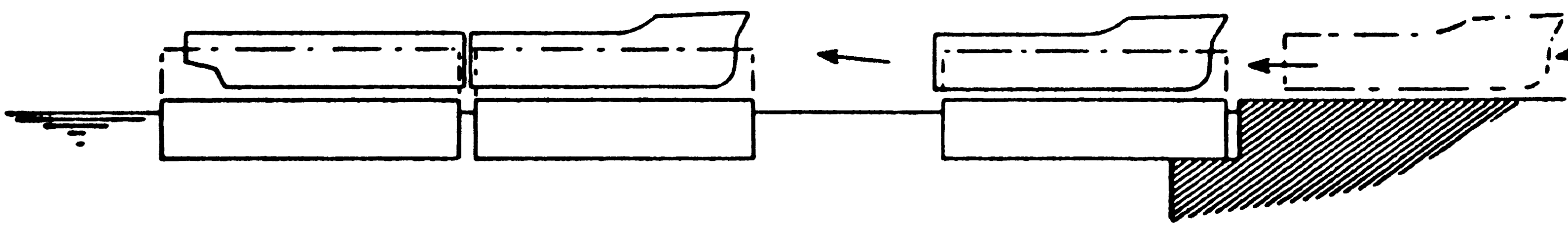
SHIPBUILDING METHODS

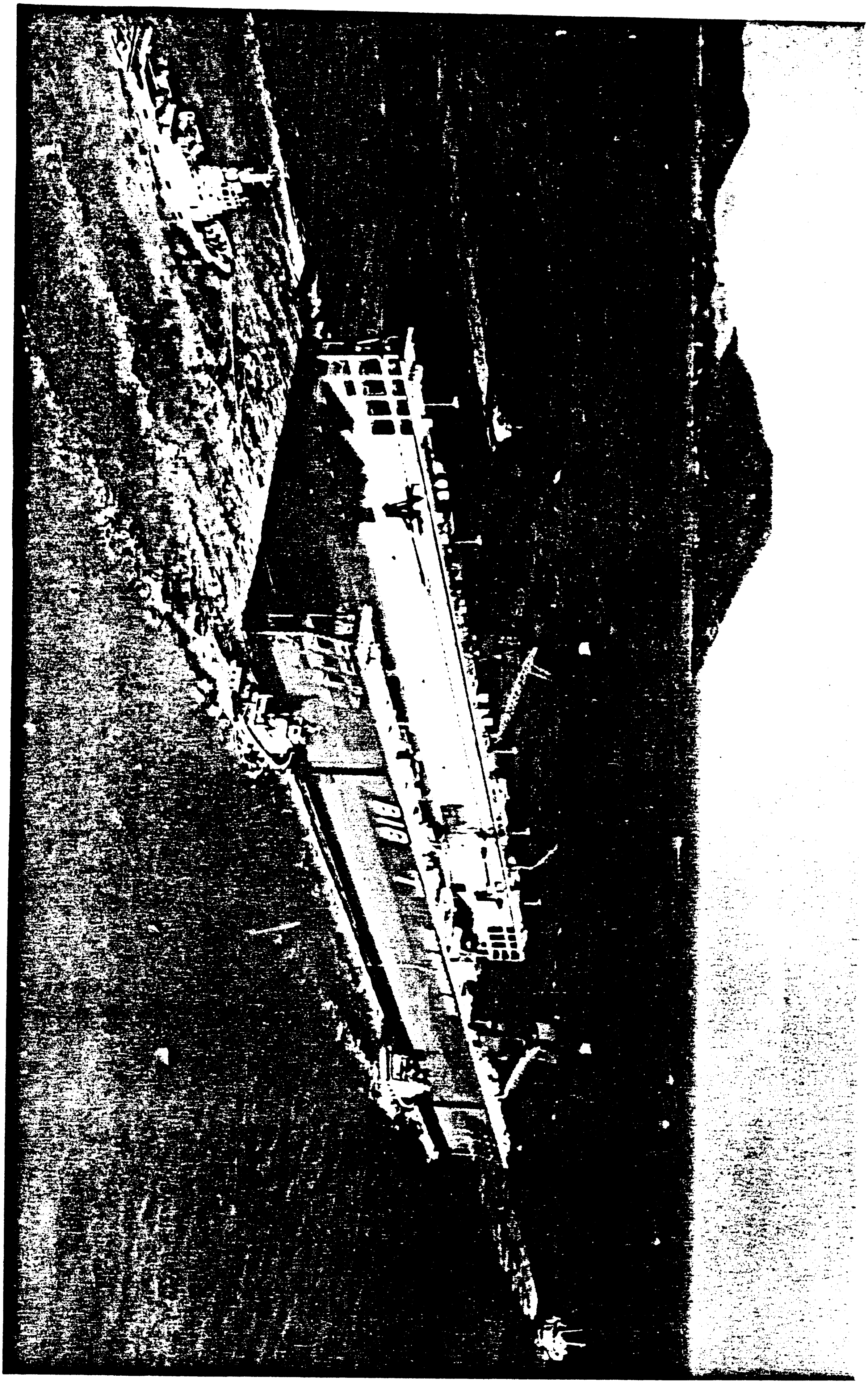
LAUNCHING (FLOATING DRYDOCK)

A. SIDEWAYS TRANSFER



B. END ON TRANSFER





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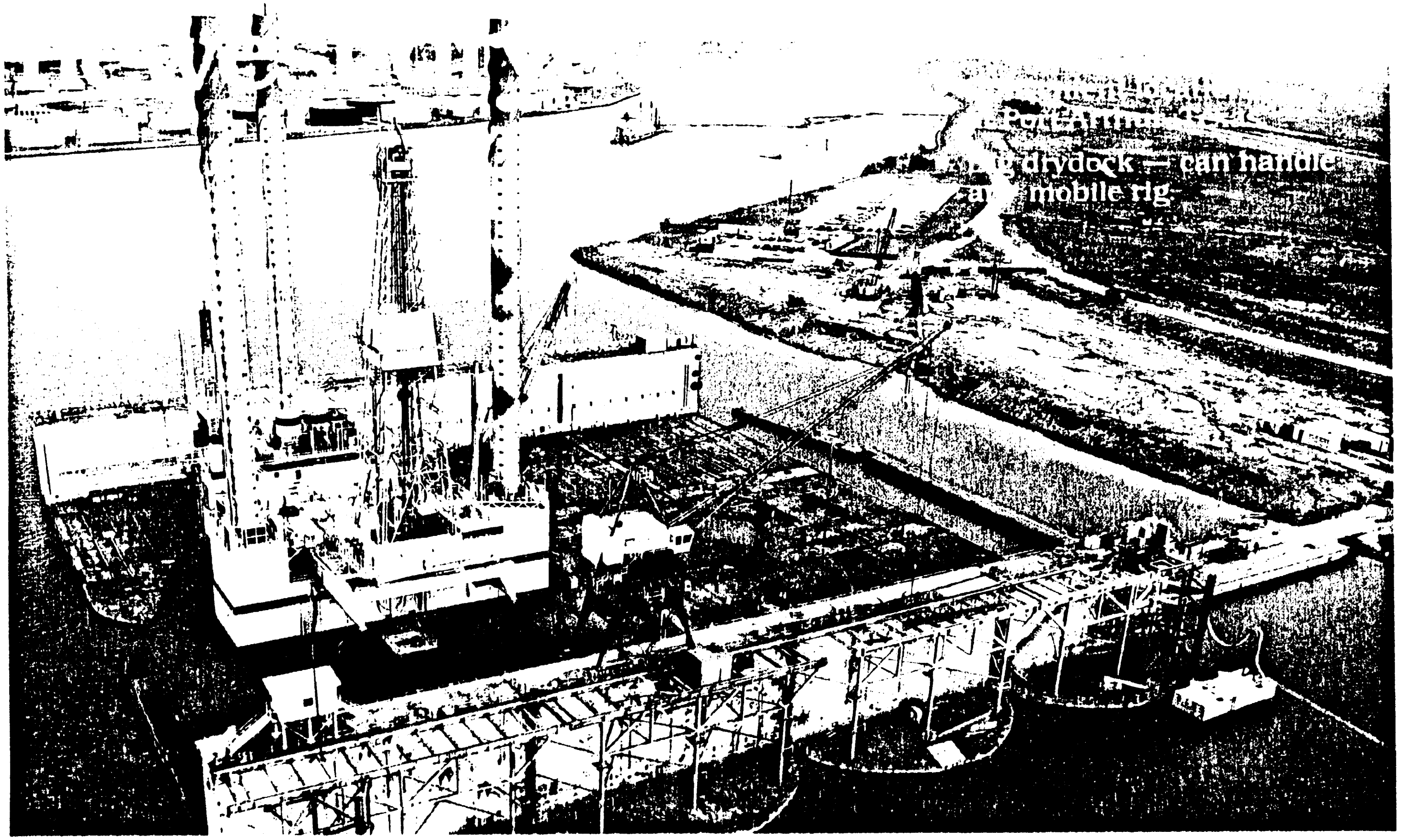


SHIPBUILDING METHODS

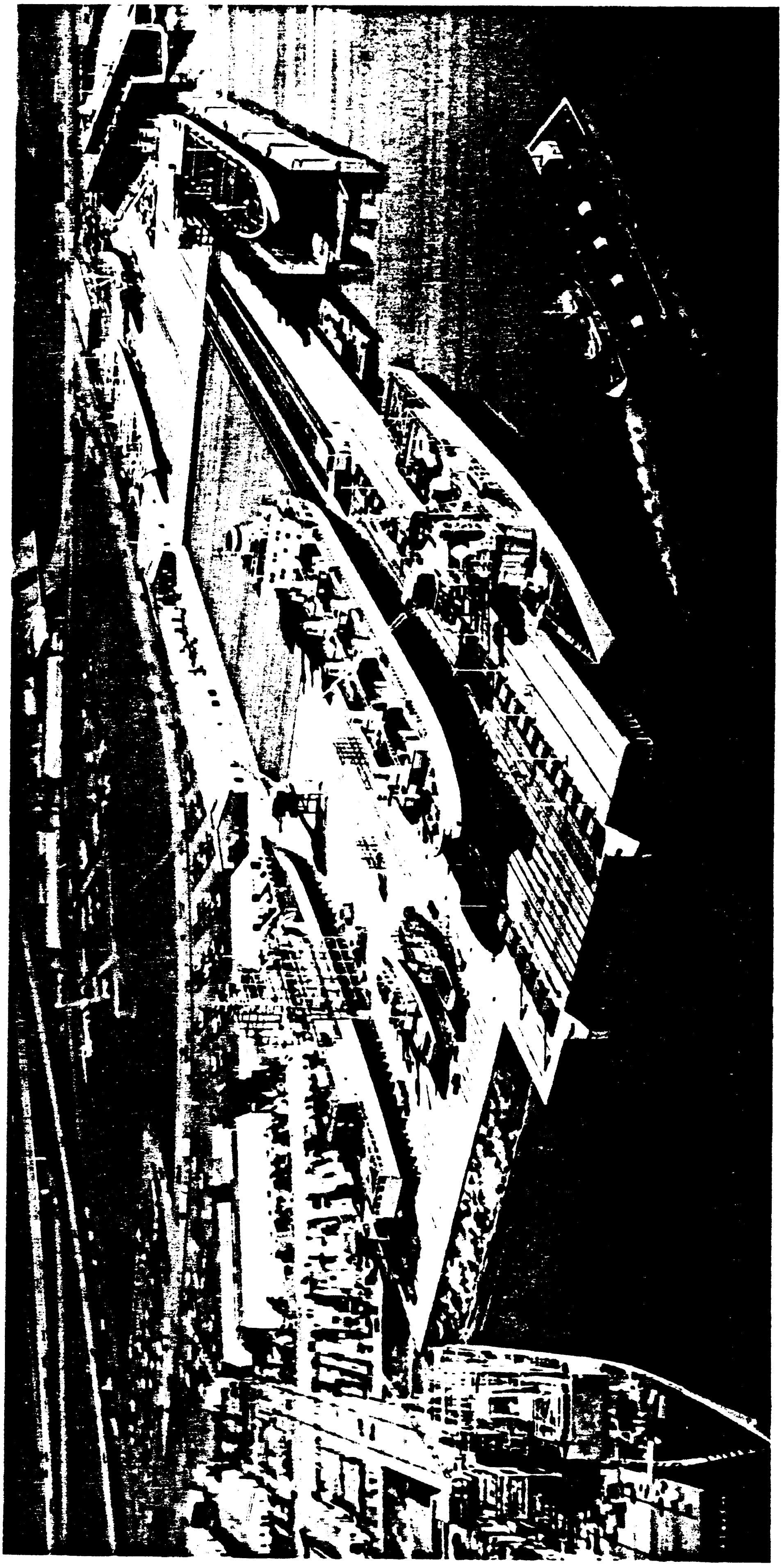
PLATFORM LAUNCHING

LAUNCHING FROM A GRAVING DOCK. VERY LARGE SHIPS (E.G., AIRCRAFT CARRIERS, ULCC'S) MAY BE CONSTRUCTED IN A GRAVING DOCK. LAUNCHING CONSISTS SIMPLY OF FLOATING THE SHIP OFF OF ITS CONSTRUCTION BLOCKING. KEY FACTOR: IF THE SHIP WILL FLOAT WITH A SIGNIFICANT TRIM CRUSHING BLOCKS AND SPECIAL PACKING MUST BE PROVIDED IWO THE BEARING AREA.

SHIPBUILDING METHODS

PLATFORM LAUNCHING

LAUNCH FROM A MOVEABLE PLATFORM. "SYNCROLIFT" OR SIMILAR TYPES OF PLATFORMS WHICH CAN BE RAISED AND LOWERED BY ELECTRIC MOTORS LEND THEMSELVES WELL TO MODERN SHIP CONSTRUCTION METHODS. THE ASSEMBLED SHIP IS MOVED BY JACKING, BY TRANSPORTER OR OTHER TYPES OF TRANSLATION SYSTEMS FROM THE ASSEMBLY SITE TO THE PLATFORM AND THE PLATFORM LOWERED. SIMILAR PRECAUTIONS TO THOSE FOR A GRAVING DOCK MUST BE TAKEN IN THE CASE OF A SHIP WHICH WILL FLOAT OFF WITH TRIM.



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PLATFORM LAUNCHING